ANZIAM 2016

The 52nd ANZIAM Conference
QT Canberra, 1 London Circuit
Canberra ACT
7-11 February 2016

www.anziam2016.com

The abstracts of the talks in this handbook were provided individually by the authors. Only minor typographical changes have been made by the editors. The opinions, findings, conclusions and recommendations in this book are those of the individual authors.

We thank the organisers of the ANZIAM 2015 conference for providing their LaTeX template files.

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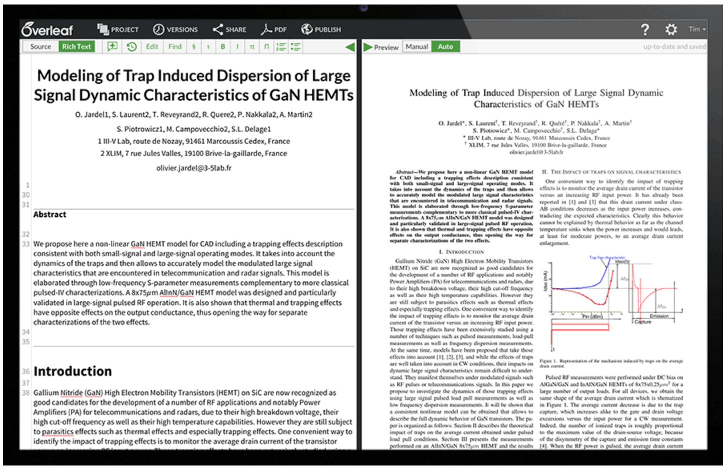

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1 Conference Details and History

1.1 Organising Committee

- Harvi Sidhu (UNSW Canberra) — Director, ph. 04 10103804
- Tristram Alexander (UNSW Canberra)
- Rowena Ball (ANU) ph. 04 88938138
- Alexandra Hogan (ANU)
- Zlatko Jovanoski (UNSW Canberra)
- Julia Piantadosi (University of South Australia) — SIAM representative
- Rachael Quill (UNSW Canberra)
- Jason Sharples (UNSW Canberra)
- Leesa Sidhu (UNSW Canberra)
- Isaac Towers (UNSW Canberra)
- Edward Waters (The University of Notre Dame Australia) ph. 04 25567655

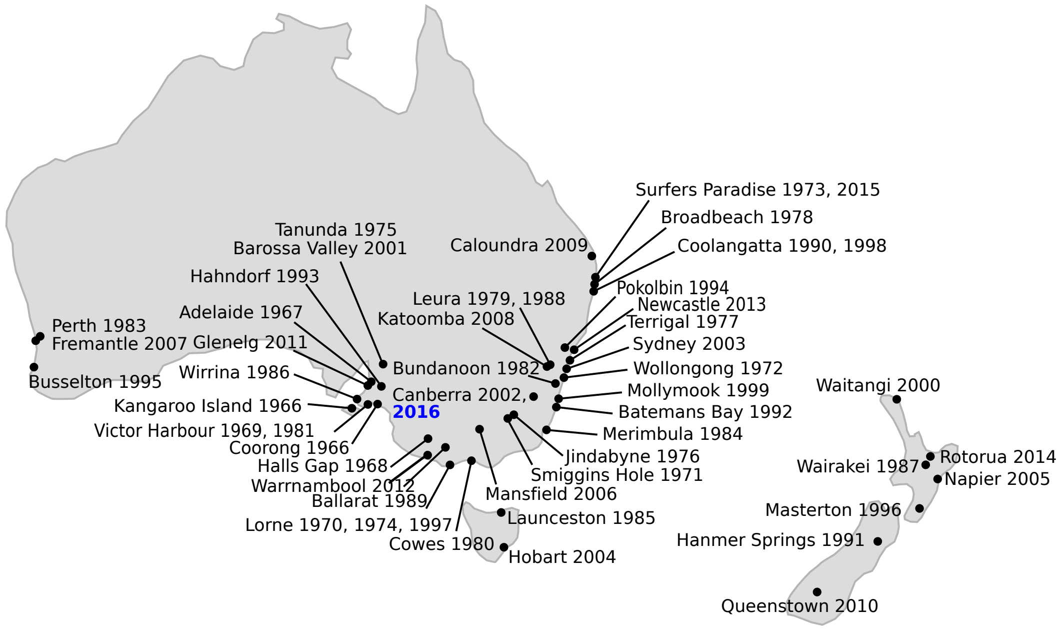
1.2 Invited Speakers Committee

- Peter Taylor (University of Melbourne) — Chair
- Boris Baeumer (University of Otago)
- Sanjeeva Balasuriya (University of Adelaide)
- Richard Clarke (University of Auckland)
- Markus Hegland (Australian National University)
- James McCaw (University of Melbourne)
- Kerrie Mengersen (Queensland University of Technology)
- Mary Myerscough (University of Sydney)
- Jason Sharples (UNSW Canberra)
- Harvinder Sidhu (UNSW Canberra)
- Natalie Thamwattana (University of Wollongong)

1.3 Invited Speakers

- Dr Barry Cox (University of Adelaide) — 2015 JH Michell Medallist
- Professor Edmund Crampin (University of Melbourne)
- Professor Jim Denier (Macquarie University)
- Professor John Dold (University of Manchester)
- Professor Troy Farrell (Queensland University of Technology)
- Associate Professor Vivien Kirk (University of Auckland)
- Dr Petra Kuhnert (CSIRO, Adelaide)
- Professor Karen Willcox (Massachusetts Institute of Technology)

1.4 Past Conference Locations



1966	Kangaroo Island (Aug)	1981	Victor Harbor	1999	Mollymook
1966	Coorong (Dec)	1982	Bundanoon	2000	Waitangi
1967	Adelaide	1983	Perth	2001	Barossa Valley
1968	Halls Gap	1984	Merimbula	2002	Canberra
1969	Victor Harbor	1985	Launceston	2003	Sydney
1970	Lorne	1986	Wirrina	2004	Hobart
1971	Smiggin Holes	1987	Wairakei	2005	Napier
1972	Wollongong	1988	Leura	2006	Mansfield
1973	Surfers Paradise	1989	Ballarat	2007	Fremantle
1974	Lorne	1990	Coolangatta	2008	Katoomba
1975	Tanunda	1991	Hanmer Springs	2009	Caloundra
1976	Jindabyne	1992	Batemans Bay	2010	Queenstown
1977	Terrigal	1993	Hahndorf	2011	Glenelg
1978	Broadbeach	1994	Pokolbin	2012	Warrnambool
1979	Leura	1995	Busselton	2013	Newcastle
1980	Cowes	1996	Masterton	2014	Rotorua
		1997	Lorne	2015	Surfers Paradise
		1998	Coolangatta	2016	Canberra

1.5 The T.M. Cherry Student Prize

An annual prize for the best student talk was introduced in 1969 at Victor Harbor. In May 1976 the Division of Applied Mathematics titled it the "T.M. Cherry Student Prize" in honour of Professor Sir Thomas MacFarland Cherry. Past recipients are listed below.

1970	J. Rickard	UCL	1993	D. Standingford	U Adelaide
1971	J. Jones	Mount Stromlo	1994	B. Barnes	Monash U
1974	R. P. Oertel	U Adelaide	1995	A. Buryak	ANU
1975	R. E. Robinson	U Sydney	1996	A. Gore	U Newcastle
1976	J. P. Abbott	ANU		D. Scullen	U Adelaide
1977	J. Finnigan	CSIRO	1997	S. Cummins	Monash U
	S. Bhaskaran	U Adelaide	1998	J. Clark	U Sydney
1978	B. Hughes	ANU		T. Gourlay	U Adelaide
	P. Robinson	UQ	1999	E. Ostrovskaya	ANU
1979	J. R. Coleby	U Adelaide	2000	C. Reid	Massey U
	B. Hughes	ANU 2001		M. Haese	U Adelaide
1980	M. Lukas	ANU	2002	V. Gubernov	ADFA
1981	A. Plank	UNSW		W. Megill	UBC/UoW
1982	G. Fulford	UoW	2004	K. Mustapha	UNSW
	J. Gear	UniMelb	2005	J. Looker	UniMelb
1983	P. Kovesi	UWA	2006	C. Fricke	UniMelb
1984	A. Kucera	UoW	2007	S. Harper	Massey U
	S. Wright	UQ	2008	E. Button	UniMelb
1985	G. Fulford	UoW		M. Haythorpe	UniSA
	F. Murrell	UniMelb	2009	S. Cohen	U Adelaide
1986	A. Becker	Monash U	2010	L. Mitchell	U Sydney
	K. Thalassoudis	U Adelaide	2011	S. Butler	U Sydney
1988	W. Henry	ANU		J. Caffrey	UniMelb
1987	M. Rumsewicz	U Adelaide	2012	J. Nassios	UniMelb
1989	M. Myerscough	U Oxford	2013	D. Khoury	UNSW
	J. Roberts	UniMelb		T. Vo	U Sydney
1990	J. Best	UoW	2014	M. Chan	U Sydney
1991	S. K. Lucas	U Sydney	2015	H. Tronnolone	U Adelaide

1.6 The Cherry Ripe Prize

Since 1995 the students have run an alternative competition for the best non-student talk. Past recipients are listed below.

1995	Natashia Boland	UniMelb	2006	Vicky Mak	Deakin U
1996	Andrew Pullan	U Auckland		James Sneyd	U Auckland
1997	Neville de Mestre	Bond U	2007	Geoffry Mercer	USW
1998	David Stump	UQ	2008	Neville de Mestre	Bond U
1999	Mark McGuinness	VUW	2009	Philip Maini	U Oxford
2000	Joseph Monaghan	Monash U	2010	Larry Forbes	U Tasmania
	Andy Philpott	U Auckland	2011	Larry Forbes	U Tasmania
2001	Phil Broadbridge	UoW		Darren Crowdy	Imperial College
2002	Ernie Tuck	U Adelaide	2012	Martin Wechselberger	U Sydney
	Larry Forbes	U Tasmania	2013	Scott McCue	QUT
2004	Stephen Lucas	UniSA		Sheehan Olver	U Sydney
2005	Kerry Landman	UniMelb	2014	Peter Kim	U Sydney

1.7 The J.H. Michell Medal

The J.H. Michell Medal is awarded to outstanding new researchers who have carried out distinguished research in applied or industrial mathematics, where a significant proportion of the research work has been carried out in Australia or New Zealand. Past recipients are listed below.

1999	Harvinder Sidhu	UNSW	2008	Carlo Laing	Massey U
2000	Antoinette Tordesillas	UniMelb	2009	Scott McCue	QUT
2001	Nigel Bean	U Adelaide	2011	Frances Kuo	UNSW
2002	Stephen Lucas	UniSA	2012	Matthew Simpson	QUT
2004	Mark Nelson	UoW	2013	Terence O'Kane	CMAR CSIRO
2006	Sanjeeva Balasuriya	U Sydney	2014	Ngamta Thamwattana	UoW
2007	Yvonne Stokes	U Adelaide	2015	Barry Cox	U Adelaide

1.8 The E.O. Tuck Medal

In honour of the late Ernest Oliver Tuck, FAustMS, FTSE and FAA, ANZIAM has instituted a mid-career award for outstanding research and distinguished service to the field of Applied Mathematics. The inaugural EO Tuck Medals were presented at ANZIAM 2013.

2013	Shaun Hendy	VUW and Callaghan Innovation
	Geoffry Mercer	ANU
2015	Troy Farrell	QUT

1.9 The ANZIAM Medal

The ANZIAM Medal is awarded on the basis of research achievements or activities enhancing applied or industrial mathematics and contributions to ANZIAM. The first award was made in 1995. Past recipients are listed below.

1995	Renfrey Potts	U Adelaide
1997	Ian Sloan	UNSW
1999	Ernie Tuck	U Adelaide
2001	Charles Pearce	U Adelaide
2004	Roger Grimshaw	Loughborough U
2006	Graeme Wake	Massey U
2008	James Hill	UoW
2010	Bob Anderssen	CSIRO
2012	Robert McKibbin	Massey U
2014	Kerry Landman	UniMelb

1.10 The AF Pillow Applied Mathematics Top-up Scholarship

The AF Pillow Applied Mathematics Trust offers an annual 'top-up' scholarship to a student holding either an Australian Postgraduate Award (APA) or equivalent award for full-time research in Applied Mathematics leading to the award of a PhD. The aim of the AF Pillow Applied Mathematics Top-up Scholarship is to increase the quality of postgraduate students in the field of applied mathematics in Australia. Past recipients are listed below.

2009	Christopher Lustri	QUT
2010	Alex Badran	UoW
2011	Michael Dallaston	QUT
2012	Hayden Tronnolone	U Adelaide
2013	Lisa Mayo	QUT
2014	Audrey Markowskei	Macquarie U
2015	Pouya Baniasadi	Flinders U

1.11 Acknowledgements

The Organising Committee gratefully acknowledges the financial support of the following sponsors:

- UNSW Canberra

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- College of Science and Mathematical Sciences Institute, ANU
- School of Physical, Environmental and Mathematical Sciences, UNSW Canberra
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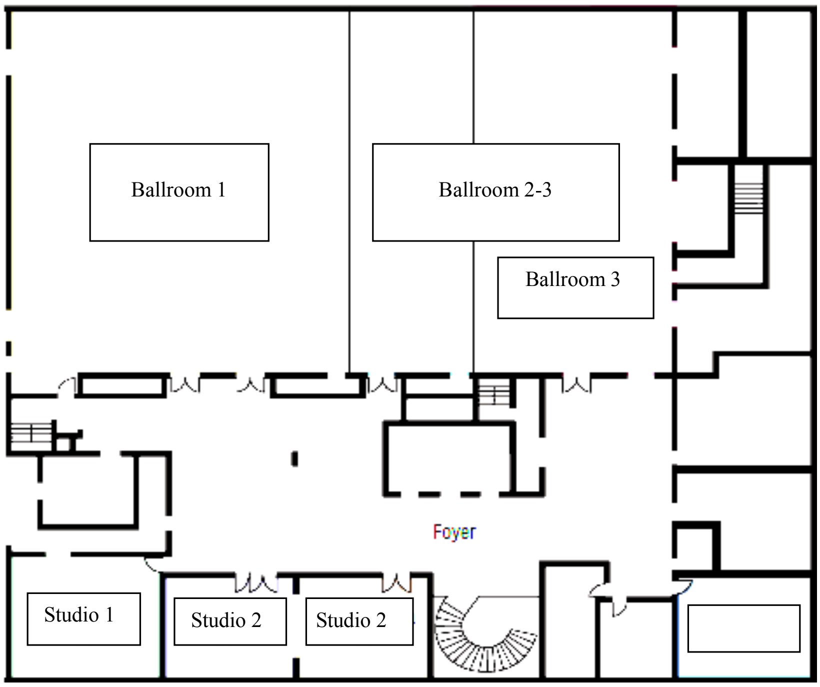
The Organising Committee is especially thankful to CSIRO for sponsoring the following students to attend the ANZIAM 2016 conference:

David Arnold	Elayaraja Aruchunan	Sherwin Bagheri
Peter Ballard	Jordan Belperio	Sangeeta Bhatia
Lachlan Bubb	Eamon Conway	Andrew Cullen
Paige Davis	Tom Dyer	Adam Ellery
Megan Farquhar	Ashish Goyal	Michael Hackney
Michael Jackson	Wang Jin	Stuart Johnston
Laura Karantgis	Ziwei Ke	Jack Keeler
Tiffany Ngo Leung	Michael Lydeamore	Jonathon Pantelis
Ravindra Pethiayagoda	James Reoch	Shrupa Shah
Alexander Tam	Amelia Thomas	Minh Tran
Alexander Zarebski	Xiangchen Zeng	

2 Conference Events, Venues and Facilities

2.1 Conference Venue

The conference is being held at QT Hotel, 1 London Circuit, Canberra, ph. 02 6247 6244. The floor plan for the conference rooms on the first floor is given below.

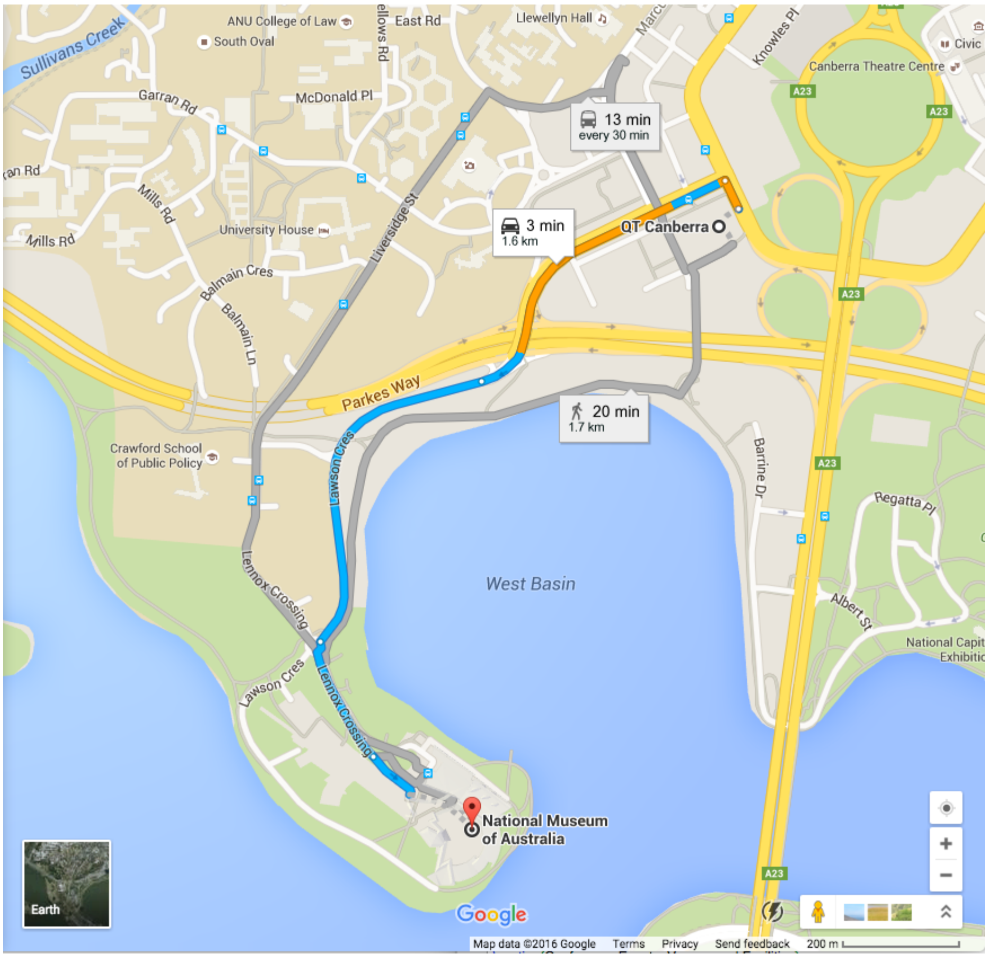


2.2 Conference Reception

The welcome reception will be held from **6-8pm on Sunday 7 February** at Capitol Bar & Grill and the Back Deck on the ground floor of QT Hotel. All ticket holders — i.e., registered delegates and their registered guests — are invited.

2.3 Conference Banquet

The banquet dinner will be held at the National Museum of Australia (NMA), Lawson Crescent, Acton Peninsula, Canberra, beginning with pre-dinner drinks from **6:30 pm, Wednesday 10 February**. The NMA is approximately a 15–20 min walk from QT Hotel. A map is given below.



2.4 Refreshment Breaks and Lunches

Morning and afternoon tea and light refreshments will be available in the First Floor Foyer. Lunches are included in the registration fee for delegates and their registered guests. They will be available after the last presentations of the morning sessions at Capitol Bar & Grill on the ground floor of QT Hotel.

2.5 Internet Access

Delegates will be provided with WiFi internet access from Monday–Thursday. Instructions will be provided at the ANZIAM 2016 Registration Desk.

2.6 Social Media

ANZIAM attendees are encouraged to use social media from their personal accounts to share ideas from the conference. The conference Twitter hashtag is #ANZIAM2016 and the Facebook page is ANZIAM 2016. It's good practice to include a reference to the presenter and their affiliation, and please seek permission from the presenter before posting a photo of them or their presentation online.

2.7 Invited Lectures and Contributed Talks

All invited lectures will take place in **Ballroom 2–3**. Contributed talks will be held in four parallel sessions in **Ballroom 2**, **Ballroom 3**, **Studio 1** and **Studio 2**. The duration of each contributed talk will be fifteen minutes with an additional five minutes for questions and room change over.

2.8 Women in Mathematics Lunch

The Women in Mathematics Special Interest Group of the AustMS (WIMSIG) is running the Women in Mathematics Lunch which will be held in conjunction with ANZIAM 2016 from 12:40–1:40pm on Tuesday 9 February in Ballroom 1 (first floor of QT Hotel). The lunch will be hosted by Dr Adelle Coster and supported by ANZIAM, WIMSIG and the Australian Research Council through Prof. Nalini Joshi's Georgina Sweet Australian Laureate Fellowship. Please RSVP by 12 noon Monday 8 February via our website (http://anziam2016.com/women-in-mathematics-lunch/) or by registering at the ANZIAM 2016 Registration Desk. See flyer on the next page for further details.

2.9 Mathematics Education Workshop

A Mathematics Education Workshop will be held in conjunction with ANZIAM 2016 from 1:40–7:00pm on Tuesday 9 February in Ballroom 2 (first floor of QT Hotel). Please RSVP by 12 noon Monday 8 February via our website http://anziam2016.com/mathematics-education-workshop/ or by registering at the ANZIAM 2016 Registration Desk.

2.10 Activities around Canberra

For information regarding the wine tour on Tuesday 9 February and other activities around Canberra, please refer to the flyer on page 18.

ANZIAM Women in Mathematics Lunch

When? Lunchtime Tuesday 9 February 2016

Where? Ballroom 1 (first floor of QT Canberra)

The Women in Mathematics Special Interest Group (WIMSIG) lunch *(including tea/coffee and cake)* is free to all registered delegates at ANZIAM 2016, and people of any gender are welcome.

Register by **12 noon Monday 8 February** via http://anziam2016.com/women-in-mathematics-lunch/ or at the ANZIAM 2016 Registration Desk.

The lunch is a showcase of the prominent female mathematicians at ANZIAM 2016. It provides an opportunity to learn about the careers of our female plenary speakers, as well as to delve into discussions on topics affecting all mathematical careers worldwide.

Vivien Kirk

Associate Professor, Mathematics Department, University of Auckland

Advice for a younger version of yourself?

“Keep trying to see the broad context for your research. … Look for mentors, both formal and informal. “

Petra Kuhnert

Research Statistician, “Data61” at CSIRO

Why do you do mathematics?

“One of the aspects of maths that I enjoy most is collaborating with different people on a wide range of interesting problems. “

Karen Wilcox

Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology

What keeps you in research?

“I love the flexibility (intellectual, strategy, focus, schedule) that my research position gives me. You could triple my salary and I would not give that up. “

The lunch is supported by ANZIAM, WIMSIG of the AustMS, and the Australian Research Council through Nalini Joshi’s Georgina Sweet Australian Laureate Fellowship.

BEWARE: Parliament is sitting this week, but there are plenty of other things to see and do in Canberra!

ANZIAM2016 CONFERENCE
7-11 February - Canberra

TUESDAY AFTERNOON ACTIVITIES

MOUNT MAJURA VINEYARD

Organised Wine Tour to Mount Majura Vineyard http://www.mountmajura.com.au/

Registrations required. There is a maximum of 30 attendees. Please see Alexandra Hogan to register.

Cost per person: $50

OTHER ACTIVITIES AVAILABLE IN CANBERRA

Exhibitions and Museums

Australian War Memorial https://www.awm.gov.au/

Australia in the Great War — Daily Last Post Ceremony (4.55pm)

Free tours run throughout the day

National Portrait Gallery http://www.portrait.gov.au/

Sideshow Alley

The National Gallery of Australia http://www.nga.gov.au/

Tom Roberts — The Last Temptation

Behind the Scenes: Tyler Graphics at Work

The National Museum of Australia http://www.nma.gov.au/

Encounters

The National Library of Australia http://www.nla.gov.au/

Celestial Empire: Life in China 1644-1911

Canberra Contemporary Art Space http://www.ccas.com.au/

Questacon http://www.questacon.edu.au/

Something More Active

Walking and Cycling Tracks http://www.canwalk.org.au/

Explore the bush capital around Lake Burley-Griffin, or with a short climb up Black Mountain or Mount Ainslie.

Cafes, Bars, Restaurants and Shopping

New Acton http://www.newacton.com.au/

Just around the corner from QT! Courtyard Cinema, Palace Electric Cinema, Monster Bar and Restaurant, Lucky's Speakeasy, A. Baker, Molly Cocktail Bar and more.

Westside Acton Park https://www.westsideactonpark.com.au/

Kingston Foreshore Walt and Burley, C Dine, The Dock , Max Brenner and more.

Braddon Lonsdale St Roasters, Bentspoke Brewery, The Hamlet, Hipsley Lane Shopping and much more!

USEFUL WEBSITES

Visit Canberra	http://visitcanberra.com.au/events/	HerCanberra "This week in the Can"	http://hercanberra.com.au/
Urban Walkabout	http://www.urbanwalkabout.com/canberra/	Out in Canberra	http://www.outincanberra.com.au/

If you have any questions or need any more pointers, see Rachael Quill or Alexandra Hogan, or speak to our volunteers at the Registration Desk.

3 Conference Programme

Monday morning

* denotes student talk

8:00–8:15	Registration at the ANZIAM desk — First Floor Foyer			
8:15–8:30	Conference Opening, **Ballroom 2–3**			
8:30–9:30	**Invited: Edmund Crampin, University of Melbourne** (#2) **Ballroom 2–3** **Title:** Mathematical modelling of calcium signalling in heart cells: from ion channels to whole cell models *Chair: Matthew Simpson*			
	Ballroom 2	**Ballroom 3**	**Studio 1**	**Studio 2**
	Chair: John Shepherd	*Chair: Elliot Carr*	*Chair: Boris Baeumer*	*Chair: Duncan Farrow*
9:40–10:00	**John Hearne** Modelling to manage overabundance of koalas on French Island (#63)	**Mark McGuinness** Mathematical Modelling of Surtseyan Bombs — Fire, Earth, and Water (#100)	**Christopher Angstmann** From discrete time random walks to numerical methods for fractional order differential equations (#14)	**Christopher Lustri** Collisions Between Nonlocal Solitary Waves (#89)
10:00–10:20	**Sara Li-Yen Loo*** Mathematical Investigation into the effect of Large-Game Hunting on Growth Rates of Hunter-Gatherer Populations (#88)	**Laura Karantgis*** Modelling rainfall induced landslides with a combined analytical and computational approach (#78)	**Elayaraja Aruchunan*** Half-sweep modified geometric mean iterative method for solving integro-differential equations (#16)	**Andrew Cullen*** Steady nonlinear dispersive waves: a numerical framework (#35)
10:20–10:40	**Rashed Saifuddin*** Application of a delayed logistic model with variable carrying capacity to a deer population (#140)	**Adam James Ellery*** Modelling transport through an environment crowded by a mixture of obstacles of different shapes / sizes (#45)	**Marianito Rodrigo** On fractional matrix exponentials and their explicit calculation (#137)	**Jerome Droniou** Implementing a characteristic-finite element numerical scheme for an oil recovery model (#41)
10:40–11:00	Morning tea — First Floor Foyer			

	Monday morning continued * denotes student talk			
	Ballroom 2	**Ballroom 3**	**Studio 1**	**Studio 2**
	Chair: Robert McKibbin	*Chair: Tony Roberts*	*Chair: Luke Bennetts*	*Chair: Peter Straka*
11:00–11:20	**Bob Anderssen** How does one quantify 'epigenetic memory'? (#13)	**Tatsuya Yamaguchi*** A non-Hebbian learning model for some periodic activities with synchronizations of phase oscillators (#169)	**Phil Broadbridge** Nonlinear 4th Order Surface Diffusion at Nanoscale Grain Boundaries: Beyond Similarity Solutions (#26)	**Mark Fackrell** Modelling Queueing Networks as Cooperative Games (#47)
11:20–11:40	**Mark Chambers*** How long is a bigeye tuna? (#29)	**James Hannam*** Phase near infinity (#61)	**James Reoch*** Incorporating cell forces into a multiphase model for collagen gel mechanics (#129)	**Stuart Johnston*** Filling the gaps: a robust description of adhesive birth-death-movement processes (#75)
11:40–12:00	**Catherine Penington** Spatial dynamics of coinfection in ocean-borne bacteriophage viruses (#119)	**Kerry-Lyn Roberts*** Torus canards and folded singularities: Analyzing the folded saddle-node type three (FSN III) bifurcation (#132)	**Tom Dyer*** Intercalating a Carbon Nanotube into Graphene Folds (#42)	**Simon Clarke** Complex spatial self-organisation in an extended Daisyworld model (#31)
12:10–12:55	**Invited: Barry Cox (2015 Michell Medallist), University of Adelaide** (#1) **Ballroom 2–3** **Title:** Various models for graphitic nanostructures *Chair: Harvi Sidhu*			
12:55–1:50	Lunch at Capitol Bar & Grill			

	Monday afternoon * denotes student talk			
1:50–2:50	**Invited: Karen Willcox, Massachusetts Institute of Technology** (#8) **Ballroom 2–3** **Title:** Multifidelity Methods for Design and Uncertainty Quantification *Chair: Peter Taylor*			
	Ballroom 2	**Ballroom 3**	**Studio 1**	**Studio 2**
	Chair: Shaun Hendy	*Chair: Simon Williams*	*Chair: Martin Wechselberger*	*Chair: Jerome Droniou*
3:00–3:20	**Frank de Hoog** Spectral Compression for Hyperspectral Images (#38)	**Alona Ben-Tal** Unidirectional airflow through avian lungs: new insights from a piecewise linear model (#25)	**Carlo Laing** Equation-free analysis of spike timing dependent plasticity (#86)	**Sarthok Sircar** Particle aggregation: a multi-scale model of two deforming cells (#146)
3:20–3:40	**Brent Giggins*** Using optimal Bred Vectors to improve Ensemble Forecasts in multi-scale systems (#53)	**Tiffany Ngo Leung*** Dynamical properties of models of transmission with immune boosting and cross immunity (#87)	**Gemma Mason** Dynamics in the neighbourhood of a PtoP cycle (#94)	**Shane Keating** Stochastic Interpolation of Satellite Imagery (#81)
3:40–4:00	**Sherwin Bagheri*** Reconstruction of refractive index from acoustic farfield data (#18)	**Ada Yan*** On the extinction probability in models of within-host infection: the role of latency and immunity (#170)	**Tony Roberts** Slowly varying, macroscale models emerge in wide but thin domains (#136)	**Kenji Kajiwara** Discrete model of dynamics of vortex filaments (#77)
4:00–4:20	Afternoon tea — First Floor Foyer			

	Monday afternoon continued * denotes student talk			
	Ballroom 2	**Ballroom 3**	**Studio 1**	**Studio 2**
	Chair: Catherine Penington	*Chair: Mark McGuinness*	*Chair: Stephen Roberts*	*Chair: Michael Page*
4:20–4:40	**Kathryn Glass** Mathematical models of gastroenteritis (#54)	**Helmut Maurer** On Optimal Control Applications in Biomedicine (#96)	**Song-Ping Zhu** Pricing European options with stochastic volatility under the minimal entropy martingale measure (#175)	**Mike Chen** Drawing tubular fibres: experiments versus modelling (#30)
4:40–5:00	**Lachlan Bubb*** Analysing influenza epidemics aboard ships (#27)	**Belinda Barnes** A framework to assess disease control in livestock industries when there is an increasing demand for free-range produce (#22)	**Khongorzul Dorjgotov*** Newton like iteration methods and its application to financial modeling (#40)	**Yvonne Stokes** Coupled flow and energy models for fibre drawing (#149)
5:00–5:20	**Joshua Ross** Determining the 'best' prophylactic allocation of vaccines in a segregated population in under a second (#138)	**Andrew Smith** Exploring the Allee effect: How does the Allee effect impact metapopulations? (#147)	**Adegboyegun Bolujo Joseph*** On the inverse finite element approach for pricing American options under linear complementarity formulations (#76)	**Hayden Tronnolone*** Deformations in Preform Extrusion (#161)
5:20–5:40	**Peter Ballard*** Is it ever counterproductive to reduce the infection rate? (#20)	**Saima Gul*** A cell growth model adapted for minimum cell size division (#58)	**Ziwei Ke*** On A Pseudo-ADM For European Option Pricing (#79)	**Yahya Alnashri*** Gradient Schemes For Signorini Problem (#12)
6:30	ANZIAM Student Gathering at PJ O'Reilly's pub, 52 Alinga St, Canberra			

	Tuesday morning * denotes student talk			
8:30–9:30	**Invited: Petra Kuhnert, CSIRO, Adelaide** (#7) **Ballroom 2–3** **Title:** Assimilating modelled catchment loads with monitoring data to estimate sediment loads to the Great Barrier Reef: A Bayesian Approach *Chair: Mary Myerscough*			
	Ballroom 2	**Ballroom 3**	**Studio 1**	**Studio 2**
	Chair: Scott McCue	*Chair: Belinda Barnes*	*Chair: Phil Broadbridge*	*Chair: Roslyn Hickson*
9:40–10:00	**Larry Forbes** Singularities at interfaces between flowing viscous fluids? (#50)	**Michael Plank** Don't be mean: modelling spatial structure in cell populations (#123)	**Adelle Coster** Ancient Starch: Fourier in the Round (#33)	**Nicoline den Breems** Mathematical model for the interaction between the immune system and cancer (#39)
10:00–10:20	**David Arnold*** Flow in spiral channels with arbitrary cross-section (#15)	**Wang Jin*** Reproducibility of scratch assays is affected by the initial degree of confluence (#72)	**Mona Bahri*** Sensitivity of the Empirical Mode Decomposition to interpolation methodology (#19)	**Adrianne Jenner*** Mathematical modelling of viral oncolysis: A PEG-modified adenovirus conjugated with herceptin (#71)
10:20–10:40	**Amelia Thomas*** Simulations of a Jet in Crossflow (#158)	**Adrian Noppe*** Modelling of cell extrusion in an epithelial monolayer (#113)	**Maryam Alavi** Real-time detection of unexpected local variability in air quality monitoring data (#9)	**Peter Kim** Cancer-immune dynamics of oncolytic virotherapy and dendritic cell vaccines (#83)
10:40–11:00	Morning tea — First Floor Foyer			

Tuesday morning continued

* denotes student talk

	Ballroom 2	Ballroom 3	Studio 1	Studio 2
	Chair: Larry Forbes	*Chair: Mick Roberts*	*Chair: Brian Gray*	*Chair: Steve Taylor*
11:00–11:20	**Elliot Carr** Semi-analytic solution of the one-dimensional multilayer diffusion problem with an application to macroscopic modelling (#28)	**Barbara Johnston** A mathematical approach for finding consistent conductivity values for the bidomain model of cardiac tissue (#73)	**Jason Sharples** Pyrogenic vorticity from fires on windward and leeward slopes (#143)	**Simon Williams** A Tale of Two Ponds or Simulation Serendipity (#168)
11:20–11:40	**Alison French*** Diffusion-driven flow in a tilted, three-dimensional, square pipe (#51)	**Zahra Al Helal*** A composite model of blood glucose with insulin injections and exercise for diabetics (#11)	**Melanie Roberts** An ember based model for bushfire risk to houses (#133)	**Winston Sweatman** Modelling the ripening of cheddar cheese (#151)
11:40–12:00	**Jordan Belperio*** Flows through helical pipes (#23)	**Zoltan Neufeld** Modelling tumour recurrence following resection (#112)	**Ross Edgar*** CFD analysis of convective plume attachment (#44)	**Andrew D. Cramer*** Physically Realisable 3D Bone Prosthesis Design with Homogenised Microstructures (#34)
12:00–12:20	**Luke Bennetts** Water wave overwash of a step (#24)	**Martin Wechselberger** The role of cell volume changes in normal and pathological dynamics of the brain (#166)	**Christopher Thomas*** Dynamic fire behaviour and fire line geometry (#159)	**Ishraq Uddin*** Free boundary PDE models of atherosclerotic plaque formation (#163)
12:20–12:40	**Scott McCue** Simulating the corner-cusp-pearling transition for sliding drops (#98)	**James Osborne** Using multicellular modelling and simulation to understand changes in cellular behaviour seen in colorectal cancer (#114)	**Ngamta Thamwattana** Wilmore energy for joining of carbon nanostructures (#157)	**Peter Taylor** Calculating optimal limits for transacting credit card customers (#155)

	Tuesday afternoon and evening
12:40–1:40	Lunch at Capitol Bar & Grill **or** Women in Maths lunch in **Ballroom 1**
1:40–7:30	Free time
1:40–7:00	Mathematics Education Workshop, **Ballroom 2**
7:30–9:30	ANZIAM AGM, **Ballroom 3**
9:30–11:30	ANZIAM Executive Meeting, **Ballroom 3**

	Wednesday morning * denotes student talk			
8:30–9:30	**Invited: Jim Denier, Macquarie University** (#3) **Ballroom 2–3** **Title:** The delightfully complex dynamics of some unsteady fluid flows *Chair: Graeme Hocking*			
	Chair: David Scullen	*Chair: John Murray*	*Chair: Song-Ping Zhu*	*Chair: Christopher Angstmann*
	Ballroom 2	**Ballroom 3**	**Studio 1**	**Studio 2**
9:40–10:00	**Michael Jackson*** An evolving viscous filament in a Hele-Shaw channel (#70)	**Michael Hackney*** Competing fishers and the balanced harvesting of marine resources (#59)	**Rachael Quill*** Sensitivity Analysis of Kolmogorov-Smirnov Style Statistics for Univariate and Bivariate Data (#126)	**Anna McGann*** Fractional Order Compartment Models (#99)
10:00–10:20	**John Shepherd** Helical flow arising from the yielded axial flow of a Bingham fluid (#144)	**Peter Johnston** A Model for Two Wolbachia Strains in an Insect Population (#74)	**Timothy Hyndman*** How many point masses do we need for non-parametric deconvolution and maximum likelihood mixture densities? (#69)	**Megan Farquhar*** Solving variable-order-in-space fractional partial differential equations using matrix function methods (#48)
10:20–10:40	**Alexander Tam*** Predicting channel bed topography in hydraulic falls (#153)	**Jairaj Promrak*** Modified Predator-Prey Model for Mealybug Population with Biological Control (#125)	**Kate Saunders*** Statistical modelling of extreme daily rainfall in South East Queensland using max-stable processes (#139)	**William Paul Malcolm** Modelling and estimation schemes for higher order Markov chains observed through arbitrary noise models (#93)
10:40–11:00	Morning tea — First Floor Foyer			

Wednesday morning continued

* denotes student talk

	Ballroom 2	Ballroom 3	Studio 1	Studio 2
	Chair: James McCaw	*Chair: Bernd Krauskopf*	*Chair: Shev MacNamara*	*Chair: Yvonne Stokes*
11:00–11:20	**Ashish Goyal*** Determining causes behind clearance, persistence or fulminant hepatitis of acute hepatitis B virus infection (#55)	**Soizic Terrien** Semiconductor laser with saturable absorber and delayed optical feedback: a bifurcation analysis (#156)	**Stephen Roberts** Numerically Solving the 1D Serre Equations with initial conditions close to discontinuous (#135)	**Sharon Stephen** Instability of non-Newtonian rotating flows (#148)
11:20–11:40	**Roslyn Hickson** The effect of an increasing burden of diabetes mellitus on tuberculosis incidence and what the risk factor really means (#66)	**Andrew Keane*** Bifurcation analysis of a model for the El Niño Southern Oscillation (#80)	**Brendan Harding*** Implementation of finite element methods with self-similar basis functions (#62)	**Ravindra Pethiyagoda*** Spectrograms of nonlinear ship waves (#120)
11:40–12:00	**Alexandra Hogan*** Seasonality of RSV and bronchiolitis in the different climatic regions of Western Australia (#68)	**Malte A. Peter** Stability of resonant loads on line arrays with respect to positional disorder (#121)	**Muhammad Yousuf Tufail*** Image registration under conformal diffeomorphisms (#162)	**Jack Keeler*** Stability of free surface flow over topography (#82)
12:00–12:20	**Michael Lydeamore*** Investigating intervention intervals for scabies infections (#90)	**Rhys Paul*** Sal'nikov's Reaction Scheme in a Spherically-Symmetric Gas (#117)	**Eamon Conway*** Comparison of meshing techniques for the solution of the Poisson-Nernst-Planck equations (#32)	**Paige Davis*** Spectral Stability of Travelling Waves for a Keller-Segel Model (#36)

Wednesday afternoon

* denotes student talk

	Ballroom 2	Ballroom 3	Studio 1	Studio 2
12:20–12:40	**Angus McLure*** Clostridium difficile infection and sensitivity analysis (#103)	**Ignacio Ortega Piwonka*** Use of a stochastic model to study the cyclic motion in nanowires trapped by focused Gaussian beams (#122)	**Jouke H.S. de Baar** Towards a robust gradient-enhanced sparse grid surrogate for uncertainty quantification of CFD results (#37)	**Trent Mattner** Large-eddy simulations of a spatially developing mixing layer using the stretched-vortex subgrid model (#95)
12:40–1:40	Lunch at Capitol Bar & Grill			
1:50–2:50	**Invited: Vivien Kirk, University of Auckland** (#6) **Ballroom 2–3** **Title:** Making good use of time *Chair: Hinke Osinga*			
	Chair: Joshua Ross	*Chair: Shaun Belward*	*Chair: Isaac Towers*	*Chair: Winston Sweatman*
3:00–3:20	**John Murray** A mathematical model of latent HIV infection and the impact of eradication strategies (#107)	**Sarah McMahon*** Examination of Student Performance on the ADFA Mathematics Diagnostic Test (#104)	**Xiang-Chen Zeng*** Numerical comparisons in two-state regime-switching model (#173)	**Ursula Weiss*** Modelling and simulation of electromagnetic emission during crack propagation in epoxy resin materials (#167)
3:20–3:40	**Jonathon Pantelis*** Household Models for Endemic Diseases (#118)	**Bonnie Yu*** Investigating preferences in university collaboration networks (#171)	**Boris Baeumer** Non-local Dirichlet problems on bounded domains (#17)	**Minh Tran*** An empirical approach for determining the state of charge of a battery (#160)
3:40–4:00	**Shrupa Shah*** Understanding the transmission dynamics of Influenza through individuals' contact networks (#142)	**Ashwani Kumar*** Bringing quality to the Healthcare Industry (#85)	**Markus Hegland** Recent developments in the theory and application of the sparse grid combination technique (#64)	**Steve Taylor** Screen Deflection: A MISG 2015 problem (#154)
4:00–4:20	Afternoon tea — First Floor Foyer			

Wednesday afternoon continued

* denotes student talk

	Ballroom 2	Ballroom 3	Studio 1	Studio 2	Studio 2 Annex
	Chair: Tammy Lynch	*Chair: Peter Johnston*	*Chair: Frank de Hoog*	*Chair: Trent Mattner*	*Chair: Harvi Sidhu*
4:20–4:40	**Rosemary J Dyson** Multiscale modelling of plant root growth (#43)	**Alexander Zarebski*** Influenza forecasting with a seasonally informed model (#172)	**Soorena Ezzati*** A Modification on Recently Proposed Reliability Analysis Method (#46)	**Arnold Reynaldi*** Kinetics of Neonatal CD8+ T Cell Responses (#130)	**Pouya Baniasadi*** Genome Assembly Using Traveling Salesman Problem Heuristics (#21)
4:40–5:00	**Duncan Farrow** Modelling hydrogen clearance from a rat retina (#49)	**Matthew Simpson** Survival probability for a diffusive process on a growing domain (#145)	**Yuancheng Zhou*** The Combination technique applied to QoI computed from the GENE code of gyrokinetic equations (#174)	**Ramya Rachmawati*** A Mixed Integer Programming approach for solving the prescribed burn planning problem to fragment high-risk regions (#127)	**Bernd Krauskopf** Interacting isochron foliations (#84)
5:00–5:20	**Catheryn Gray*** Akt Translocation in Mammalian Fat Cells (#56)	**James McCaw** The roles of innate and adaptive immunity in controlling influenza viral infection (#97)	**Vanessa Robins** Topological data analysis for materials science (#131)	**Lisa Reischmann*** A multiscale approximation of phase separation with elasticity (#128)	**Hinke Osinga** Failure of structures: can you see it coming? (#115)
5:20–5:40	**Bronwyn Hajek** Exact solutions for logistic reaction-diffusion in biology (#60)	**Mick Roberts** The dilution effect in ecological epidemiology (#134)	**Lewis Mitchell** Quantifying happiness by applying simple algorithms to Big Data: Social media and other stories (#105)	**Agah D. Garnadi** Ambiguity and Depth Resolution In Electrical Conductivity Inversion (#52)	**Richard Michael Morris** Symmetry analysis for forms of the complex-valued Klein-Gordon Equation (#106)
6:30	Pre-dinner drinks and Conference Banquet at the National Museum of Australia				

Thursday morning

8:30–9:30 — **Invited: John Dold, University of Manchester** (#4) **Ballroom 2–3**
Title: A Selective History of Combustion Modelling
Chair: Jason Sharples

	Ballroom 2	Ballroom 3	Studio 1	Studio 2
	Chair: Rowena Ball	*Chair: Carlo Laing*	*Chair: Melanie Roberts*	*Chair: Kathryn Glass*
9:40–10:00	**Shaun Hendy** Pass the Dutchie on the left hand side (#65)	**Mary Myerscough** Old is good! Exploring the role of forager age in honeybee colony collapse disorder (#108)	**Kim Ngan Le** Numerical solution of the time-fractional Fokker Planck equation with general forcing (#109)	**Laleh Tafakori** A Model for Cell Proliferation in a Developing Organism (#152)
10:00–10:20	**Mark Nelson** As a matter of fact: the influence of media campaigns upon alcoholism (#111)	**Peter Straka** Extremes of bursty events (#150)	**Mathew Zuparic** Modelling noise in competing sense/decision-making networks (#176)	**Edward Green** Pattern formation in multiphase models of chemotactic cell aggregation (#57)
10:20–10:40	**Tristram Alexander** Modelling opinion dynamics in the presence of disagreement (#10)	**Graeme Wake** Blast fron the Past: (A taste of DDDEs) (#164)	**Nobutaka Nakazono** A reduction from integrable partial difference equations on $\mathbb{Z}^4$ to A_4-surface type q-Painlevé equations (#110)	**Tammy Lynch** A mechanistic model of glucose-hydrogen-methanogen dynamics in the rumen (#91)

10:40–11:00 — Morning tea — First Floor Foyer

Thursday morning continued

	Ballroom 2	Ballroom 3	Studio 1	Studio 2
	Chair: Graeme Wake	*Chair: Christopher Lustri*	*Chair: Simon Clarke*	*Chair: Barbara Johnston*
11:00–11:20	**David Scullen** Clogging of permeable pavements — a simplified model (#141)	**Andrey Pototsky** Swarming of self-propelled particles on the surface of a thin liquid film (#124)	**Graeme Hocking** Stress effects on silica particles in semi-conductor moldings (#67)	**Edward Waters** Mystic Canberra: Distance sampling for lines of supernatural power (#165)
11:20–11:40	**Robert McKibbin** Some effects of objects embedded in soil and partially-submerged in groundwater (#102)	**Michael Page** Induced motion due to point singularities in diffusion-driven flows (#116)	**Shev MacNamara** Estimating a covariance matrix (#92)	**Mark McGuinness** A Tale of Two Boundary Conditions — Modelling Consolidation in a Pit Latrine (#100)
11:50–12:50	**Invited: Troy Farrell, Queensland University of Technology** (#5) **Ballroom 2–3** **Title:** Mathematical Modelling of Li-ion Battery Cathodes *Chair: Bob Anderssen*			
12:50–1:00	Closing remarks and announcement of the TM Cherry and Cherry Ripe prizes, **Ballroom 2–3**			
1:00–2:00	Lunch at Capitol Bar & Grill			

4 Abstracts for Invited Talks

1 Various models for graphitic nanostructures

Barry J Cox
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Scientific and engineering interest in Nanotechnology began in the second half of the last century and continues unabated in 2016. This burgeoning interdisciplinary area is fuelled by the widely-held belief that many of the challenges facing humanity: the need for food, clean water, energy and novel medical treatments; will be facilitated by these new technologies. The characterisation of the Buckminster fullerene in the mid-1980s and subsequent interest in fullerene-like tubes (carbon nanotubes) and graphene ribbons represents a significant proportion of the overall field. When modelling any system one endeavours to simplify the unimportant so that the salient behaviour is exposed to scrutiny. However the issue of which aspects of the system are important or unimportant is a relative one and thus various models will be appropriate depending on the question that one is trying to answer. In this talk we will discuss various models for graphitic materials. Models that are sometimes discrete, sometimes continuous, and employ ideas from particle mechanics, continuum mechanics, analytic geometry and the calculus of variations. The presentation will conclude with some remarks on possible future directions and questions as yet unanswered.

2 Mathematical modelling of calcium signalling in heart cells: from ion channels to whole cell models

Edmund Crampin
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The dynamics of calcium signalling in heart cells presents many puzzles for biomedical researchers. Calcium signals coordinate contraction of the heart with every heart beat. Calcium signals arising from hormonal stimulation also regulate growth of heart cells, for example during development and also in heart disease; and calcium may also regulate cellular energy metabolism. Given that these different calcium signals appear to coincide in the cell, how do they not interfere with one another? I will discuss our recent attempts to address this issue by constructing data-driven mathematical models of calcium signalling, from the scale of individual ion channels up to cell-level calcium dynamics. This forms part of a broader initiative in cardiac systems biology to understand the interactions between cellular signaling, mechanical and metabolic pathways in the heart in health and disease.

3 The delightfully complex dynamics of some unsteady fluid flows

Jim Denier
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The flow due to a rotating sphere provides a paradigm for the study of many phenomena that arise in unsteady fluid flows. How such flows develop and transition from a smooth (laminar) to a chaotic (turbulent) state is fundamental in many area of technology. Through a mix of theory (a little), some computations (through a movie or two), and comparison with some experiments done a little over 50 years ago (not by us) and some new experiments, well explore some of the delightfully complex dynamics that exist in unsteady fluid flows. In exploring this class of flows we'll uncover a wealth of fundamental problems in fluid mechanics, ranging from the develop of finite-time singularities, the ejection of jets of fluid, the development of fluid vortices, the development of a flow instability ultimately followed by the breakdown of the flow into a chaotic (turbulent) state.

4 A Selective History of Combustion Modelling

John Dold
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The study of combustion processes, using mathematical methods, has advanced considerably in the past 100 years. Along with identifying the physical and chemical complexity driving them, this has been made possible by recognising mathematically tractable simplified models that, nevertheless, describe the most important physics reasonably well. Such models have frequently raised interesting mathematical challenges. But also, rather than just mimicking reality, they have helped to identify the variety of physical phenomena that can arise over different ranges of key dimensionless parameters, and they have sometimes placed theory well ahead of experimental observation. The presentation attempts to illustrate the history of this development through a selected outline of combustion models, ranging from descriptions of flames, detonations and ignition processes to models for the spread of bushfires.

5 Mathematical Modelling of Li-ion Battery Cathodes

Troy Farrell
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Electrochemical devices such as batteries and electrochemical solar cells are often described as multi-physics devices. This is a catch-all term meant to convey the fact that these devices are inherently multi-scale, multi-component and multi-phase in nature and that their operation involves complicated interfacial charge transfer and bulk solid and solution phase charge transport. Consequently, the development of accurate and meaningful mathematical models and numerical simulations for such devices is a complex task. Such modelling however, can play a vital role in the optimization of these devices via the identification of the key parameters that control their operational behaviour for a range of conditions and material configurations.

In this seminar we will present a novel, 'multi-physics' model for modern, high-rate $LiFePO_4$ battery cathodes and highlight the challenges, approaches and outcomes of such modelling.

6 Making good use of time

Vivien Kirk
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Many physical phenomena have the property that different processes contributing to the phenomenon evolve on different time scales. For example, the electrical signals controlling brain activity may be hundreds of times faster than some of the chemical signals acting on the same cells. The behaviour of systems with multiple time scales can be very complex, frequently displaying intricate patterns of oscillation. Techniques for the analysis of such systems have been developed in recent years and a great deal is now known about characteristic behavior for systems with multiple time scales. This talk will outline some of the fundamental ideas used in the analysis of multiple time scale systems, then discuss examples of good and ill-advised use of time scales in the analysis of some mathematical models of physiological systems.

7 Assimilating modelled catchment loads with monitoring data to estimate sediment loads to the Great Barrier Reef: A Bayesian Approach

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Coauthors: Daniel Gladish, Daniel Pagendam, Christopher Wikle , Rebecca Bartley , Ross Searle, Robin Ellis , Cameron Dougall , Ryan Turner, Stephen Lewis, Zoe Bainbridge and Jon Brodie

The export of pollutants from coastal catchments within Australia has important implications for the health of the Great Barrier Reef (GBR) lagoon. To quantify end of catchment loads of constituents such as total suspended sediment, and assess progress towards defined constituent load targets, requires robust statistical methods that can provide some measure of confidence in estimates. This means we need to be able to quantify uncertainty and communicate it effectively to catchment managers and policy makers.

We have developed a spatio-temporal statistical model for the Upper Burdekin catchment in Queensland, Australia that is mechanistically motivated by a process-based deterministic model known as Dynamic SedNet. The model is developed within a Bayesian hierarchical modelling framework that uses dimension reduction to accommodate seasonal and spatial patterns. The first level of dimension reduction projects the time series of flow and sediment concentration onto a seasonal basis set that captures the inter-annual variation across sites, while the second dimension reduction attempts to capture the dominant patterns of spatial variability across the region. The Bayesian model assimilates monitored sediment concentration and flow data with daily output of sediment concentrations, stream discharge volumes, and sediment loads generated from Dynamic SedNet for 411 spatial locations across 22 years.

Our approach offers a new way to estimate and interpret flow, concentration and loads with a level of confidence that can lead to meaningful changes in catchment management and reporting and lead to more scientifically defensible decisions.

8 Multifidelity Methods for Design and Uncertainty Quantification

Karen Willcox

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Multifidelity modeling refers to the situation where we have available several numerical models that describe a system of interest. These numerical models vary both in fidelity and in computational costs. Different models may arise from a choice to resolve the physics at different scales and/or from invoking different modeling assumptions; they may also include derived surrogates such as projection-based reduced-order models and data-fit models. A multifidelity approach seeks to exploit optimally all available models and data for a particular task, such as optimization or uncertainty quantification. The idea is to use the cheaper models as much as possible but to maintain the quality of higher-fidelity information and associated guarantees of convergence. This talk describes our recent work in developing multifidelity methods for optimization under uncertainty of large-scale problems in engineering design.

5 Abstracts for Contributed Talks (Student talks are denoted *.)

9 Real-time detection of unexpected local variability in air quality monitoring data

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Studies to model, interpolate or forecast variations in air quality data both in time and space have traditionally been designed for regional or global spatial scales in low temporal resolution to give understanding of the variation in the pollutants' dispersion in long-term. However, with the increasing demand to monitor air quality at local scale, techniques are required to detect unexpected variations in the signals in real time (preferably) or with small time delay. Such local scale changes could be due to a subtle indication of monitoring instrument malfunction (requiring network maintenance) or a change in the local condition which may require implementation of additional air quality management strategies. In this talk, we address a framework for such real-time techniques. First, we derive a norm or expectation for the signal variation and second, we establish decision rules to detect deviation from the expected behavior at a (fixed) false alarm rate. As a case study, we consider detection of unexpected local variations in ozone data on the hourly and daily scales by proposing a causal Wiener filter and normal approximation to the distribution of the residuals. We discuss the trade-offs, not only between the sensitivity and specificity of the technique to changes, but also between the complexity of the filter and the establishment of the decision rule.

10 Modelling opinion dynamics in the presence of disagreement

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Understanding the way people form opinions is of continued interest to a wide range of researchers, including social scientists, economists and, due to the overlap with significant physical problems, physicists. There are many elements which may influence the development of an opinion, such as personality, culture and peer interaction, however attempts have been made to capture the key features of the resulting dynamics with relatively simple models. Perhaps the simplest is the voter model, which assumes people hold one of two opinions and may randomly change their opinion depending on interactions with their neighbours. Attempts to move beyond this binary model have included introducing a wider range of discrete choices, a continuous scale for opinions, and the possibility of agreement and disagreement between neighbours. All these models however are stochastic in nature, relying on shifts in opinion with some probability. In this work I introduce a model of continuous opinion which incorporates nonlinear interactions between players to model the opinion dynamics. In the presence of both possible agreement and disagreement I show that extreme opinions may spontaneously appear in the population. I also explore the effect of interactions with a global player ("the government") showing that, depending on the stance of this player, extremism may dramatically increase.

11 *A composite model of blood glucose with insulin injections and exercise for diabetics

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Coauthors: Volker Rehbock, Ryan Loxton

In this paper, we develop a composite model that is capable of capturing the effects of exercise and subcutaneous insulin injections on the dynamical model of the blood glucose regulatory system presented in [1]. This model consists of 12 state variables naturally divided into five subsystems: the glucagon and insulin transition subsystem, the receptor binding subsystem, the glucose subsystem and the effect of exercise on insulin dynamics and glucose dynamics. We formulate a combined optimal control and optimal parameter selection problem which seeks to determine optimal injection times and volumes as well as optimal exercise regimes to regulate blood glucose. A well known time scaling transformation is then applied to make the problem suitable for the application of standard optimal control algorithms. Numerical results show that optimal treatment regimes can be readily determined via the proposed approach. Significant improvements can be made in regulating the blood glucose level for diabetics.

[1] Z. Al Helal, V. Rehbock and R. Loxton. Modelling and optimal control of blood glucose levels in the human body. Journal of Industrial and Management Optimization **11**, 1149–1164, 2015.

12 *Gradient Schemes For Signorini Problem

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Variational inequalities with Signorini boundary conditions have been used to study many physical problems, fluid dynamics, elasticity, seepage models and electrochemical reactions, for instance. Such inequalities have been discretised by different numerical methods, such as two-points finite volumes and linear finite elements. However, studying the convergence rate for the case of variational inequalities can be met with difficulties owing to insufficient regularities on the exact solution.

In this talk I will introduce a generic framework to find the unified convergence analysis of many conforming and nonconforming numerical schemes for the linear and the nonlinear Signorini problem. This framework offers a simpler formulation to improve known convergence rates for some methods and to obtain new rates for methods not previously applied to any kind of variational inequalities. Moreover, this framework is also utilised to perform a new numerical method for the Signorini problem, the Hybrid Mimetic Mixed method (HMM method). Finally, to highlight the efficiency of this new scheme, I will provide numerical results including a novel analytical test-case, which is completely unlike any test presented in the previous studies.

13 How does one quantify 'epigenetic memory'?

Bob Anderssen

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Coauthors: Jean Finnegan, Chris Helliwell and Masumi Robertson of CSIRO Agriculture.

In order to guarantee species survival, plants must determine when spring has started. Many use the cold of winter to cue the change from vegetative to reproductive growth. In Arabidopsis, this transition is driven by the gradual repression of the transcription of *FLOWERING LOCUS C (FLC)* and the activation of the genes that orchestrate the flowering.

This process is 'epigenetic', since the change in the level of expression of FLC is 'remembered' even when the weather warms. In fact, the repression occurs through a cumulative chromatin modification in the histone composition at the nucleosome immediately downstream of the start of FLC transcription.

The memory of winter is reflected in the fact that the flowering time for vernalization-responsive plants is inversely proportional to the intensity and duration of winter. Consequently, in order to model the response of plants to environmental change, there is a need to formalize how the memory process is quantified and modelled.

In this talk, the possibility is considered of adapting rheological causal modelling of fading memory to quantify epigenetic memory.

This talk is based on a joint and ongoing research collaboration with Jean Finnegan, Chris Helliwell and Masumi Robertson of CSIRO Agriculture.

14 From discrete time random walks to numerical methods for fractional order differential equations

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We present a method for finding an numerical scheme to solve a class of fractional order differential equations. The scheme is derived from the master equations that govern the evolution of the probability density of a discrete time random walk. Under the appropriate limit the master equation approaches the fractional order differential equation of interest. The limiting procedure guarantees the consistency of the numerical scheme, provided that the underlying random walk exists. Using this approach numerical schemes have been found for fractional Fokker-Planck equations, reaction subdiffusion equations, and fractional compartment models.

15 *Flow in spiral channels with arbitrary cross-section

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Spiral particle separators are widely used in the mineral processing industry to segregate mixtures of particles with differing densities. Mathematical understanding of such devices is limited, and the design process is largely experimental. The cross-sectional shape of particle separators is considered important in their separation performance, and in this talk I will discuss a model for particle-free flow in channels with arbitrary cross-section. Although we cannot solve for the flow completely analytically (except in the rectangular cross-section case), we have only to solve a simple ordinary differential equation for the free-surface shape. We present results for some different channel shapes and discuss the potential implications for particle separation.

16 *Half-sweep modified geometric mean iterative method for solving integro-differential equations

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Coauthors: Benchawan Wiwatanapataphee, Yonghong Wu

The theory and application of integro-differential equations (IDEs) are crucial theme within applied mathematics. Therefore, solving high-order IDEs are difficult even using numerical approximation due to its computational complexities. The prime objective of this paper is to reduce computational complexities of the Modified Geometric Mean (MGM) iterative method in solving second and fourth order IDEs. As such, the half-sweep iteration concept is implemented to scrutinise and evaluate the performance in solving dense linear system. Finite difference and three-point composite closed Newton-Cotes quadrature (FD-3CCNC) are formulated to approximate the IDEs to generate the system of linear equation incorporated with half-sweep iteration. Some relevant theories and proofs are also demonstrated for the convergence of the proposed method. A discussion of the computational efficiency index alongside numerical comparisons with some existing methods are also carried out. Finally, the application of the new schemes illustrated with some examples.

17 Non-local Dirichlet problems on bounded domains

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Stochastic jump processes can be modelled using non-local partial differential equations which are often defined on the whole space. We show that the process that is stopped if it leaves a bounded domain is goverened by a well-posed Dirichlet problem. This result justifies the usage of the Lax-Richtmyer Equivalence Theorem for many of the numerical approximation results in use today.

18 Reconstruction of refractive index from acoustic farfield data

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In this talk we consider an impenetrable 2D scatter with piecewise smooth boundary, surrounded by a heterogeneous dielectric coating. Our problem of interest is to reconstruct the refractive index of the heterogeneous dielectric coating from acoustic farfield data. We reformulate the problem as a nonlinear equation, which we then solve using a regularised Newton type solver. We will discuss the main features of our algorithm, and then present reconstructions for various challenging media.

19 *Sensitivity of the Empirical Mode Decomposition to interpolation methodology

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The Empirical Mode Decomposition (EMD) is a data sifting procedure, which provides a way to decompose nonlinear and non-stationary time series into component functions. This method offers a practical alternative to more traditional methods such as the Fourier transform, which is not well-suited to such circumstances. Moreover, it forms the basis of the Hilbert Huang Transform (HHT), which has been applied in a number of areas, including biomedicine, neuroscience, epidemiology, chemical engineering, finance, atmospheric turbulence, seismology and ocean dynamics. Despite the wide use of the HHT, its theoretical basis is still not well understood. *(continued next page)*

The EMD process decomposes a signal into intrinsic mode functions (IMFs), which are analogous to the harmonic modes of Fourier analysis, but which can have variable amplitude and frequency throughout the time domain. A critical step in determining each of the IMFs involves constructing upper and lower envelopes of the local maxima and minima. In the original presentation of the EMD methodology, cubic spline interpolation was recommended to construct these envelopes. However, there does not appear to be any literature to support such a recommendation and so it is natural to wonder how employing alternative interpolation methods would affect the ultimate outcome of the EMD method.

In this paper we consider this issue by studying the EMD procedure, as it applies to several synthetic data sets. IMFs for each of the data sets are derived separately using cubic spline, linear spline and smoothing spline interpolation techniques and the resulting structures scrutinized for systematic differences.

20 *Is it ever counterproductive to reduce the infection rate?

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Epidemic fade-out refers to the situation where an infection dies out after the first wave of an outbreak. We consider the probability of epidemic fade-out in the SIRS (Susceptible-Infectious-Recovered-Susceptible) infection model. We report the interesting feature that the relationship between infection rate and probability of epidemic fade-out is non-monotonic: a higher infection rate can sometimes, paradoxically, lead to a higher probability of epidemic fade-out. We show that this probability peaks near $R_0 = 2$, and provide an explanation.

This raises the question of whether there are times when it is best to not try to reduce the infection rate, or at least to save resources for a more critical time. We present a method for determining when are the best times to reduce the infection rate, and when it may be best to do nothing.

21 *Genome Assembly Using Traveling Salesman Problem Heuristics

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The ground-breaking discovery of DNA structure in the 1950s opened up an unparalleled opportunity for multidisciplinary efforts, such as the multi-billion dollar Human Genome Project, to come together in a quest for understanding 'life'. Mathematics has proved to be vital in many such efforts, especially the DNA Sequencing Problem; aligning and merging fragments of DNA to construct the original sequence.

The importance and mathematical beauty in the DNA-Sequencing Problem stem from its close ties to fundamental problems in Combinatorial Optimization and Complexity Theory. In particular, the basic idealized DNA-sequencing Problem can be easily embedded in a Traveling Salesman Problem (TSP) which, arguably, is the most widely studied problem in combinatorial optimization. While the close relationship between the two problems is not sufficiently exploited due to the computational difficulty of TSP, recent advances in the quality of TSP heuristic algorithms provide a compelling opportunity for a new approach to DNA-Sequencing Problem. Our project is aimed at exploring this opportunity for developing TSP-based models and algorithms to advance our mathematical understanding of the DNA-Sequencing Problem as well as offering practical solutions to the DNA-sequencing Problem.

22 A framework to assess disease control in livestock industries when there is an increasing demand for free-range produce

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In recent years there has been an increasing demand for free-range produce from livestock industries. For example, in Australia, demand for free-range eggs has increased from 10% in 2000 to 50% in 2014. Since a driving mechanism for disease importation into livestock populations is thought to be contact with wild or feral animals, a natural question is to assess the impact of time livestock spend outdoors on the risk of infection.

Stochastic branching process models are valuable for estimating the probability of disease outbreaks in populations, and they are particularly robust in the assessment of mitigation and response strategies when comparing the impact of disease outbreaks under different scenarios. We formulate such a model, allowing for distinct local conditions (such as fixed grow-out periods, stock density and free-range access), transmission at both on-farm (local) and between-farm (global) scales, and an on-going low-level risk of infection from external sources. The model we construct is a multilevel Galton-Watson process with immigration.

While our main focus is on the poultry industry, this framework is also relevant to other enterprises, such as the pork industry, where disease may be introduced through feral animals, livestock have fixed grow-out or breeding periods, and it is thought that free-ranging stock could increase the risk of disease introduction.

23 *Flows through helical pipes

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Flows through helical pipes are important in several applications, such as blood flow through the coiled veins and arteries of an umbilical cord, and flow through industrial heat exchangers and reactors. In this talk, I will examine flow through helical pipes with elliptic cross-section. The steady incompressible Navier-Stokes equations are solved for these geometries at low Reynolds numbers using the finite-element method library oomph- lib. The non-dimensional parameters that will be investigated are the aspect ratio of the ellipse, the rate of twist of the cross section, the ratio of the equivalent radius of the ellipse to the radius of the helix and the Reynolds number. Preliminary results indicate that the behaviour of the flow is between that of a flow between a straight tube with an elliptic cross section and flow through a helical pipe with a circular cross section.

24 Water wave overwash of a step

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Overwash is the highly nonlinear process where water waves run over the upper surfaces of partially submerged bodies. At ANZIAM 2015, David Skene presented a mathematical model of overwash of a thin floating plate, based on combined linear potential flow and shallow water theories. He compared predictions of overwash depths to measurements made by a wave gauge mounted on a plate during a series of wave tank experiments, and showed that the model was accurate for shallow to moderate overwash depths, but lost accuracy as the overwash became relatively deep. Here, I will compare the mathematical model to CFD simulations for the canonical problem of overwash of a step.

25 Unidirectional airflow through avian lungs: new insights from a piecewise linear model

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Avian lungs are remarkably different from mammalian lungs in that air flows unidirectionally through rigid tubes in which gas exchange occurs. It has been hypothesized that the unidirectional flow is due to aerodynamic valving during inspiration and expiration, resulting from the anatomical structure and the fluid dynamics involved, however, theoretical studies to back up this hypothesis are lacking. We have constructed a novel mathematical model of airflow in the avian respiratory system that, for the first time, can produce robust unidirectional flow. The model consists of two piecewise linear ordinary differential equations with lumped parameters and discontinuous, flow-dependent resistances that mimic the experimental observations. Using dynamical systems techniques and numerical simulations, we show that unidirectional airflow can be produced by either effective inspiratory or effective expiratory valving, but that both inspiratory and expiratory valving are required to produce the high efficiencies of flows observed in avian lungs. We further show that when the relative airsacs compliances vary, it affects the timing of the airflow across the gas exchange area. These and other insights obtained by our study will be presented in this talk.

26 Nonlinear 4th Order Surface Diffusion at Nanoscale Grain Boundaries: Beyond Similarity Solutions

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Crystal surface technology requires fabrication of surface structures that are smaller than a micron. These structures evolve by surface diffusion which is modelled by a nonlinear 4th order PDE for curvature-driven flow. The nonlinear coefficients of the transport equation may depend on surface orientation relative to crystal planes. There is an integrable nonlinear surface diffusion model that is almost isotropic. The boundary value problem with fixed angle at the groove root, has a similarity reduction with exact solution in terms of generalised hypergeometric functions. This was solved last century by Tritscher and Broadbridge. The groove angle may also be time dependent, since surface tension depends on temperature as well as concentrations of surfactants. This case was developed recently by Broadbridge and Goard. The time dependent case still admits an exact power series solution in time, with coefficients that again are generalised hypergeometric functions, with the similarity solution at leading order. Unlike in second order problems with standard boundary conditions, discretised 4th order nonlinear diffusion with central finite differences does not always have a real valued solution. This is an interesting curiosity piece but there is a way around it: use an integral variable as the dependent variable, and the solution will be smooth and manageable.

27 *Analysing influenza epidemics aboard ships

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Analysing historical influenza outbreaks can improve our understanding of influenza epidemiology and inform potential approaches to controlling future outbreaks. We consider here historical data of eleven influenza epidemics aboard ships in the period 1891–1977. The unique nature of the ship environment removes external factors that typically have to be controlled for, and allows for the use of stochastic models. We propose improvements to a recent simulation-based approach to inference — Particle Marginal Metropolis-Hastings (PMMH) algorithm built upon a Sequential Monte Carlo (SMC) estimate — and demonstrate the effectiveness of this algorithm. We use this new methodology to perform a concurrent analysis of eleven influenza epidemics.

28 Semi-analytic solution of the one-dimensional multilayer diffusion problem with an application to macroscopic modelling

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The focus of this talk is the one-dimensional m layer diffusion equation:

$$\frac{\partial u_i}{\partial t} = \kappa_i \frac{\partial^2 u_i}{\partial x^2}\,, \qquad i = 1, \ldots, m \tag{1}$$

where $u_i(x,t)$ is the temperature/concentration, and κ_i is the diffusivity, in the ith layer ($l_{i-1} < x < l_i$). When the number of layers m is large, this problem provides a simple example of a two-scale problem: the physical domain ($l_0 < x < l_m$) is much larger than the length scale at which the material properties (in this case the diffusivity) vary spatially. In this talk, I will present a novel semi-analytic approach for solving (1) subject to suitable initial, boundary and interface conditions. The new approach, based on the Laplace transform and an orthogonal eigenfunction expansion, overcomes several issues that arise with classical analytical approaches when m is large. A highlight of the work is the application of the new method to macroscopic modelling of multilayer diffusion, where the solution of a multilayer diffusion model consisting of a large number of layers is smoothly approximated by the solution of a macroscopic model consisting of a single effective layer.

29 *How long is a bigeye tuna?

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The bigeye tuna (*Thunnus obesus*) stock in the western central Pacific Ocean is a commercially important resource with annual catches exceeding 100,000 tonnes. Scientists have been concerned about the status of the bigeye population for some years now and stock assessments suggest harvest rates are too high and the population is arguably overfished. A better understanding of growth rates has been identified as an opportunity to potentially improve the complex stock assessment model used to inform management of the resource. Tag-recapture data are important for modelling the growth of bigeye, but these data are difficult to fit because the ages of the tagged fish are unknown, individuals grow at dfferent rates and tagged fish are recaptured at most once. Laslett *et al.* (2002) describe an approach for estimating individual-specific growth curves from tag-recapture data. We use a Bayesian methodology to apply the Laslett *et al.* (2002) approach to records from tagging studies of bigeye tuna. The use of a Bayesian approach allows the ages of the tagged fish to be estimated and facilitates fitting models that are more robust to potentially inaccurate recapture length measurements by fishers. We also examine the effect of tagging on growth.

Reference: Laslett, G.M., Eveson, J.P. and Polacheck, T. (2002) A flexible maximum likelihood approach for fitting growth curves to tag-recapture data. *Canadian Journal of Fisheries and Aquatic Sciences,* 59:976–986.

30 Drawing tubular fibres: experiments versus modelling

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A series of experiments where glass tubes of diameter ∼10 mm are heated and stretched to produce long fibres of diameter ∼160 microns are compared to a model of this fabrication process, where the softened glass is modelled as a 3D Stokes flow. The importance of fibre tension in determining the internal geometry of the fibre is demonstrated, confirming a key prediction of the model. There is evidence of self-pressurisation of the internal channel, where an additional pressure is induced in the channel as the fibre is drawn, and the dependence of the magnitude of this pressure on various experimental parameters is discussed.

31 Complex spatial self-organisation in an extended Daisyworld model

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We consider a two-dimensional variant of the original non-spatial Daisyworld model, developed by Watson and Lovelock. We examine how the environmental regulation which emerges in the original Daisyworld model translates in a spatially two-dimensional context. To achieve this, we introduce the capacity for migration of the systems biota via diffusion, and diffusion of the temperature, to the original equations. It is demonstrated mathematically two distinct modes of spatial equilibrium, consistent with the preservation of spatially averaged optimal environmental regulation, are possible under this scenario. Firstly, the Turing mode of diffusion-driven instability, resulting from the combined diffusive motions over space of the systems biota and temperature, drives the formation of static spatial patterns, in the form of spots and stripes, over the Daisyworld surface. Secondly, we identify a spatiotemporal Hopf mode, arising from a Hopf bifurcation in the non-spatial dynamics, and show the existence of travelling plane and rotating spiral wave solutions.

32 *Comparison of meshing techniques for the solution of the Poisson-Nernst-Planck equations

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The Poisson-Nernst-Planck (PNP) equations are widely used in electrochemistry to describe the flow of ionic species subject to an electric field. The non-linear coupling between the electric field and the concentration of ionic species makes an analytic solution intractable unless simplifying assumptions are made, namely, ignoring the charge of the double layer. To solve the full two dimensional PNP equations, we avoid such assumptions by using the Control-Volume-Finite-Element (CVFE) method to obtain an accurate numerical solution. Motivated by ionic transport through a nanopore, we investigate the differences between a triangular (linear) mesh and non-orthogonal quadrilateral (bilinear) mesh. The initial results presented show that the choice of a bilinear mesh can reduce the computational cost of the numerical solution. We attribute the reduction in cost to the ability of the bilinear mesh to increase the aspect ratio of each element whilst maintaining the necessary error tolerances.

33 Ancient Starch: Fourier in the Round

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Starch grains associated with food preparation and consumption are preserved for millennia on the surfaces of stone tools, ceramics and other material culture. The starch grains can be easily extracted, but identifying which plant species they come from is problematic. Different analysts use different methods, and identification relies on subjective interpretation. Many grains cannot be identified with any confidence.

Here a novel system is presented for identifying the plant species origin of starch grains using image analysis of light micrographs. Geometric and morphological features of each starch grain were determined from a mask of the two-dimensional maximum-projection-area.

A Fourier expansion of the periphery radius into the sum of a series of radial harmonics yields a model that can regenerate the grain shape as precisely as required. For grains with a dominant axis of symmetry, the magnitude of the second component is larger than that for circularly symmetric grains. The magnitudes of the first 11 radial harmonic components were determined for each grain generating a Fourier signature of the grain. Whilst further harmonics could have been added, for this study, it was found that they did not provide any additional discriminative power. In practice, the perimeter features can be represented by a handful of terms.

In combination with other geometric and morphological measures, the Fourier signature of the grains enabled the creation of effective classifiers to undertake a quantitative evaluation of starch grains, thereby reducing the need for subjective qualitative determination. The system provides a robust framework in which plant microfossils of unknown species origin can be compared with reference grains for effective identification.

34 *Physically Realisable 3D Bone Prosthesis Design with Homogenised Microstructures

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Failure of bone prostheses leads to revision surgeries which are costly and cause great discomfort. Aseptic loosening is the primary cause of failure in total hip replacements and is linked to interface stress and bone resorption. Here we examine the use of varying 3D microstructures applied to femoral implant optimisation to develop physically realisable, optimised designs with spatially varying effective material properties. We optimise for shear stress at the interface with constraints on bone resorption measured through strain energy.

35 *Steady nonlinear dispersive waves: a numerical framework

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Steady dispersive waves on the surface of channel flows have been the focus of numerous studies, due to the implications for wave breaking processes. The dynamics of atmospheric flows such as Rossby waves are fundamentally dictated by these breaking processes, and as such it is important to be able to develop a strong physical of understanding of when and why these events happen.

These wave trains will be studied by examining solutions of the forced Korteweg de Vries and forced extended Korteweg de Vries equations subject to both step and larger-scale topographic functions, using a novel numerical methodology based upon the Spectral Homotopy Analysis Method. This technique allows for the calculation of numerical solutions to variable coefficient nonlinear differential equations using a sparse framework which requires significantly fewer operations than other techniques.

36 *Spectral Stability of Travelling Waves for a Keller-Segel Model

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The spectral stability of travelling wave solutions to a Keller-Segel model of bacterial chemotaxis with logarithmic sensitivity and a constant consumption rate is studied. The existence of travelling wave solutions is well studied for this model but some aspects of the stability analysis of the travelling waves remain open. The linear (in)stability of these solutions depends on the location of the essential and point spectrum of the linearised operator about the travelling waves. The asymptotic behaviour of the linearised operator is analysed to determine the location of the essential spectrum. We show, in contrast to previous results, that in the singular limit of zero-diffusivity of the attractant there exists a range of parameter values such that the linearised operator is spectrally stable in a weighted space. The chemotactic coefficient is found to act as a bifurcation parameter from a convectively stable to an absolutely unstable regime. The effect of including a small but non-zero diffusivity of the attractant on the location of the essential spectrum is also analysed. If time permits, we will also discuss a procedure to compute the point spectrum. This is joint work with Peter van Heijster (QUT) and Robert Marangell (U Sydney).

37 Towards a robust gradient-enhanced sparse grid surrogate for uncertainty quantification of CFD results

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The objective of surrogate-based uncertainty quantification (UQ) is to efficiently propagate uncertainties in the design parameters, in order to obtain a probability distribution for a quantity of interest (QoI). The surrogate is effectively an interpolation over the parameter space for a number of realizations of the QoI, obtained from a numerical solver.

Recently adjoint capability has become available in a number of computational fluid dynamics (CFD) solvers. This enables computation of the gradient of the QoI with respect to the design parameters at relatively low cost. There is now an ongoing search for surrogate methods that incorporate gradient information. Currently, we develop a gradient-enhanced sparse grid surrogate based on the combination technique.

Using an error splitting obtained from classical interpolation estimates on each sub-grid we obtain an error estimate for the gradient-enhanced sparse grid surrogate. The error is dominated by the mixed derivatives of the QoI.

One important issue with adjoint-based gradients is that they can contain a significant amount of numerical noise, of up to 10% in typical engineering problems. This tends to give rise to oscillations, resulting in an inaccurate surrogate. Proper treatment of this gradient noise is work in progress.

We consider two applications: a one-dimensional heat convection-diffusion problem and the flow over a transonic airfoil.

38 Spectral Compression for Hyperspectral Images

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This talk will address some of the challenges of applying compressive sensing to the design of hyperspectral cameras. Essentially, there are two types of compressions that can be utilised in the design, namely compression in the spatial domain and compression in the spectral domain, and features of these will be described from the viewpoint of compressive sensing. However, the main focus will be on utilising an approximate singular value decomposition to provide compressibility in the spectral domain. Specifically, we will demonstrate that:

- Direct SVD provides effective compressibility in the spectral domain
- Effective approximations can be derived from
  - A small amount of the image data
  - A small number of random projections
- Basis functions derived from a hyperspectral image can be used as the basis function for a similar image
- With some loss of compressibility, this can be implemented with projection matrices whose elements are $+1$ or -1.

39 Mathematical model for the interaction between the immune system and cancer

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The anti-tumor role of the immune system has been documented for more than a century. Despite recent success with some types of immunotherapies (e.g., involving antibodies or cancer vaccines), many anti-tumor therapies are still not leading to the expected outcomes. One reason is that there are still numerous questions regarding the biological mechanisms behind the interactions between the immune cells and tumor cells. The complexity of these interactions is acknowledged by the immune-editing hypothesis, which emphasizes the dual role of the immune response: tumor-promoting and tumor-suppressing. A ratio that seems to have predictive outcome on tumor growth and patient prognosis involves the M1 and M2 macrophages, with M1 macrophages tumor-suppressing and M2 macrophages tumor-promoting. However, several studies have shown contradictive results. To elucidate these contradictions we need to have a better understanding of the interactions between the M1 and M2 macrophages and other cells in the tumor environment. To this end, we derived a non-spatial mathematical model that describes the interactions between the tumor cells and the immune system.

40 *Newton like iteration methods and its application to financial modeling

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Here I will talk about 2 and 3 step Newton like iteration methods for solving a system of nonlinear equations. Two step is constructed from continuous analogy of Newtons method and an ordinary Newtons method. Previously known result was the convergence region of a parameter τ. In other words, from what region we choose τ, the iteration method converges was known. Here we found how choosing τ influences to the way of its convergence. For 3-step case, we have introduced 3 methods, each of these is a generalization of previously studied and published methods and for each of the iteration methods we found convergence region and convergence rate.

For an application part, we applied above iterations to the Black-Scholes equation of financial modeling. Following quadratic approximation procedure of Black-Scholes equation, we get nonlinear moving boundary equation. After solving this equation, to show how proposed methods working, we compared the results obtained by our iteration to other methods and the comparison is shown in the table.

41 Implementing a characteristic-finite element numerical scheme for an oil recovery model

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Tertiary oil recovery is modelled by a system of an elliptic and a parabolic partial differential equations. This system has dominating convection terms, which require special treatment in numerical implementations.

The Eulerian-Lagrangian Localised Adjoint Method (ELLAM) is a numerical method that combines the method of characteristics, for an exact solution of the convective terms, and finite element methods, for diffusion terms. It has been implemented in Wang et al. for the tertiary oil recovery model, with apparently good numerical outcomes.

We will however show that, under the conditions described in the numerical tests, the ELLAM method of Wang et al. cannot provide the claimed results and gives rise to concentrations that explode beyond 22 after only one time step. We will also explain how to modify and properly implement the method, to recover acceptable numerical results.

Reference: H Wang, D Liang, RE Ewing, S L Lyons and G Qin. An approximation to miscible fluid flows in porous media with point sources and sinks by an Eulerian-Lagrangian localised adjoint method and mixed finite element methods. SIAM J Scientific Computing, 22:561–581, 2000.

42 *Intercalating a Carbon Nanotube into Graphene Folds

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Folding graphitic materials have the potential to create complex structures with new properties. Intercalating molecules into these folds is an interesting method of one-dimensional functionalisation of a graphene sheet. We investigate the incorporation of a single-walled carbon nanotube into folded graphene structures and between sheets of graphene. The optimal curved structure caused by both the elastic and van der Waals energies is examined using variational calculus. Results are shown to match with molecular dynamics simulations.

43 Multiscale modelling of plant root growth

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Understanding the growth of plants is fundamental to current efforts in food security and bioenergy. Cellular level growth is driven by a high internal turgor pressure, which causes viscous stretching of the cell wall, combined with new material deposition, whilst growth at the level of e.g. a root involves coordination across multiple cells. The cell wall is a complex material with a highly ordered microstructure, producing non-linear anisotropic mechanical behaviour that can be manipulated under enzymatic control to alter the cellular growth rate. We present a series of models across multiple spatial scales, from the cell wall microstructure to whole organ level, aiming to elucidate the mechanical mechanisms underpinning plant growth.

44 *CFD analysis of convective plume attachment

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The behaviour of a convective plume, such as that generated above a fire, can vary markedly depending on a number of factors including the source intensity and the geometry of the terrain from which it emanates. For example, in 1987 a small fire burning within an escalator trench in the King's Cross Underground Complex, surprised firefighters when it explosively sped up the trench, ultimately killing 31 people. This unexpected fire behaviour was found to be due to attachment of the convective plume to the floor of the escalator trench - a phenomenon subsequently termed the 'trench effect'. In this presentation we use computational fluid dynamics (CFD) to analyse the threshold behaviour of convective plumes in trenches of various inclinations. In particular, we provide the first numerical confirmation of the existence of a threshold angle of inclination above which convective flows will attach to a surface.

45 *Modelling transport through an environment crowded by a mixture of obstacles of different shapes / sizes

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Many biological environments are crowded by macromolecules, organelles and cells which can impede the transport of other cells and molecules. Previous studies have sought to describe these effects using either random walk models or fractional order diffusion equations. Here we examine the transport of both a single agent and a population of agents through an environment containing obstacles of varying size and shape, whose relative densities are drawn from a specified distribution. Our simulation results for a single agent indicate that smaller obstacles are more effective at retarding transport than larger obstacles; these findings are consistent with our simulations of the collective motion of populations of agents. In an attempt to explore whether these kinds of stochastic random walk simulations can be described using a fractional order diffusion equation framework, we calibrate the solution of such a differential equation to our averaged agent density information. Our approach suggests that these kinds of commonly used differential equation models ought to be used with care since we are unable to match the solution of a fractional order diffusion equation to our data in a consistent fashion over a finite time period.

46 *A Modification on Recently Proposed Reliability Analysis Method

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Reliability related issues are well known as significant and difficult problems in system design. Reliability analysis problems often need to be solved in order to meet required safety levels of engineering systems. First-order reliability analysis, which has been applied in different non-deterministic design optimisation problems, is a powerful tool for system safety investigation. The strategy is to find a reliability index so that failure probability of a system can be estimated and taken into account. By solving this problem, a particular safety level is obtained that can then be used to formulate a probabilistic constraint inside the mentioned non-deterministic optimisation problem. A new reliability analysis method has recently been introduced, based on conjugate gradient direction, to solve this kind of problem. In this method, a conjugate gradient direction is used at each iteration to update the current design point. However, we have found that this method shows unstable and inefficient behaviour in some situations, especially when the system performance function is highly nonlinear. In this presentation, an improvement is proposed for this method to prevent the problem from diverging and also to speed up its convergence. In our proposed method, a self-adaptive conjugate search direction is employed to modify the existing reliability analysis method. The performance of this method is compared with other methods by solving different numerical examples. We will show that the proposed new method needs fewer iterations and a shorter time than the existing reliability analysis methods. Furthermore, this method is able to solve some problems for which the existing methods diverge. Thus, our new method is more stable and efficient than the existing methods.

47 Modelling Queueing Networks as Cooperative Games

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We consider n M/M/1 queues working in parallel where servers are allowed to pool their resources and cooperate. That is, they can form coalitions where the members can serve customers from other members arrival streams. Each coalition of queues functions as an M/M/1 queue where the arrival rate is the sum of the individual members arrival rates, and the service rate is the sum of the individual service rates. We model this cooperative system as a transferable utility game, and show that if the characteristic function is the mean queue length, the core is nonempty. We first consider the case where all individual queues are stable (that is, the mean queue length is finite), and then the unstable case where some of the queues are unstable but the coalition of all queues is stable.

48 *Solving variable-order-in-space fractional partial differential equations using matrix function methods

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Variable-order-in-space fractional partial differential equations model anomalous diffusion in heterogeneous material with varying properties in space. Recent research suggests that fractional order partial differential equations could be a beneficial tool in modelling electrical impulses in the human heart. Recent research suggests that damaged tissue within the heart results in variable-order-in-space fractional differential equations. We propose a numerical technique based on matrix functions to efficiently solve variable-order-in-space fractional partial differential equations. The method extends previous work that considered solving constant-order fractional partial differential equations efficiently on GPU machines.

49 Modelling hydrogen clearance from a rat retina

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Blood flow in biological tissue can be studied by measuring the clearance of an injected inert solution such as hydrogen saturated saline. Studying clearance in the eye is complicated by the vascular structure varying significantly through the choroid and retina. The majority of the blood flow is in the choroid but hydrogen diffuses into the retina complicating the measured clearance response. This talk will present two models of hydrogen clearance. The results of these models will be compared with laboratory measurements of hydrogen clearance in a rat retina.

50 Singularities at interfaces between flowing viscous fluids?

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Your Abstract: When two fluids flow past each other, the interface between them is subject to the Kelvin-Helmholtz instability. Small disturbances grow rapidly and eventually form over-turning billows and “cat’s eyes”. However, if the fluids are inviscid (non viscous), it is now known that the interface develops a singularity in the curvature, before the interface gets a chance to develop these exotic shapes. So it is natural to look at viscous fluids, since intuitively we would expect that viscosity will damp out the curvature singularity. Surprisingly, this doesn’t quite happen. A simple asymptotic theory shows that sharp interfaces between viscous fluids develop arbitrarily large spikes in the curvature, at certain points along the interface. Technically, these aren’t exactly “singularities”, but pragmatically there is no real difference. This will be illustrated in a couple of examples, and is confirmed numerically. So, if viscosity can’t prevent (near) singularities from forming, how do the “cat’s eyes” billows actually form? The answer appears to come from the fact that interfaces, in reality, have some finite thickness with a mixing layer.

51 *Diffusion-driven flow in a tilted, three-dimensional, square pipe

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Surprisingly, when a stably stratified fluid is bounded below by an inclined insulating boundary, the lower and thus denser fluid will flow up that boundary. This phenomenon is termed diffusion-driven flow. The aim of my research is to extend the understanding of two-dimensional diffusively driven flow problems to similar three-dimensional problems. In particular, diffusively driven flow in a three-dimensional tilted square pipe will be discussed. Analytical solutions for this problem have been found using asymptotic methods. Both boundary layer and outer flow region solutions were sought, and matched together based on a small parameter R. After leading order in the boundary layer, and generally in the outer flow region, the extension to three dimensions produced significantly different solutions to those for the two-dimensional problem. Numerical solutions will also be presented, and the way in which they informed the analytical solutions will be discussed.

52 Ambiguity and Depth Resolution In Electrical Conductivity Inversion

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Inverse conductivity problems have ambiguous solutions, and a unique solution can only be computed if additional a priori information is incorporated into the solution process. We discuss several kinds ambiguity, and show how each type of ambiguity occurs and is handled differently. We demonstrate that in electrical conductivity data provide depth information when used in connection with certain discretization of the problem, and that the role of the regularization term in the Tikhonov formulation is primarily to filter out noise. In addition we show how the inspection of two graphical tools, based on the Singular Value Decomposition, can guide the regularization and also reveal how much depth information can be achieved for a given noisy problem.

Keywords: Inverse problems, electrical conductivity inversion, regularization, SVD analysis, ambiguity, depth resolution.

53 *Using optimal Bred Vectors to improve Ensemble Forecasts in multi-scale systems

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Weather and climate models are inherently complex, multi-scale systems with natural instabilities occurring on spatial and temporal scales ranging from several millimetres to thousands of kilometres and from seconds to decades. Generally, the most unstable dynamics are associated with the small scale, fast processes, but the variables of interest are often the large scale slow variables. We examine this in the context of ensemble forecasting using a toy model multi-scale Lorenz-96 system, and aim to provide enhanced predictability over the slow system. In particular, we use bred vector perturbations to generate the ensemble members and show that with a few modifications to the bred vectors we can improve the ensemble accuracy and diversity.

54 Mathematical models of gastroenteritis

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We estimate that there are 4.1 million cases, 31,000 hospitalisations and 60 deaths due to foodborne illness each year in Australia. One of the key challenges in producing these estimates is the lack of evidence concerning transmission routes for gastroenteritis. Unlike many infectious diseases, gastroenteritis can spread through many routes, including person-to-person transmission, foodborne transmission, zoonotic transmission, or contamination of water or the environment. Current best practice in Australia and internationally is to use expert opinion to estimate the proportion of transmission that occurs through each of these routes. Mathematical models allow us to quantify many components of this process but are currently under-used for gastrointestinal infections. We show how transmission routes can be modelled using national survey data, and compare seasonal patterns for gastroenteritis and respiratory infections. We also use typing data for Salmonella — one of the main causes of hospitalisation and death in Australia — to show that most foodborne infections can be linked to eggs or chicken meat.

55 *Determining causes behind clearance, persistence or fulminant hepatitis of acute hepatitis B virus infection

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Cell-free virus is a well-recognized and efficient mechanism for the spread of hepatitis B virus (HBV) infection in the liver. Cell-to-cell transmission (CCT) for viruses such as HIV can be a more efficient means of virus propagation. Despite experimental evidence implying CCT occurs in HBV, its relative impact is uncertain. In this paper, we develop a 3-D agent based model to determine the relative importance of CCT in the development of acute HBV infection and its impact on the immune mediated resolution of acute HBV infection. Our study inferred that HBV supports CCT as a mechanism of viral spread. Simulations with CCT did not alter mean cccDNA levels of 15-20 copies/cell at the peak of the infection. However it was found that as the strength of CCT increases, T-cell response or T-cell numbers required to clear infection also increase. Thus CCT can negatively impact immune mediated clearance of acute HBV infection. T-cell response was also found to be on the higher side if the degree of non-CTL inhibition was low indicating a high probability of T-cell exhaustion if cytokine production is minimal. In general a stronger T-cell response leads to quicker and less destructive clearance. Cytolytic mechanisms that prioritize killing of cells with higher numbers of the HBV genome perform better, given they all exhibit same T-cell response. Simulations also indicated that one mechanism alone such as massive infiltration of T-cells or enhanced viral replication cannot fully explain fulminant hepatitis. The degree of non-CTL inhibition along with T-cell infiltration and viral replication decide whether infection will result in clearance, persistence or fulminant hepatitis.

56 *Akt Translocation in Mammalian Fat Cells

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Akt is a key cross-talk node between numerous signal transduction pathways in the mammalian cell. It plays an important role in cellular processes such as proliferation, cell survival, and metabolism. In particular, Akt is a key mediator of glucose transport in response to insulin. The phosphorylation (activation) of only a small percentage of the Akt pool of insulin-sensitive cells results in maximal translocation of glucose transporter 4 (GLUT4) to the cell membrane, which enables the diffusion of glucose into the cell. The dysregulation of Akt signalling is associated with the development of diabetes, cancer and cardiovascular disease. *(continued next page)*

Akt is synthesized in the inactive state, and in unstimulated cells is found predominantly in the cell interior. Upon stimulation by insulin, the Akt translocates to the inside of the cell membrane by a process that is currently not well understood. At the membrane, the Akt is able to bind to a docking site provided by phosphatidylinositol-3,4,5-triphosphate (PIP_3), an upstream activator of Akt in the insulin signalling cascade. Binding to PIP_3 brings about a conformational change to the Akt that allows it to become fully activated. The now-activated Akt can then leave the membrane and in turn phosphorylate its downstream substrates.

The process of translocation is largely unknown. The arrival of Akt at the membrane can be visualised using total internal reflection fluorescence microscopy. Using the experimental data as a guide, we develop a three-compartment deterministic ordinary differential equation model of Akt translocation. The model embodies the observed behaviour both in the presence and absence of insulin. This model forms a key component of a larger signalling cascade that controls the glucose metabolism in the cell. We present some initial results of the analysis of the behaviour of this dynamical system, its optimisation to experimental data, and discuss the biological insights that this gives into the translocation process.

57 Pattern formation in multiphase models of chemotactic cell aggregation

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We consider a model for the aggregation of cells cultured in a nutrient-rich medium in a culture well. The model uses a continuum mechanical approach, treating the cells and culture medium as a two-phase fluid mixture. The cell phase can generate forces in response to environmental cues, which include the concentration of a chemoattractant that is produced by the cells within the culture medium. We consider two commonly employed model simplifications, appropriate when the cell layer depth is thin compared to the typical lengthscale of the culture well: a (simple) one-dimensional and a (more involved) thin-film extensional flow reduction. By analysing the resulting systems of equations both analytically and numerically, we investigate the conditions under which perturbations to a homogeneous steady state (corresponding to a spatially-uniform cell distribution) can lead to a non-spatially uniform patterns.

58 *A cell growth model adapted for minimum cell size division

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In this talk I present a cell growth model in which cells divide only when they have reached a certain minimum size. Study shows that the determination of the steady size distribution to certain functional differential equations involve an eigenvalue that is not known explicitly for this particular model and is defined through the continuity condition. We show that there is a steady size distribution solution to this problem.

59 *Competing fishers and the balanced harvesting of marine resources

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Balanced harvesting of marine resources occurs when stocks are exploited in proportion to the natural productivity of the species, and can result in greater stock resilience and increased yields when compared to commonly used size-at-entry harvesting methods. A dynamic size-spectrum model, which explicitly tracks biomass through the population, is used to investigate population abundance. This is coupled with an individual based model of the harvesting behaviour of small-scale fisheries. Previous results have shown that when each individual agent acts to maximise their own yield in the short term without explicit regard for sustainability, a Nash equilibrium emerges, in which no agent is able to alter their behaviour without reducing their personal yield. Furthermore agents self-organise into a balanced harvesting situation. These results were obtained under the assumption of fixed fishing pressure. Here, we let the fishing pressure to change over time by allowing agents to enter or exit the fishery over the entire harvesting period. These changes will occur depending on whether agents personal yields reach a critical level associated with the costs of remaining in the fishery. We wish to determine if balanced harvesting (and a Nash equilibrium) will still occur under these conditions.

60 Exact solutions for logistic reaction-diffusion in biology

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Reaction-diffusion equations with a nonlinear source have been widely used to model various systems, with particular application to biology. Here, we provide a solution technique for these types of equations in n dimensions, when the diffusion coefficient is also nonlinear. The nonclassical symmetry method is used to find a single relationship between the nonlinear diffusion coefficient and the nonlinear reaction term such that the spatial and temporal variables can be separated. We give some example solutions for equations with Fisher (quadratic) and Fitzhugh-Nagumo (cubic) source terms.

61 *Phase near infinity

Phase near infinity

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In many practical situations one finds stable oscillations, which can be described mathematically as attracting periodic orbits of systems of differential equations. One can assign an asymptotic phase to any initial condition that approaches such a periodic orbit; all initial conditions with the same asymptotic phase lie on what is known as an isochron, and their trajectories synchronise with the same point on a periodic orbit. The technique of numerical continuation allows us to accurately compute isochrons of planar oscillators and to visualise them as smooth curves in the basin of attraction of the periodic orbit.

Isochrons have intriguing geometric properties, and this talk will present an example planar system which showcases some of these properties. More specifically, it will discuss the issue of what isochrons look like near the boundary of the basin of attraction, when it contains saddle points or extends to infinity.

62 *Implementation of finite element methods with self-similar basis functions

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In this talk we discuss recent work on the implementation of finite element methods using continuous self similar basis functions, that is basis functions whose graph is the attractor of an affine iterated function system. In particular we will discuss the problem of solving various one dimensional problems and demonstrate how carefully choosing the scaling factor for particular elements can lead to improved estimates around singularities without the need for local mesh refinement. We will also discuss some of the challenges in extending this work to higher dimensions whilst maintaining both generality and continuity. We conclude that self-similar basis elements may be better suited to discontinuous Galerkin methods.

63 Modelling to manage overabundance of koalas on French Island

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In 1880 koalas were introduced to French Island, located near Melbourne. By 1923 there was evidence of over-browsing and active management was needed to prevent widespread defoliation of trees and subsequent crashes in koala abundance. Until recently, this management involved translocation of koalas to sites off French island to reduce the population and allow for vegetation recovery. In 2012 removal of koalas from the island stopped and the current management strategy is to retain all koalas on the island and treat females with contraceptive implants to reduce the size of the population over time. This new management approach is in the early stage and modelling is required to determine the rate of implants needed to control the population numbers.

A simple Leslie matrix model was an obvious first approach to the problem. Fecundity and mortality rates for koala were available from a study by a zoologist. This yielded information about the proportion of females (by age group) that needed implants. Unfortunately as the total population on the Island is unknown this analysis could not produce the actual numbers that needed implants.

So what is observable? And will any observable variable be useful to feed into the control decisions? A system dynamics model comprising the koala and trees was constructed. In addition to age and sex classes the koala population was divided into those that had, and those that had not, been implanted. Trees were classified according to whether they were currently occupied, defoliated trees, and unoccupied recovered trees. Experiments were conducted to understand whether adjusting the implant rate depending on indices relating to the proportion of defoliation of trees would a timeous strategy to control the koala.

64 Recent developments in the theory and application of the sparse grid combination technique

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The sparse grid combination technique is used to solve complex systems of partial differential equations. Basically, it determines a linear combination

$$u^C = \sum_k c_k u_k$$

of component solutions u_k for different grid resolutions. The main example considered here are the gyrokinetic equations of plasma physics which are derived from the Boltzmann equations for ion and electron densities and are combined with the Maxwell equations for the electromagnetic fields. The component solutions are determined with the strongly scalable code GENE.

The sparse grid combination technique provides an additional level of parallelism which is well suited for exascale computing. A new version of the combination technique where both the underlying component grids and the combination coefficients are adapted is shown to lead to scalable algorithms which moreover are algorithmically fault-tolerant and thus provide an alternative to check-point restart. New methods based on the combination technique are derived for the solution of initial value problems and eigenvalue problems.

65 Pass the Dutchie on the left hand side

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When New Zealanders or Australians walk down a busy street in London, they often find themselves in a standoff with the locals who don't seem to want to let them pass. It turns out that Antipodeans expect to pass each other on the left, whereas in Britain they pass each other on the right. While it is evident that people that live in close proximity to each other can make a collective choice to avoid bumping into each other, there is no compelling reason why people should prefer the left or the right. In this talk I describe a simple model for collective decision-making by pedestrians that breaks the left-right symmetry of passing when the heterogeneity of individual preferences is sufficiently low. We test this model in simulations of pedestrian flow to show how the emergence of a particular collective decision can affect pedestrian dynamics. It is left as an exercise to the reader to discover the side on which side the Dutch prefer to pass each other.

66 The effect of an increasing burden of diabetes mellitus on tuberculosis incidence and what the risk factor really means

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In recent times, the evidence to support an association between TB and diabetes has been growing, and epidemiological analyses have demonstrated an association between TB and diabetes, highlighting its importance as a public health problem. In 2008, a systematic review of 13 observational studies demonstrated that diabetes was associated with a three-fold risk of developing active TB, regardless of study design, background TB incidence or geographic region of the observational study (Jeon and Murray 2008). Another review found that the risk of TB is 1.5-8 times higher in patients with diabetes compared to those without diabetes, and the increased risk is even higher for sputum smear positive and culture positive TB, and the findings apply to both high and low income settings.

We develop a compartmental model for TB transmission with the co-morbidity of DM, quantifying the effect of an increasing burden of DM on the TB dynamics. The process of becoming a diabetic is not explicitly modelled, as we are interested in the effect of diabetes prevalence in a community on TB, and not in diabetes per se. We use indicative numbers for economically developed nations and developing nations; those with low burdens of TB and compared to those with high, with a variation of DM burdens. We quantify the effect of TB incidence in these settings, and show how the identified risk factor is commonly misinterpreted.

67 Stress effects on silica particles in semi-conductor moldings

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Semi-conductors consist of a copper "paddle", the circuitry and a layer of plastic to cover the circuitry. During manufacture, the plastic is added at high temperature and then allowed to cool. However, the different components contract at different rates as they cool and as a consequence there are stress effects in the circuit that cause anomalous behaviour of the chip. In order to mitigate this effect, silica particles are included in the plastic compound to reduce the amount of contraction. However, there is concern that this may have some undesirable effects also. I will describe a simple model of the cooling/heating process that gives some insight into the procedure and perhaps provides some guidance as to how it might be improved. Note: This problem was brought to the 2015 Study Group in Limerick, Ireland.

68 *Seasonality of RSV and bronchiolitis in the different climatic regions of Western Australia

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Respiratory syncytial virus (RSV) is the most common cause of severe respiratory illness in young children, with up to 70% of bronchiolitis hospital admissions linked to RSV infection. In temperate regions, RSV exhibits annual or biennial epidemics, but the epidemiology of RSV in the tropics is less well understood. Western Australia is Australias largest state by land area and is characterised by a range of climatic zones, including temperate, subtropical and tropical. We extracted linked data for RSV diagnoses and bronchiolitis hospital admissions in Western Australia over 2000–2013.

Complex demodulation is a method for capturing the changing amplitude and phase of seasonal data over time. Previously applied to geomagnetic storm data and analysis of cardiovascular rhythms, complex demodulation is a potentially useful tool for the analysis of seasonal epidemiological data.

Using Fourier analysis, we assessed the dominant periodicity of RSV and bronchiolitis epidemics in different climatic zones. We then used complex demodulation to compare RSV and bronchiolitis epidemics over time. We found that there is a clear difference in RSV and bronchiolitis seasonality between the southern and northern regions of Western Australia, with annual epidemics clearer in the southern (temperate) region. We also found that while the size of epidemics differed, the timing of RSV and bronchiolitis coincided, indicating bronchiolitis admissions are a good proxy for RSV epidemics.

69 *How many point masses do we need for non-parametric deconvolution and maximum likelihood mixture densities?

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In non-parametric density deconvolution problems where the error distribution is unknown, we need to solve an optimization problem to find a discrete probability distribution that approximates a continuous target distribution. In practice, we find that this discrete distribution has surprisingly few point masses. The same phenomenon is also observed while finding maximum likelihood mixture densities. Our goal is to try to understand why this is happening. In this talk we will look at both of these problems as well as an interesting geometrical perspective on mixture likelihoods.

70 *An evolving viscous filament in a Hele-Shaw channel

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When an inviscid fluid invades a viscous fluid in an infinitely-long Hele-Shaw channel, the interface between the two fluids is unstable and small perturbations grow into large fingers in a process known as "viscous fingering". If the viscous fluid has a finite volume, there are two interfaces and the problem is more complicated. In this talk, we consider the more extreme case of a thin filament of viscous fluid and present a simple model that is in the form of a geometric flow rule. For the zero surface tension case, the problem is known to be ill-posed with generic initial conditions leading to finite-time blow-up. By including surface tension, this blow-up becomes regularised. We present a linear stability analysis and numerical simulations to describe a range of solution behaviours.

71 *Mathematical modelling of viral oncolysis: A PEG-modified adenovirus conjugated with herceptin

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Cancer has been an ongoing problem in our society for many years and oncolytic virotherapy is a field investigating possible treatments. A mathematical model using ordinary differential equations is developed for this field and optimised to current experimental data. In addition, a stochastic simulation based on the Gillespie algorithm is created based on the previous optimisations to simulate the effects of randomness and investigate what changes could be made to the treatment to possibly improve its effectiveness. Modifications to the lysis rate and infectivity of the virus are shown through the stochastic simulations to provide improvements to the effectiveness of the treatment. The model is used to further understand the complex dynamics of the virus-tumour interaction and simulate possible treatment improvements.

72 *Reproducibility of scratch assays is affected by the initial degree of confluence

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Scratch assays are difficult to reproduce. Here we identify a previously overlooked source of variability which could partially explain this difficulty. We analyse a suite of scratch assays in which we vary the initial degree of confluence (initial cell density). Our results indicate that the rate of re-colonisation is very sensitive to the initial density. To quantify the relative roles of cell migration and proliferation, we calibrate the solution of the Fisher-Kolmogorov model to cell density profiles to provide estimates of the cell diffusivity, D, and the cell proliferation rate, λ. This procedure indicates that the estimates of D and λ are very sensitive to the initial density. This dependence suggests that the Fisher-Kolmogorov model does not accurately represent the details of the collective cell spreading process, since this model assumes that D and λ are constants that ought to be independent of the initial density. Since higher initial cell density leads to enhanced spreading, we also calibrate the solution of the Porous-Fisher model to the data as this model assumes that the cell flux is an increasing function of the cell density. Estimates of D and λ associated with the Porous-Fisher model are less sensitive to the initial density, suggesting that the Porous-Fisher model provides a better description of the experiments.

73 A mathematical approach for finding consistent conductivity values for the bidomain model of cardiac tissue

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This talk presents the results of a study that uses a mathematical approach, based on recent experimental results, to produce consistent sets of six conductivity values that can be used in the bidomain model of cardiac tissue. Such an approach is of interest because it is not yet possible to obtain these values experimentally. To date, the only sets that are available are of four, not six, conductivity values and to use these in the bidomain model it is then assumed that the conductivities in the directions transverse and normal to the cardiac fibres are equal, something that recent experimental results have confirmed is incorrect.

The effect of these new sets of conductivity values is then considered in a ‘heart in a bath’ model of an implantable cardiac defibrillator. Threshold values for defibrillating the heart are computed for the new six-conductivity sets and these values are compared with those found for the four-conductivity sets mentioned above, as well as with those for two other non-experimental datasets that are found in the literature. It is found that the most extreme defibrillation values correspond to two of the three four-conductivity datasets.

74 A Model for Two Wolbachia Strains in an Insect Population

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Wolbachia is a bacterial symbiont of insects, which has been shown to disrupt viral replication. Consequently, *Wolbachia* is being developed as a bio-control agent against dengue virus. As *Wolbachia* are transmitted by infected females to all of their offspring, *Wolbachia* manipulates host reproduction to enhance reproductive success of infected females relative to that of un- infected hosts. Recently, *Wolbachia* has also been shown to affect mating behaviour. What effect these behavioral changes would ultimately have on *Wolbachia* invasion and spread in host populations is unknown. We will develop a model for the interaction of three different insect types: uninfected insects; insects infected with a naturally occurring strain of *Wolbachia*, and insects infected with an introduced strain of *Wolbachia*. The introduced strain is assumed to be released into the wild population through a controlled release programme. We will derive a system of six ordinary differential equations that takes into account certain breeding rules and includes a choice factor for mating relationships. Based on several simplifying assumptions, the six equation model can be reduced to a two equation model. We will present preliminary data from this model showing the existence of different steady states corresponding to: the establishment of the introduced *Wolbachia* strain within the population; the maintenance of the dominance of the naturally occurring strain, and situations where both strains co-exist.

75 *Filling the gaps: a robust description of adhesive birth-death-movement processes

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Continuum descriptions of discrete adhesive birth-death-movement processes provide accurate predictions of the average discrete behavior for limited parameter regimes. We present an alternative continuum description in terms of the dynamics of groups of contiguous occupied and vacant lattice sites. Our method provides more accurate predictions, is valid in parameter regimes that could not be previously described, and provides information about spatial clustering of occupied sites. Furthermore, we present a simple analytic approximation for steady-state spatial clustering.

76 *On the inverse finite element approach for pricing American options under linear complementarity formulations

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In this work, we extend the inverse finite element method for pricing American options proposed by Zhu and Chen (2013) to option problems under linear complementarity formulations. The unknown optimal exercise price is inversely determined by over-specifying the boundary where such value is measured. The algorithm developed is robust to deal with a large number of meshes with acceptable computation cost. The solution accuracy is examined with respect to various element shape functions and the results suggest that the approach can be used as an efficient method even for pricing other types of financial derivatives with American-style exercise. The work offers an alternative perspective and means to the valuation of financial securities in quantitative finance.

77 Discrete model of dynamics of vortex filaments

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The local induction equation, or the binormal flow on space curves is a well-known model of deformation of space curves as it describes the dynamics of vortex filaments, and the complex curvature is governed by the nonlinear Schrdinger equation. In this talk, we present its discrete analogue, namely, a model of discrete deformation of discrete space curves by the discrete nonlinear Schrdinger equation. We also present explicit formulas for both continuous and discrete models in terms of the τ functions of the two-component KP hierarchy.

78 *Modelling rainfall induced landslides with a combined analytical and computational approach

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Landslide events have a devastating impact on communities and industries. Modelling these complex systems is valuable for predictive and preventative measures to reduce the impact of these events. Landslides are often caused by heavy rainfall so soil water content is important to consider when considering slope stability as it alters the soil strength. We have constructed analytic series solutions for the phreatic free surface problem of two dimensional steady downslope saturated-unsaturated flow, with water exiting at a seepage face. This model will be used to predict the water table and flow of water through soil for varying parameters such as slope angle, length, rainfall rate, and soil type. We use a computational method Smoothed Particle Hydrodynamics to model the slope failure. The results for the water table will be used to define a saturated region that considers pore water pressure and a change of the soil strength parameters of cohesion and friction angle. The results of this investigation will be compared with experimental data to validate results.

79 *On A Pseudo-ADM For European Option Pricing

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European option prices can be obtained by solving the well-known Black-Scholes (BS) equation. The Adomian Decomposition Method(ADM) is a popular numerical technique, providing an efficient way to solve ordinary and partial differential equations. However, because of the non-differentiability of the payoff function of the vanilla European option, applying the ADM to the BS equation is difficult. Previous works on this project, either assume that the payoff function is differentiable or use an approximation of the payoff function, both of which can be shown to lead to incorrect solutions. In this talk, I will present a modified ADM, which can be used to solve the BS equation successfully. Numerical results show that the solution obtained from our new algorithm is accurate.

80 *Bifurcation analysis of a model for the El Niño Southern Oscillation

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Climate models can take many different forms, all the way from very detailed highly computational models with hundreds of thousands of variables, down to more phenomenological models of only a few variables that are designed to investigate fundamental relationships in the climate system. Important ingredients in these models are the periodic forcing by the seasons, as well as global transport phenomena of quantities such as air or ocean temperature.

We consider a phenomenological model for the El Niño Southern Oscillation system, where the delayed effects of energy transport across the Pacific Ocean are incorporated explicitly into the model, which gives a description by a delay differential equation. We conduct a bifurcation analysis of the model, in the strength of the seasonal forcing and different delay times, by means of dedicated continuation software. This allows us to find regions of different types of solutions in the parameter space. In this way, we determine how the observed dynamics is influenced by changing certain parameters of the model. Our bifurcation analysis explains some previously published results, highlights parameter sensitivity and also uncovers surprisingly complicated behaviour concerning the interplay between seasonal forcing and delay-induced dynamics.

81 Stochastic Interpolation of Satellite Imagery

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Satellite observations of Earth's ocean and atmosphere have revolutionised our understanding of the climate system. However, these data present unique challenges due to the complex spatiotemporal sampling patterns of satellites and the turbulent dynamics of geophysical flows. In this talk I will present some novel stochastic methods for interpolating satellite observations of geophysical flows. The effective resolution of the observations is enhanced by using standard Bayesian inference to combine low resolution imagery with a computationally inexpensive stochastic model that forecasts the unresolved scales. The stochastic model parameters are estimated from climatological data obtained from the observations themselves. The technique is tested using synthetic satellite observations of quasigeostrophic turbulence driven by realistic climatological shear and stratification profiles. The super-resolved satellite observations result in significantly improved estimates of turbulent fluxes compared with raw observations.

82 *Stability of free surface flow over topography

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The forced Korteweg De-Vries equation (fKdV) is used as a model to analyse the wave behaviour on the free surface in response to a prescribed topographic forcing. Recent work by Binder, Blyth & Balasuriya (2014) has shown that non-unique steady solutions can be found at critical Froude number, $F = 1$. This non-uniqueness is further demonstrated with a Gaussian type topography where non-unique solutions are found and are classified according to a phase-plane analysis. We investigate the stability of these solutions through time-dependent calculations and by computing eigenvalue spectra of the linearised fKdV operator exploiting the Hamiltonian structure of the fKdV. The spectrum is computed numerically and spectral stability is determined if non of the eigenvalues lie in the right-half plane. Additionally, formal stability is demonstrated by showing that the second variation of the Hamiltonian is of definite sign. A direct comparison is made between these results and a suite of time-dependent calculations, and excellent agreement between prediction of the growth rates extracted from these calculations and the computed eigenvalues is confirmed.

83 Cancer-immune dynamics of oncolytic virotherapy and dendritic cell vaccines

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Recent experiments with engineered oncolytic adenovirus have caused substantial reduction in growth rates of tumors in mice. We develop ordinary differential equation (ODE) models based on the data from five different treatments: (Ad) oncolytic adenovirus, (Ad/4-1BBL) Ad virus co-expressing the molecule 4-1BBL, (Ad/IL-12) Ad virus co-expressing the cytokine IL-12, (Ad/4-1BBL/IL-12) Ad virus co-expressing both 4-1BBL and IL-12, and Ad/4-1BBL/IL-12 in conjunction with dendritic cell (DC) vaccines.

By fitting time series data of tumor growth to our ODE models, we attempt to elucidate the underlying cancer-virus and cancer-immune dynamics to clarify the strengths and limitations of oncolytic virotherapy combined with DC vaccines. Using modeling, we consider how different treatment strategies can be used to (1) rapidly kill the tumor with a goal of complete elimination or (2) maintain the tumor long-term at low levels.

We also describe the problem of improving the delivery of oncolytic virus into tumors. Images show that viruses seem to penetrate hardly more than a few millimeters from the site of injection and only infect isolated and sparse clusters of cells, rather than dispersing comprehensively throughout the tumor. Understanding the kinetics of virus delivery into a tissue and the extracellular matrix poses a useful problem that could require the formulation of partial differential equation or other spatial models.

84 Interacting isochron foliations

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We consider isochrons of a stable periodic orbit of a the planar vector field, which are curves of points that converge to the periodic orbit in phase with each other. We extend this notion to isochrons of a focus equilibrium and also define what we call backward-time isochrons, that is, isochrons of the reversed-time system. With the FitzHugh-Nagumo system as a specific example, we show that a cubic tangency may occur between the foliations by forward-time and backward-time isochrons, which we call a cubic isochron foliation tangency (CIFT). This phenomenon is not a local feature but happens globally throughout the annulus where both foliations exist. We discuss how a CIFT may arise more generally in the context of slow-fast systems and what it means for the observed dynamics.

85 *Bringing quality to the Healthcare Industry

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Demand for healthcare services is growing rapidly in Australia, and rising healthcare expenditure is increasing pressure on the sustainability of the government-funded healthcare system. To keep up with the rising demand, we need to bring efficiency into our healthcare system and, to make the system more efficient, we need to be innovative.

There are a number of scientific tools which could be used in the healthcare industry to improve its efficiency. In this talk, we will address the problem of how to apply operations research tools to make the healthcare delivery process more efficient.

First, we will develop some strategies to understand and fit distributions to healthcare data. Understanding the healthcare data is important in order to characterise the load each patient brings to the system.

Next, we will develop a simulation model to analyse the patient flow process in a surgical suite of a major metropolitan hospital. Using the simulation model we will analyse patient flow in the surgical suite, and find out causes of sub-optimal patient flow.

Then, we will develop a heuristic-based elective surgery scheduling scheme to improve the efficiency of the surgical suite. We will test our scheduling scheme by using the simulation model, and will analyse patient flow after implementing the new scheduling scheme.

Finally, we will demonstrate the usefulness of operations research tools in improving the efficiency of the surgical suite.

86 Equation-free analysis of spike timing dependent plasticity

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Neurons communicate by passing action potentials (voltage “spikes”) between them. The strengths of connections between neurons are not fixed but can change depending on the precise relative timing of action potentials: this is known as spike time dependent plasticity. I will show the behaviour of a network in which this type of plasticity occurs. By data-mining the results of simulating this network we can derive a much simpler model of the network which shows the same behaviour. This reduced model is much cheaper to simulate and its form provides insight into the dynamics of the full network.

87 *Dynamical properties of models of transmission with immune boosting and cross immunity

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Understanding the cross-protective interactions between multiple pathogens is important for the design of vaccination programs. Previously, a susceptible-infected-recovered-susceptible (SIRS)-type model of transmission with immune boosting, the SIRWS model, was introduced following the idea that those whose immunity has waned sufficiently (W) may have their immunity ‘boosted’ at a rate proportional to the force of infection and the relative strength of immune boosting upon re-exposure. The SIRWS model can generate sustained oscillations under the biological scenario where exposure insufficient to initiate infection in a susceptible individual may nonetheless be sufficient to boost an individuals immunity.

Here I extend this model to include a second pathogen that is capable of inducing cross-protection against the first pathogen and study the consequent dynamics. Numerical simulations and bifurcation analysis show that the inclusion of the second pathogen can generate sustained oscillations under a broader range of biological scenarios, including in situations where boosting is relatively weaker than infection.

With potential application to pertussis infection, a poorly controlled vaccine-preventable childhood disease, my study of the dynamical properties of the system will aid our understanding of the roles of immune boosting and cross immunity at the population level. My research will provide insight into the assessment of the impact of alternative disease control strategies for pertussis and inform the development of improved public health policy.

88 *Mathematical Investigation into the effect of Large-Game Hunting on Growth Rates of Hunter-Gatherer Populations

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Choices in food acquisition and sharing within hunter-gatherer populations are driven by fertility-mortality tradeoffs. Despite low daily success probabilities and large proportions of sharing, hunter-gatherer males are observed to make greater investments in large-game hunting and food sharing [Hawkes, 1991]. An agent-based model (ABM) that includes and quantifies the fertility benefits and survival handicap of large-game hunting is formulated to demonstrate Hawkes [2002, 1993] show-off hypothesis. The evolution of large-game hunting in human life history is analysed by way of its effect on population growth rates. Using this ABM model, the growth rates of simulated populations that a) invest in large-game hunting, and b) those that invest in provisioning nuclear families via small-game hunting, are extracted and compared. The effect of these two male investment strategies on the population growth rates is investigated. A McKendrick-von Foerster partial differential equation system incorporating grandmothering effects [Kim, 2014] and male large-game hunting investment is presented. The growth rates of populations with and without large-game hunting are extracted by analytical means and compared to that simulated by the ABM.

89 Collisions Between Nonlocal Solitary Waves

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The Korteweg-de Vries (KdV) equation is a well-studied model of waves on a shallow water surface. In order to include the effects of surface tension, a fifth-order derivative is required, producing the fifth-order KdV equation (KdV5).

The KdV equation famously permits soliton solutions: localized waves of constant form that propagate without decaying or altering their form. If two solitons collide, they retain their form, undergoing only a change in phase. Previous studies have demonstrated that solutions to KdV5 do not contain solitons. They do, however, contain nonlocal solitary waves. These waves behave in many respects like solitons, except they have a nonlocal component consisting of a finite-amplitude wavetrain, extending indefinitely. Individual nonlocal solitary waves have been studied in the past, however I am interested in their behaviour when the waves interact.

Using analytic continuation, I will extend nonlocal solitary wave solutions to KdV5 into the complex plane and show how their behaviour is controlled by singularities in the analytic continuation. Finally, using exponential asympototic methods, I will show that the waves do not change in form upon interaction, but experience only a change in phase, and therefore that the nonlocal component of the solution exhibits correct solitary wave behaviour.

90 *Investigating intervention intervals for scabies infections

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Infections with Sarcoptes scabiei (scabies) are a widespread issue in remote communities. Besides the intense scratching and discomfort, the infection also creates a pathway for invasive disease. Despite this, the infection process has not yet been the focus of mathematical attention. By modeling the life cycle of the mite, as well as the eggs, a biologically accurate compartmental model for a population in which scabies is present can be derived. Lab experiments provide feasible values for all but two parameters of the model, and these remaining parameters can be determined using prevalence data. Parameter sensitivity analysis shows that the model is relatively stable to almost all biological parameters, with those affecting treatment being most critical. By including the effects of treatment in the model, various intervention strategies can be considered. We consider the impact of continuous background treatment, as well as a mass drug administration (MDA), to determine the optimal interval between successive interventions. We also consider whether the primary driver of prevalence is continuing infections through reinfestation, or new infection events post-cure, and use this to inform the focus of intervention strategies. Finally, we consider the impact of reducing the variance in a number of key states in the model, showing which life cycles of the mite are the most important for infection control.

91 A mechanistic model of glucose-hydrogen-methanogen dynamics in the rumen

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Existing mathematical models to estimate methane production in the rumen are based on the calculation of hydrogen balances without considering the presence of methanogens. In this talk, we present a mathematical model in three parts. First, a mechanistic model of methane production is proposed that depicts the interaction between hydrogen concentration and methanogens in the rumen. Second, a thermodynamic term is implemented to model the thermodynamic control of hydrogen concentration on the rates of hydrogen generation and hydrogen metabolism. Finally, we note that hydrogen in the rumen is generated by feed fermenters through feed (glucose) fermentation pathways. Our model is extended to include these fermenters and fermentation pathways.

92 Estimating a covariance matrix

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It often happens that we know some but not all of the numbers in a covariance matrix. How should we choose the missing entries to complete the matrix? Harvard statistician Dempster suggested completing according to the principle of maximum entropy. That choice of covariance matrix involves some attractive computational aspects that I will highlight.

93 Modelling and estimation schemes for higher order Markov chains observed through arbitrary noise models

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The most basic, if not fundamental of models representing an indirectly observed stochastic process is a Markov chain in discrete time of known order. This class of stochastic processes offers us a very simple and accessible finite-state model with a temporal dependency. In this work we propose to extend modeling and estimation techniques with latent Markov chains in two separate, but complimentary ways. Firstly, we develop a new representation for higher order Markov chains which is immediately amenable to the writing down of recursive estimators, such as filters smoothers and detectors in higher order scenarios. Our representation of higher order chains is firstly based upon taking the state space of a Markov chain as a canonical basis of indicator-function-valued random variables. This state space is extended to higher order models through the use of a tensor product of indicator functions. Our representation naturally leads to recursive dynamics for the temporal evolution of a higher order Markov chain and provides some interesting modelling opportunities.

Our second extension to estimation with Hidden Markov models enables relaxing the usual and perhaps ubiquitous assumption of simple Gaussian additive noise in measurement models. We assume an arbitrary non-Gaussian noise model may be represented by a Gaussian mixtures model and in so doing appeal to an L_1 approximation theorem for approximating a known uni-variate non-Gaussian density by a Gaussian mixture. A proof of the L_1 approximation is given. Finally, making use of the approximation result just described, we develop state estimation schemes for non Gaussian noise models. We do so via change of probability measure techniques exploiting the fact that a convex combination of Radon Nikodym derivatives is again a Radon Nikodym derivative.

94 Dynamics in the neighbourhood of a PtoP cycle

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We investigate a four-dimensional ordinary differential equation model for intracellular calcium dynamics. This system has been shown to feature a codimension-one heteroclinic cycle between two saddle-periodic orbits, also known as a PtoP cycle. This invariant object is of interest because it has been shown that nearby one should expect complicated behaviour including secondary homoclinic and periodic orbits. With numerical continuation software and boundary value problem formulations, we find and follow several nearby structures to investigate how they interact and where in parameter space they may be found. The observed behaviour consists of repeated switching between two types of underlying oscillations.

95 Large-eddy simulations of a spatially developing mixing layer using the stretched-vortex subgrid model

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Mixing layers form at the interface between two parallel streams of fluid moving at different velocities. Hydrodynamic instability of this flow leads to the formation of turbulent eddies, which mix fluid from the two streams. Mixing layers are important in technological applications such as scramjets, and in the fundamental study of nonhomogeneous turbulent flow, where the relatively simple flow configuration helps to facilitate experiment, analysis and numerical simulation.

It is usually computationally infeasible to resolve the entire range of spatial and temporal scales in simulations of high Reynolds-number turbulent flows, such as the mixing layer. In a large-eddy simulation, only the large-scale features are resolved, while the effects of the fine-scale subgrid motions are modelled. Previous large-eddy simulations of a temporally evolving mixing layer using the stretched-vortex subgrid model and spectral-like numerical methods overpredict the amount of mixed fluid. In this talk, I will describe large-eddy simulations of a spatially developing mixing layer using the stretched-vortex model and staggered-grid finite-difference methods.

96 On Optimal Control Applications in Biomedicine

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In this talk, we address two optimal control applications in biomedicine. First, we discuss a SEIR model which describes the spread of an infectious disease. Optimal vaccination strategies are presented under various control and state constraints. Then we extend the model by introducing a second control variable, the treatment rate of the infectious individuals. The computed controls are combinations of bang-bang and singular arcs (joint work with Rosario de Pinho).

The second application concerns the treatment of cancer by a combination of an anti-angiogenic drug and a chemotoxic agent. A Gompertzian type growth function considered in earlier papers with U. Ledzewicz and H. Schaettler typically leads to an anti-angiogenic control of bang-singular-bang type, while the chemotoxic control is bang-bang. However, for logistic type growth functions both the anti-angiogenic and chemotoxic controls are of bang-bang type. We also obtain bang-bang controls, when control delays are introduced in the model (joint work with A. Swierniak).

97 The roles of innate and adaptive immunity in controlling influenza viral infection

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Despite extensive study, the role of different components of the immune response in resolving influenza infection remains quantitatively unclear.

In this presentation I will discuss how current influenza virus dynamics models, while capturing particular aspects of the natural history of infection, have been unable to reproduce the full gamut of observed viral kinetic behaviour in a single coherent framework. By drawing on a series of experimental studies in the ferret and mouse I will introduce a mathematical model of influenza viral dynamics that incorporates all major immune components. These data and models provide new opportunities to test alternative hypothesised mechanisms of action for the innate and adaptive responses.

In particular, I will begin by demonstrating how host re-infection studies provide a new pathway to test alternative mechanisms of action for the innate immune response. I will then explore how mouse infection and knock-out experiments enable us to dissect the relative roles of cellular and antibody immune responses in controlling influenza infection, before linking these studies to emerging clinical evidence on the relationship between CD8+ T cell numbers and recovery time for A(H7N9) infection.

98 Simulating the corner-cusp-pearling transition for sliding drops

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This study is concerned with numerical simulations of droplets sliding down an inclined plane. If the substrate is carefully prepared, such droplets can develop a corner or a cusp at their rear, or undergo a pearling transition whereby the tail breaks up into a number of smaller satellite droplets. These phenomena have been of interest since the experimental work of Podgorski et al. (2001) *Phys Rev Lett* **87**, 036102. By applying a lubrication model with a disjoining pressure term, we investigate these flows numerically in order to further shed light on how certain conditions (such as contact angle) affect the corner-cusp-pearling transition.

99 *Fractional Order Compartment Models

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Compartment models are widely used to model the dynamics of a range of phenomena in epidemiology, physiology, ecology, chemistry, pharmacokinetics and economics. There has recently been considerable interest in the incorporation of fractional derivatives into these models. This is usually done in an ad hoc manner that may introduce unphysical behaviours. We have addressed this issue by deriving fractional order compartment models from an underlying stochastic process. Some illustrative examples from epidemiology and pharmacokinetics will be discussed.

100 Mathematical Modelling of Surtseyan Bombs — Fire, Earth, and Water

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A Surtseyan bomb is a lump of very hot magma that trails steam behind it when erupted from a volcano. These bombs are observed alongside cocks tails and cypress tree-like steam and magma emissions that are also features of volcanic eruptions where magma interacts with lots of water.

Surtseyan ejecta are formed in shallow sub-aqueous eruptions. They occur when a combination of liquid water and sediments penetrates into molten magma during an eruption, and is then ejected from the volcano as an inclusion inside a ball of magma. After ejection there is a large temperature gradient between magma and inclusion. As the temperature of the inclusion increases, the liquid water vaporises causing a pressure increase inside the ejected ball.

The volcanological question is whether the ball of magma ruptures. Simple lumped calculations indicate the steam pressures could far exceed the tensile strength of rock. However, there is evidence of intact ejecta so we know that rupture does not always occur. Hence a more careful modelling approach is needed to explain and inform observations.

We present partial differential equations that model transient changes in temperature and pressure in Surtseyan ejecta. These equations are solved numerically and asymptotically to derive a parametric condition for rupture of ejecta. Steam escape times are also computed.

101 A Tale of Two Boundary Conditions — Modelling Consolidation in a Pit Latrine

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I will talk about the appropriate boundary condition to use at the top of the material in a latrine model. We are modelling consolidation of a mixture of solid and liquid with a Richards Equation. It is Neumann vs Dirichlet, and possibly a little surprising.

102 Some effects of objects embedded in soil and partially-submerged in groundwater

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This study is motivated by a possibility of re-use of buried cylindrical tanks, once a facility for fuel storage at motor vehicle service stations (now relinquished by oil companies), but remaining for use as thermal reservoirs connected to space heating systems (e.g. for convenience stores). The ground in which a tank is buried is assumed to be of uniform porosity and permeability, with a phreatic groundwater surface (water table) that may rise and fall, albeit slowly, over time. The ground and the water are subject to heating and cooling according to the season and weather conditions. Here, it is assumed that such changes are slow, and that conditions are quasi-steady for the duration of the analysis.

The technique is to find a conformal mapping of the flow region into a rectangular region, say, where the stream function and velocity potential remain harmonic. The transformed problem is then simpler to solve, but requires the mapping to be found. Most previous investigations have been for fully-immersed circular cylinders, but is extended here to other cylindrical shapes. In this talk the formulation and use of the method are described for a partially-immersed body. Combinations of analytical and numerical techniques are used. A variety of parameters are pertinent including diameter, burial depth and temperature of the cylinder; the water table depth and temperature; surface (ambient) temperature; thermodynamic properties of the soil. Their effects on the heat transfer will be illustrated for a selection of configurations.

103 *Clostridium difficile infection and sensitivity analysis

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Clostridium difficile infection (CDI) can cause serious gastrointestinal disease and death, and is endemic in developed and developing countries worldwide. As CDI is most often reported and studied in healthcare settings, it has long been assumed to be primarily transmitted in healthcare facilities, however a growing body of evidence suggests that a large portion of CDI cases are imported from the community. We formulate a novel continuous time Markov Chain model of CDI transmission which has the flexibility to model healthcare facilities, communities and their interaction. The relative complexity of CDI epidemiology requires a model with many parameters, a number of which quantify aspects of the disease which are not well understood. Thus the parametrisation and interpretation of the model requires extensive sensitivity analysis. We present a robust and efficient method proposed by David Anderson of estimating derivatives with respect to parameters of key model outcomes at the level of the community (e.g. the expected number of infective individuals). This method has not been used to date in an epidemiological setting. We also present a method of sensitivity analysis which allows assessing effects of parameters on model outcomes at the level of the individual (e.g. probability a patient is infected at discharge from hospital or the probability of a patient getting recurrent CDI).

104 *Examination of Student Performance on the ADFA Mathematics Diagnostic Test

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The Australian Defence Force Academy (ADFA) is a unique environment where university education (delivered through the University of New South Wales; UNSW) and military studies are combined. Entrance into ADFA is highly competitive whereby students must obtain the appropriate Australian Tertiary Admissions Ranking (ATAR) for university entrance as well as meet additional selection criteria to determine suitability to undertake military training. Since the introduction of the ATAR system in 2009, there has been debate regarding the use of this single numeric figure, calculated using results from multiple subjects, to predict competency in particular subjects. In order to overcome this limitation of the use of the ATAR score to measure mathematics competency, ADFA has incorporated a mathematics diagnostic test prior to the commencement of their first academic year to indentify at risk students who may benefit from additional mathematics support and career guidance.

The current research will focus on reviewing student performance on the ADFA diagnostic test. Of particular interest, is the relationship between ATAR scores and diagnostic test results. Additional demographic factors such as level of mathematics studied, gender, and state in which secondary education was completed, will also be examined. Additionally, the results of a Rasch analysis will be presented to demonstrate the validity of the diagnostic test, which holds up to the assumption of uni-dimensionality and displays adequate reliability. Results of the current research add to the wider literature on the use of diagnostic tests, and the potential limitations of the use of ATAR scores in performance prediction.

105 Quantifying happiness by applying simple algorithms to Big Data: Social media and other stories

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The explosion in recent years of open data about human interactions and expression leads to many exciting new opportunities to applying computational methods to questions in social science. In this talk we explore a few of these problems, namely: how informative are social media in uncovering patterns of human dynamics and population-level wellbeing?, and, can such sentiment analysis tools be used to predict the emotional trajectories of stories? Drawing on unusual text-based datasets including millions of geolocated tweets and thousands of film scripts, we explore how one extremely simple sentiment analysis method can be used to uncover meaningful information about population demographics and the shapes of stories. Along the way well answer important questions such as: where is the happiest place on Earth? What is the saddest movie ever made? How many types of stories are there? What does your Twitter profile say about how you vote or what you eat? This is joint work with undergraduate students Amelia Briggs and Michelle Edwards.

106 Symmetry analysis for forms of the complex-valued Klein-Gordon Equation

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We analyse some forms of the complex-valued Klein-Gordon Equation from an integrability perspective by the implementation of the Lie Theory of Continuous Groups, where the equations are governed by power-law nonlinearity. We write the equations in terms of real dependent variables and examine both the two-dimensional and three-dimensional models. In the case of the two-dimensional model the analysis is extended by the determination of Noether point symmetries and conserved vectors via the construction of a Lagrangian.

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107 A mathematical model of latent HIV infection and the impact of eradication strategies

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New eradication strategies are being investigated for HIV. Although several of these, including the use of histone deactylase inhibitors (HDACi), have shown some experimental benefits their impact in achieving eradication is uncertain. A quantitative framework of latent HIV infection is needed that can estimate the impact of these strategies and how best to implement them. A mathematical model is derived that simulates levels of memory CD4+ T cells, the major HIV reservoir, and latent HIV infection within these cells. The model reproduces viral and memory CD4+ T cell dynamics prior to and during antiretroviral therapy (ART). It furthermore replicates the slow decay of the latent reservoir resting memory CD4+ T cells containing integrated HIV DNA. Model simulations show that plasma viral levels (pVL) arising from homeostatic proliferation of the latent reservoir limit the impact of short term ART intensification, as observed in several clinical trials. Using this model as a basis, we overlay a pharmacokinetic model of the impact of two recently described HDACi. The model accurately describes the limited pVL outgrowth with each HDACi and the minimal impact on the latent reservoir. This mathematical model provides an in silico framework for estimating the impact of HIV eradication strategies that are currently under development.

108 Old is good! Exploring the role of forager age in honeybee colony collapse disorder

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Honeybees are the most important commercial pollinator for many foods that need insect pollination. But in many parts of the world honey bee colonies are struggling and their number is in decline. The health, productivity and longevity of foragers is crucial for the well-being of any colony. If foragers are depleted because of stressors in the environment (such as pesticides) or in the colony itself (such as disease or malnutrition) then there are significant effects, on the amount of food (nectar and pollen) that can be collected and also on the colony's capacity to raise brood (eggs, larvae and pupae) to produce new adult bees to replace lost or aged bees. As the effect of these stressors grows, individual bees make the transition from hive bees to foragers at younger and younger ages. These young foragers tend to make fewer foraging trips and do not survive as long as older foragers. We use a set of delay differential equation models to explore the effect of forager age on colony survival. In particular we show that including age in our model can leads to a sudden rapid decline of adult bees and the death of the colony, similar to what is observed in colony collapse disorder.

109 Numerical solution of the time-fractional Fokker Planck equation with general forcing

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We study two schemes for a time-fractional Fokker Planck equation with space and time-dependent forcing in one space dimension. The first scheme is continuous in time and is discretized in space using a piecewise-linear Galerkin finite element method. The second is continuous in space and employs a time- stepping procedure similar to the classical implicit Euler method. We show that the space discretization is second-order accurate in the spatial L_2-norm, uniformly in time, whereas the correspond- ing error for the time-stepping scheme is $O(k^\alpha)$ for a uniform time step k, where $\alpha \in (1/2, 1)$ is the fractional diffusion parameter. In numerical experiments using a combined, fully-discrete method, we observe convergence behaviour consistent with these results.

110 A reduction from integrable partial difference equations on $\mathbb{Z}^4$ to A_4-surface type q-Painlevé equations

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In this talk, we talk about a relation between ABS-equations (integrable partial difference equations) classified by a property known as consistency around the cube (3D consistency) and discrete Painlevé equations (nonlinear ordinary 2nd order difference equations) characterized by theory of rational surfaces. We show that a reduction from a 4-dimensional hypercube to a rhombic dodecahedron causes a reduction from ABS equations to A_4-surface type q-Painlevé equations.

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111 As a matter of fact: the influence of media campaigns upon alcoholism

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SIR models were originally developed to analyse the spread of infectious diseases. More recently the SIR framework has been applied to study the dynamics of social and behavioural processes such as eating disorders, drug additions, the spread of ideas and alcoholism. The SIR analogy can be employed when the problem 'state', i.e. the infection, can be viewed as occurring as the result of frequent or intense interactions between individuals in different compartments.

The analogy is not always perfect, because routes in the generation or eradication of addictive behaviours for social problems can differ from those in infectious diseases. One such route is the effect of media campaigns. Depending upon the nature of any particular campaign these can be viewed as either promoting addiction or withdrawal.

In this work we view alcoholism (the demon drink!) as a disease that is spreading a population. We investigate how media campaigns influence the proportion of problem drinkers in a population.

112 Modelling tumour recurrence following resection

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We consider a simple one-dimensional travelling front model for the growth of glioblastoma brain tumours. Resection of the diffuse tumour cannot fully eliminate all cancer cells and therefore the tumour typically reappears, nevertheless resection may be able to delay the invasion of cancer cells into healthy tissue. We use a general reaction-diffusion model of front propagation and investigate how the delay of the invasion front relative to the untreated tumour depends on the accuracy of resection, proliferation rate and diffusivity of the cancer cells.

113 *Modelling of cell extrusion in an epithelial monolayer

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Epithelial cell extrusion is a process by which certain cells are eliminated from the cell layer without disrupting the protective barrier role of the epithelium. This can happen as part of the normal turnover of cells in a tissue, or it may involve mutated cells that may lead to metastatic spread of cancer cells. We use computer simulations based on an extended three-dimensional Cellular Potts Model to investigate the effects of localised biomechanical changes in a layer of cells to determine the key factors that can induce extrusion of a modified cell. Our results suggest that reduced cell-cell adhesion and/or increased contractile tension around the cell cortex both promote extrusion in a cooperative manner, while the strength of adhesion of the neighbouring normal cells to the basal surface also plays an important role in the process. Using theoretical approximations we develop a simplified model to determine and analyse qualitatively the thresholds in the values of the cell parameters for the extrusion of the cell from the layer.

114 Using multicellular modelling and simulation to understand changes in cellular behaviour seen in colorectal cancer

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Changes in a cells responses to external signals underpin many diseases, particularly cancer, and can provide biomarkers for detection and therapy. Its hierarchical structure and dynamic turnover makes the intestinal epithelium an excellent system in which to study cell responses, in the context of whole tissues. Specifically, understanding the mechanism(s) responsible for changes in proliferation patterns observed in colorectal crypts exposed to Gamma radiation provides a useful model for early changes in colorectal cancer.

In this talk we present an investigation which combines experimental data with multicellular mathematical modelling and simulation to investigate how proliferation in crypts is normally regulated, and to identify parameters altered in radiation-induced tumorigenesis. In addition we are able to predict the composition of a tissue that has recovered post irradiation.

115 Failure of structures: can you see it coming?

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Failure of structures in an earthquake is an important problem that is still not well understood. Design specifications use guidelines that are based on the magnitude of an earthquake, among other things. We investigate how an external force with varying magnitudes and principal frequencies affect structurural stability. As an example we consider a model of a planar, post-tensioned frame. We compute the failure boundary directly to determine its nature. This shows that inherent nonlinearities in the system can have dramatic effects on structural stability, especially when the structure has a natural frequency close to that of the external forcing.

116 Induced motion due to point singularities in diffusion-driven flows

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Independent studies by Wunsch and Phillips in 1970 (Deep Sea Res., 17, p293/435) showed that steady flow can be generated in a stable density-stratified fluid simply due to the container having sloping insulated surface. Most of the subsequent analysis for this type of problem has been undertaken within two-dimensional containers with uniformly sloping planar surfaces in the small-R boundary-layer limit when the Rayleigh number is large, see eg Page (2011 doi:10.1093/qjmam-hbr007).

Isolated objects in an unbounded fluid can also generate this type of flow, and even induce motion of the object itself. Perhaps the neatest illustration is provided by the experiments of Allshouse et al (2010, Nature Physics, doi:10.1038/nphys1686).

However, this phenomenon does not only occur in the small-R regime as the same principles can apply at many scales. In particular it can also be expected with relatively small objects at effectively very low Reynolds numbers, when boundary layers are not present. Arguably, small particles of sediment or even organic detritus in a stratified ocean may experience similar effects, including slow induced motion.

In this talk, an asymptotic structure for the induced motion due to a small particle is outlined. Building upon analytical results for viscous motion near a small cylindrical or spherical object, a larger-scale 'outer region' is found to extend large distances horizontally from the particle. On this scale the motion is effectively induced by a point singularity. This analytical structure in this parameter regime is illustrated and elucidated using numerical calculations for two pertinent classes of isolated point singularity.

117 *Sal'nikov's Reaction Scheme in a Spherically-Symmetric Gas

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The Sal'nikov combustion scheme is a simple yet important model in the study of chemical kinetics. The model consists of a two-step reaction, each stage of which is endothermic or exothermic and occurs at a temperature-dependent rate. In this talk we consider a chemical reaction, proceeding according to the Sal'nikov model, in a spherically-symmetric cloud of gas. Using linear theory, we show that a single, simple parameter determines the form of the solution. When this parameter is zero we are able to find exact solutions to the linearised equations, and use integral transforms to solve them otherwise. We also present a brief stability analysis and show that the stability of the solutions is also dependent only on this one parameter. Finally, we compare the linear results to a numerical scheme which is used to solve the full non-linear problem.

118 *Household Models for Endemic Diseases

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Household modelling frameworks are becoming increasingly popular when modelling the spread of diseases such as measles. Many models assume that everyone interacts with one another homogeneously, however, it is well established that children are often the main drivers of disease dynamics. This motivates a structured population of households where one can distinguish between children and adults.

In this talk we consider a susceptible-exposed-infectious-recovered (SEIR) household continuous-time Markov chain model. Our households are characterised by the number of adults and children in them. It has become customary to allow births and deaths to occur alongside the disease dynamics, but we incorporate additional demographic events such as children moving out of home, couples forming and separating, and immigration and emigration to provide a more realistic framework for modelling disease dynamics. We investigate the impact of the additional demographic details on the spread of a disease using demographic and disease parameter values relevant to measles in the pre-vaccination era.

119 Spatial dynamics of coinfection in ocean-borne bacteriophage viruses

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Bacteriophages (viruses which infect bacteria) in the oceans are both abundant and diverse. Multiple viruses can coinfect the same host, which allows interactions between viruses and exchange of genetic material. I investigate the spatial dynamics of coinfection, and the effects of space on the frequency of coinfection and the distribution of multiplicity of infection (the number of viruses infecting a single host).

120 *Spectrograms of nonlinear ship waves

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The spectrogram is a useful way of using short-time discrete Fourier Transforms to visualise surface height measurements taken of ship waves in the real world. Five components of a spectrogram of a ship wave have been recently identified. We will use computer simulations to recreate some of the identified components. For this purpose we shall consider nonlinear potential flow past a pressure distribution in a fluid of infinite depth. Spectrogram analysis is applied to the computed nonlinear ship waves. Key features of the spectrograms, such as the linear dispersion curve, primary and secondary modes are identified. The multiple modes identified in this study bear a striking resemblance to a component identified on spectrograms taken from previous experimental measurements.

121 Stability of resonant loads on line arrays with respect to positional disorder

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It is well-known that finite arrays of identical scatterers arranged in straight lines and with constant spacing experience exceptionally high loads at certain frequencies. This phenomenon is related to array trapped modes and has been intensively investigated for the case of plane linear water waves incident on rigid bottom-mounted cylinders using methods based on local expansions of the solution (e.g. interaction theories). We consider a different approach based on analysis of the spectrum of modes supported by a single scatterer, which gives new insights and, in particular, allows for investigation of the stability of the resonant loads with respect to positional disorder.

122 *Use of a stochastic model to study the cyclic motion in nanowires trapped by focused Gaussian beams

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Nanowires are very small wires with a radius of the order of a nanometer and a length that can be up to several micrometers. Nanowires used in this research project are made of Indium Phosphide (InP). Nanowires have potential applications in electronics and microscopy that are still to be fully exploited.

A simple two-dimensional, stochastic model is proposed to study the dynamics of high aspect ratio nanowires axially trapped in linearly polarized, Gaussian optical beams. A parameter reduction is rendered in order to simplify the equations involved and provide a full description of the system response in terms of the probability distribution, the power spectral density and its critical frequencies. This simplification also allows to characterize the persistent bias to cyclic motion around the equilibrium trapping position, which has direct relation with the non-conservative nature of the optical force.

This model is in good agreement with simulations of nanowires modeled as arrays of particles, and it is in partially good agreement with results from experiments conducted with indium phosphide nanowires. While the former can be described by means of a set of two-dimensional uncoupled systems, the latter requires coupling terms to be added in the equations.

123 Don't be mean: modelling spatial structure in cell populations

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Many PDE-based models of collective cell behaviour implicitly assume that the population of cells is 'well mixed'. This is called a spatial mean-field assumption. In reality, populations often have a more complex spatial structure, such as clusters and/or spatial segregation of cells. This spatial structure is both a cause and an effect of interactions among neighbouring cells and can make a significant difference to model predictions about, for example, cell densities and invasion speeds. I will describe an individual-based model of collective cell behaviour that is based on interactions between pairs of cells. I will show how a neighbour-dependent directional bias can be included in the model and how spatial moment dynamics can be used to give a continuum-level description of the population that retains spatial structure beyond the mean-field.

124 Swarming of self-propelled particles on the surface of a thin liquid film

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We consider a colony of self-propelled particles (swimmers) in a thin liquid film resting on a solid plate with deformable liquid-gas interface. Individual particles swim along the surface of the film predominantly in circles and interact via a short range alignment and longer-range anti-alignment. The local surface tension of the liquid-gas interface is altered by the local density of swimmers due to the soluto-Marangoni effect. Without the addition of swimmers, the flat film surface is linearly stable. We show that a finite wave length instability of the homogeneous and isotropic state can be induced by the carrier film for certain values of the rotational diffusivity and a nonzero rotation frequency of the circular motion of swimmers. In the nonlinear regime we find square arrays of vortices, stripe-like density states and holes developing in the film.

125 *Modified Predator-Prey Model for Mealybug Population with Biological Control

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Mealybugs are a major pest for many crops (such as the vegetable Cassava, in Thailand). An environmentally-friendly control method is implemented using an introduced predator (green lacewings) of the mealybugs to mitigate plant damage. This is analyzed so as to devise an optimal strategy for control of the mealybug population.

A predator-prey model has been proposed and analyzed to study the effect of the biological control of the spread of the mealybugs in the plant field. The behavior of the system in terms of stability, phase space and bifurcation diagrams are considered. The results obtained from different numbers of green lacewings being released are compared. In particular we obtain thresholds of introduced-predator level above which the prey is driven to extinction.

Future models will include age-structured multi-compartments for both the prey and predator populations.

126 *Sensitivity Analysis of Kolmogorov-Smirnov Style Statistics for Univariate and Bivariate Data

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The sensitivity of Kolmogorov-Smirnov (K-S) style tests to changes in distribution structures, such as modal location, size or shape, is not well-known. In order to interpret distribution comparison results in terms of real-world changes, it is necessary to better understand these sensitivities. In this study, univariate and bivariate Normal (and wrapped Normal) distributions are simulated and manipulated for comparison using K-S style statistical tests. Thresholds for significance testing are defined in terms of distribution structure, such as shifts in modal mean, density or spread, and thresholds for significance in bivariate distribution comparisons will be analysed in relation to equivalent thresholds found in the univariate case. Findings from this study not only allow for better real-world interpretation of statistical test results, but allow for evaluation of the robustness of extended bivariate K-S style tests. One application of this research occurs when recasting wind fields in probabilistic terms. The directional response of prevailing winds to changes in the landscape at the surface are represented as joint circular distributions. To understand the impacts of physical features such as vegetation or topography on wind fields, K-S style tests can be used to compare wind response distributions observed across complex terrain. This study will allow the interpretation of such test results in terms of wind direction changes experienced on the ground.

127 *A Mixed Integer Programming approach for solving the prescribed burn planning problem to fragment high-risk regions

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Uncontrolled wildfires can lead to loss of life and destruction of property and natural resources. At the same time, fire plays a vital role to support ecological balance in many ecosystems. Prescribed burning is an important tool used in many countries where fire is a major component of the ecosystem. We propose an approach to reduce the spatial connectivity of fuel hazards while considering the ecological fire requirements of the ecosystem. A Mixed Integer Programming (MIP) approach for prescribed burn planning is formulated in such a way that it fragments the high-risk regions as a means to reduce risk of fuel hazards in the landscape. This multi-period approach keeps track of the age of each vegetation type and determines the optimal time and locations to conduct prescribed burn. The approach takes into account the minimum and maximum Tolerable Fire Intervals (TFIs) that define the ages at which a certain vegetation type can be burned for ecological reasons. Previous work has been limited to using a single vegetation type implemented within rectangular grids. In this study, we significantly extend previous work by modelling multiple vegetation types implemented within a more realistic polygon-based network. Our approach is then demonstrated using data from 711 treatment units in the Barwon-Otway district of Victoria, Australia.

128 *A multiscale approximation of phase separation with elasticity

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We consider the process of phase separation of a binary homogeneous system under the influence of mechanical deformation and we derive a mathematical multiscale model, which describes the evolving microstructure including the elastic properties of the involved materials. Motivated by phase-separation processes observed in lipid monolayers in film-balance experiments, the starting point of the model is the Cahn-Hilliard equation coupled with the equations of linear elasticity, the so-called Cahn-Larché system. Owing to the fact that the mechanical deformation takes place on a macrosopic scale whereas the phase separation happens on a microscopic level, multiscale approximation techniques are required. We assume the pattern of the evolving microstructure to have an intrinsic length scale associated with it, which allows the introduction of a reference cell scaled by a small parameter $\epsilon > 0$, and we develop a scaled model, which is suitable for periodic homogenisation methods. The so-called homogenised problem is then obtained by letting ϵ tend to zero using the method of asymptotic expansion.

129 *Incorporating cell forces into a multiphase model for collagen gel mechanics

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Cells are often grown within collagen gels in vitro for applications in tissue engineering. The behaviour of cells is regulated by their mechanical environment; however the forces exerted by cells in turn affect the mechanical behaviour of the gel. Therefore we aim to gain more insight into the interactions between the cells and the gel using mathematical modelling. In this talk, I will detail how we have incorporated cells and their traction forces into our multiphase model for the gel, alongside chemical effects like osmosis. I will discuss how these cellular forces affect gel swelling and contraction, and how they impact upon the predicted equilibrium outcomes for the gel. Analytical results on the stability of the system's equilibria will be presented.

130 *Kinetics of Neonatal CD8+ T Cell Responses

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Newborns are particularly susceptible to a number of infections, and their immune response demonstrates differences in both functionality and magnitude of the responses. CD8+ 'killer' T cells are a subset of the immune cells that is important in controlling infections by killing infected cells. Previous studies have shown faster early growth of neonatal killer T cells compared to the adult. Furthermore, neonatal killer T cells were present in higher numbers during the early stages of infection, and were more 'functional' at this time. The aim of this study is to explain the kinetic differences between neonatal and adult killer cell responses. We used a combination of biological experiment and mathematical modeling approach to study the differences between adult and neonatal killer T cells.

We compared the proliferation kinetics between adult and neonatal cells during viral infection. The experiment involved adding both adult and neonatal cells into an adult recipient, followed by viral infection. We modeled the dynamics of T cell proliferation during an infection using a piecewise model of exponential growth and decay. Furthermore, we also looked into the dynamics of killer T cell differentiation. Killer cells undergo a process of differentiation to become fully functional. Here, we modeled the process of differentiation linked to T cell division. The assumption of this simple 'division-linked differentiation' is that on each division, cells will have a certain probability to become a functional cell. To obtain an accurate description of the experimental data, we applied a non-linear mixed-effect model, which can capture the statistical variability in our system. The models were fitted with the non-linear mixed effect model R (v3.0.2) function nlme in library nlme (v3.1-113).

The results suggest that neonatal killer T cells had faster proliferation early after stimulation, and that they quickly differentiated to become functional. However neonatal cell division slowed by day 4 post-infection, suggesting this faster proliferation cannot be maintained due to the accumulation of mature (old) cells in the neonatal CD8+ T cell response.

131 Topological data analysis for materials science

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Topological data analysis is a rapidly maturing field that provides mathematically rigorous computational tools for quantifying topological structure in data. The primary mathematical theory is called persistent homology, it measures topological quantities such as connected components and loops as a function of a geometric parameter allowing us to track all topological features individually and the length-scales over which they exist.

Recent applications of persistent homology in materials science include the characterisation of configurations of spheres in large packings, atomic arrangements in fluids, the robust generation of network models for porous materials and identification of their percolating length scales. This talk will be an introductory overview of topological data analysis covering the elementary concepts, a brief outline of computational techniques and available packages, and the very latest developments in statistical methods for analysing persistent homology signatures from many samples.

132 *Torus canards and folded singularities: Analyzing the folded saddle-node type three (FSN III) bifurcation

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Canards are special solutions of slow-fast systems which pass near a fold of the critical manifold and follow the repelling section of the manifold for some time before jumping off. Less well understood are torus canards, which arise when solutions pass near a fold of a manifold of periodic orbits, instead of an equilibrium manifold. In systems with two or more slow variables, special structures located on the fold (called folded singularities) play a crucial role in organizing the dynamics and funneling canard trajectories across the fold. Furthermore, these folded singularities may collide and interact at so-called folded saddle-node (FSN) bifurcations. In this talk we will discuss the novel FSN III bifurcation and its applications in a coupled two neuron model for respiratory rhythm generation, the Butera Model.

133 An ember based model for bushfire risk to houses

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Bushfire risk management in the peri-urban fringes is often focused around the risk to properties from radiant heat or direct flame ignition. With embers a contributing factor in the majority of property damage and loss cases from bushfires in Australia, further consideration to the risk posed by embers is required for effective bushfire risk management. The ember risk of a property is a function of the characteristics of the house (e.g. construction methods, materials, etc.) and of the expected ember load were a fire to occur in nearby bushland. In this work we introduce a model for ember risk based on the potential distribution of embers for a given bushland fuel load distribution and wind speed and direction. This model is applied to example scenarios to illustrate the features of the model.

134 The dilution effect in ecological epidemiology

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The *dilution effect*, where an increase in biodiversity results in a reduction in prevalence of an infectious disease, has been the subject of speculation and controversy. A model of an ecosystem with two prey species, two predator species and a pathogen is used to investigate the connection between population and pathogen dynamics. The model includes frequency-dependent transmission of the pathogen within host populations, transmission from prey to predator during consumption, and density-dependent environmental transmission between host species. Criteria are derived that determine when increasing the population density of one host species reduces the prevalence of infection, or the risk of transmission of the pathogen to other species.

135 Numerically Solving the 1D Serre Equations with initial conditions close to discontinuous

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The Serre equations are a shallow water approximation to the incompressible Euler equations that retain the terms of the Shallow Water Wave Equations while introducing dispersive terms that make the Serre equations more relevant when wave amplitude is significant compared to water depth. Most of the literature numerically solves these equations for smooth initial conditions, however, in real world applications such as the Dam-Break problem it is important to handle discontinuous initial conditions.

Thus the numerical scheme of O. Le Metayer, et.al. [Le Metayer, O., Gavrilyuk, S., and Hank, S. (2010). 'A numerical scheme for the Green-Naghdi model.'Journal of Computational Physics, 229(6), 20342045] has been extended to second- and third-order to investigate the capabilities of this scheme in the presence of discontinuities, which we expect to be good since it utilises a Finite Volume Method.

These methods were validated and their order of convergence was confirmed for smooth initial conditions using the analytic soliton solution. The methods also compared well with the experimental results of Hammack and Segur [Hammack, J. L. and Segur, H. (1978). 'The Korteweg-de Vries equation and water waves. Part 3. Oscillatory waves.' Journal of Fluid Mechanics, 84(2), 337358] which contains a discontinuity.

To further investigate the behaviour of discontinuities a smooth approximation of the Dam-Break problem was used to observe how the numerical solutions of the smooth dam break problem behaved as the initial conditions converge to a discontinuous state. The results of these methods are compared to the results of two second-order finite difference methods. One being the second-order centred finite difference approximation to the Serre equations and the other from Grimshaw, et.al [El, G., Grimshaw, R. H. J., and Smyth, N. F. (2006). 'Unsteady undular bores in fully nonlinear shallow-water theory.' Physics of Fluids, 18(027104)]. These schemes show the same behaviour in the presence of steep gradients as those derived from the numerical scheme of interest and included all the observed behaviour for discontinuous and smooth initial conditions thus observed far in the literature.

136 Slowly varying, macroscale models emerge in wide but thin domains

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Many practical approximations in science and engineering invoke a physical domains which are large in some directions but relatively thin in other directions. The proposed new approach is to analyse the dynamics based at each station in a rigorous multivariate Taylor multinomial. Then centre manifold theory supports the modelling of the system's dynamics with coupling to neighbouring locales treated as a non-autonomous forcing. Our resolution of the coupling between neighbouring locales leads to novel quantitative estimates of the error induced by long slow space variations. A simple example illustrates the approach and results. The approach developed here may be used to quantify the accuracy of known approximations, to extend such approximations to mixed order modelling, and to open previously intractable modelling issues to new tools and insights.

137 On fractional matrix exponentials and their explicit calculation

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Fractional matrix exponentials are introduced, which extend the usual matrix exponential involving ordinary derivatives to the case of fractional derivative operators. Two fractional analogues are defined, corresponding to the Caputo and Riemann-Liouville fractional derivatives. Moreover, explicit methods similar to Putzer's method for calculating the usual matrix exponential are developed for these fractional matrix exponentials.

138 Determining the 'best' prophylactic allocation of vaccines in a segregated population in under a second

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A fundamental problem in public health is how to allocate a given supply of vaccines in order to have the greatest benefit. Here we present an algorithm which answers this question — in under a second using standard computing and with demonstrated relative error of at most a few percent — when minimising the expected number of individuals infected following the (attempted) import of infection into a population occupying two or more interconnected regions, such as farms or cities. Our results represent a significant advance towards understanding the optimal use of scarce resources in spatially-structured disease systems.

139 *Statistical modelling of extreme daily rainfall in South East Queensland using max-stable processes

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In Australia we know the El Niño Southern Oscillation (ENSO) to be a large scale climate driver that affects mean and total rainfall. Whilst we also know ENSO to affect extremes, we yet have to clearly answer to the question of by how much? This question is particularly important for applications in engineering, climatology and insurance, as we are often concerned with estimating the exceedance level associated with design events, such as a 1 in 100 year rainfall event. To calculate the exceedance level associated with a 1 in 100 year event we can fit a generalised extreme value distribution, however in a univariate setting it is difficult to identify whether the inclusion of ENSO as a covariate is significant. To improve our statistical power, we can use the natural extension of univariate extreme value theory to spatial extremes, max-stable processes. In this work we fit a max-stable process to rainfall gauges in the South East Queensland and demonstrate that ENSO both shifts and scales the distribution of annual maximum daily rainfall. This result is important because it shows that the exceendance level associated with a 1 in 100 year rainfall event is subject to change conditional on the state of ENSO.

140 *Application of a delayed logistic model with variable carrying capacity to a deer population

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A single-species population growth model with a variable carrying capacity is considered. The carrying capacity is treated as a state-variable, representing the availability of a non-renewable resource (the environment). We investigate models based on the logistic equation where the rate of decrease of the carrying capacity is proportional to the size of the population. We apply these models, with and without constant time-delays, to a deer population. The model that best fits the data includes a delay in the population and a delay in the term describing the carrying capacity. We provide a physical justification for these delays.

141 Clogging of permeable pavements — a simplified model

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Permeable pavements allow water to drain between pavers rather than to pool or to flow over them. This can have advantages, e.g. for reducing the impact of flooding, water harvesting, and for replenishing the water table. In practice, over time the bedding material may become clogged due to sediment being transported and deposited in the pores between the coarse stones. This clogging effectively makes the bedding material non-porous, reducing and eventually removing the original advantages.

A complete model of the clogging process would include bedding material, water and sediment, and an exhaustive list of mechanisms by which they interact. Although they would intractably complicate the model, not all of the mechanisms would have a significant impact and most likely only a few will be needed to reproduce the gross behaviours of the system.

Instead, our current objective is simplicity. In the model being presented, the mechanism by which the sediment particles are transported remains undefined, as does most of the geometry of the medium and sediment particles and their interactions. We only require that the particles are transported into the medium, where some particles are trapped and clog their channel, while others pass through, depending only on their size relative to the channel width.

We develop a model of multiple channels of various widths with particles whose sizes and arrival times are described by probability distributions. Expressions are formulated for the evolution of key quantities such as the counts of open and blocked channels, counts of sediment particles and their transition and retention rates, volumetric flow rates, and the volume of fluid to pass through the medium. Graphs are presented showing these key quantities for cases with simplified inputs.

Most quantities are shown to have strong relationships to the distribution of particle inter-arrival times, except for the long term count of transitioned particles which depends only on channel width and particle size distributions.

142 *Understanding the transmission dynamics of Influenza through individuals' contact networks

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When analysing the spatial-temporal dynamics of an infectious disease such as Influenza in a region like Melbourne alone, it can be noted that there is great variability in the incidence and prevalence of infectious cases across the different suburbs. One of the explanatory factors for variability in local transmission is the contact structure of individuals. The question then is, how to infer realistic contact networks from sparse data to capture epidemiologically important sources of variability in mixing?

I will discuss my elementary attempt of inferring realistic contact networks, on synthetic populations simulated following the demographic distributions for two spatially disjoint regions in Melbourne, using information collected about mixing patterns stratified by age and gender, in a telephone interview survey. I will also talk about the estimation of transmission parameters after initiating outbreaks on these synthetic representative populations. *(continued next page)*

This will help us gain a better understanding of the transmission dynamics which will help improve control and intervention strategies.

143 Pyrogenic vorticity from fires on windward and leeward slopes

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Research into dynamic bushfire behaviour conducted over the last few years has shown that bushfires burning on lee-facing slopes can exhibit atypical forms of propagation under extreme weather conditions. For instance, recent numerical simulations have indicated that pyrogenic vorticity (the curl of the velocity field) is a key driver of rapid lateral fire spread - as a consequence, this type of fire propagation is being referred to as Vorticity-driven Lateral Spread (VLS). The VLS phenomenon has also been reproduced in laboratory-scale experiments, some of which show clear vortex structures. The presence of vorticity in the experiments and simulations suggests that additional insights into the physical processes may be drawn from direct examination of the fluid dynamical equation governing vorticity. We neglect Coriolis effects and divergence but do not make the Boussinesq approximation, giving the governing vorticity equation:

$$\frac{D\boldsymbol{\omega}}{Dt} = (\boldsymbol{\omega} \cdot \nabla)\boldsymbol{u} + \frac{1}{\rho^2}\nabla\rho \times \nabla p + \nabla \times \boldsymbol{F},$$

where $\boldsymbol{u}$ is the velocity field, $\boldsymbol{\omega} = \nabla \times \boldsymbol{u}$ is the vorticity, ρ is the density, p is the pressure and $\nabla \times \boldsymbol{F}$ represents eddy viscosity and body forces.

In this presentation we provide a rudimentary theoretical analysis of the vorticity equation for the separate situations of fires burning on leeward and windward sides of a triangular ridge under the influence of a strong cross-wind and assumed separation of the flow in the lee of the ridge. We consider the behaviour of the right and left flanks of the fire with some simplifying assumptions about the effects of the fire on the local wind flows.

While these analyses should be considered as preliminary and approximate, they do provide some useful insights into the dynamics of the VLS phenomenon. For instance they provide a physical explanation of why the VLS phenomenon occurs exclusively in connection with steep, lee-facing slopes, which act to promote flow separation. Moreover, they demonstrate the importance of the various driving factors, namely tilting of ambient lateral vorticity, stretching of vertical vorticity by Lagrangian acceleration of the buoyant plume and baroclinic forcing arising due to the effect of the heat of the fire on the density of the flow.

144 Helical flow arising from the yielded axial flow of a Bingham fluid

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The Bingham fluid model represents a viscoplastic material that displays yielding, that is, it behaves as a solid at low stress, but flows as a Newtonian fluid at high stress. In any Bingham fluid, there may be solid regions separated from fluid regions by socalled yield boundaries. Such materials arise in a range of industrial applications. Here, we consider the helical flow of a Bingham fluid between infinitely long coaxial cylinders, where the flow arises from the imposition of a steady rotation of the inner cylinder (annular flow) on a steady axial flow driven by a pressure gradient. We apply a perturbation procedure to obtain approximate analytic expressions for the fluid velocity field and related quantities such as the stress and viscosity. In particular, we examine the location of yield boundaries in the flow and how these vary with the rate of rotation of the inner cylinder and other flow parameters. These analytic results are shown to agree very well with numerical results.

145 Survival probability for a diffusive process on a growing domain

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We consider the motion of a diffusive population on a growing domain, $0 < x < L(t)$, which is motivated by various applications in developmental biology. Individuals in the diffusing population, which could represent molecules or cells in a developmental scenario, undergo two different kinds of motion: (i) undirected movement, characterized by a diffusion coefficient, D, and (ii) directed movement, associated with the underlying domain growth. For a general class of problems with a reflecting boundary at $x = 0$, and an absorbing boundary at $x = L(t)$, we provide an exact solution to the partial differential equation describing the evolution of the population density function, $C(x, t)$. Using this solution, we derive an exact expression for the survival probability, $S(t)$, and an accurate approximation for the long time limit, $\mathcal{S} = \lim_{t\to\infty} S(t)$. Unlike traditional analyses on a non-growing domain, where $\mathcal{S} \equiv 0$, we show that domain growth leads to a very different situation where $\mathcal{S}$ can be positive. The theoretical tools developed and validated allow us to distinguish between situations where the diffusive population reaches the moving boundary at $x = L(t)$ from other situations where the diffusive population never reaches the moving boundary at $x = L(t)$. Making this distinction is relevant to certain applications in developmental biology, such as the development of the enteric nervous system. All theoretical predictions are verified by implementing a discrete stochastic model.

146 Particle aggregation: a multi-scale model of two deforming cells

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We present a unified, multiscale model to study the attachment/detachment dynamics of two deforming, charged, near spherical cells, coated with binding ligands and subject to a slow, homogeneous shear flow in a viscous, ionic fluid medium. The binding ligands on the surface of the cells experience both attractive and repulsive forces in an ionic medium and exhibit finite resistance to rotation via bond tilting. The microscale drag forces and couples describing the fluid flow inside the small separation gap between the cells, are calculated using a combination of methods in lubrication theory and previously published numerical results. For a selected range of material and fluid parameters, a hysteretic transition of the sticking probability curves (i.e., the function g^*) between the adhesion phase (when $g^* > 0.5$) and the fragmentation phase (when $g^* < 0.5$) is attributed to a nonlinear relation between the total nanoscale binding forces and the separation gap between the cells. We show that adhesion is favoured in highly ionic fluids, increased deformability of the cells, elastic binders and a higher fluid shear rate (until a critical threshold value of shear rate is reached). Within a selected range of critical shear rates, the continuation of the limit points (i.e., the turning points where the slope of g^* changes sign) predict a bistable region, indicating an abrupt switching between the adhesion and the fragmentation regimes. Although, bistability in the adhesion-fragmentation phase diagram of two deformable, charged cells immersed in an ionic aqueous environment has been identified by some in vitro experiments, but until now, has not been quantified theoretically.

147 Exploring the Allee effect: How does the Allee effect impact metapopulations?

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Populations are often assumed to mix amongst themselves homogeneously. However, not all populations satisfy this assumption and, for the ones that do not, a metapopulation structure is required. A metapopulation is a ‘population of populations’ and assumes individuals are segregated into patches. Another modelling assumption that is often adopted is that of density dependence; the growth rate of the process will decrease or increase depending on the density, rather than the size, of the population. It is the latter of these two phenomenons that will be explored during this talk; an increase of the growth rate, often referred to as an Allee effect. If a species exhibits a strong Allee effect, then the initial conditions of the species determines whether the species persists or goes extinct. The model presented in this talk differs in two ways to typical models that account for an Allee effect. Firstly, my model is stochastic, using a Markov process to model the evolution of a two patch metapopulation. And secondly, an Allee effect is not artificially introduced by manipulating the birth rate. Extinction and persistence of the species is explored using functional central limit theorems.

148 Instability of non-Newtonian rotating flows

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The stability of a non-Newtonian rotating boundary-layer flow is considered to investigate the transition process from a laminar to a turbulent flow at large Reynolds number. The motivation comes from experiments in the oil recovery industry revealing spiral corrosion patterns on marble rotating discs in viscoelastic gelled acids and the study has many industrial applications. The effect of different viscosity models on the stability of crossflow vortices due to flow over a rotating disc will be presented. Numerical and asymptotic methods are used to determine the basic flows and the neutral stability curves. Predictions are able to be made for the number and orientation of the vortices and the stabilising or destabilising effect of the non-Newtonian flow. The results indicate that it is important to model the variation of viscosity accurately in boundary-layer flows.

149 Coupled flow and energy models for fibre drawing

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An optical fibre is fabricated by feeding a preform into a heated neck-down region and pulling it at a higher speed by winding onto a spool some distance downstream beyond the neck-down region. Where the geometry through the neck-down region is important an energy model must be coupled with the flow model to give the change in temperature and, therefore, viscosity, with axial position. I will discuss the dependence of the specific form of the energy model, and its coupling to the flow model, on the problem parameters. I will also show preliminary results for a particular model.

150 Extremes of bursty events

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A signature of complex systems is that events occur in bursts, i.e. not according to a Poisson process. Scaling limits of Continuous-Time Random Maxima (CTRM), or max-renewal processes, are a simple phenomenological model for the largest event in a bursty sequence, where event size and hiatus time may be coupled. We discuss recent advances in the harmonic analysis on the bivariate plus-max semigroup, which provides a tool for the representation of the limit laws, and show take first steps towards a general statistical approach.

151 Modelling the ripening of cheddar cheese

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Cheese undergoes a number of ripening processes as it matures. These processes were mathematically modelled in a project brought to the 2013 mathematics-in-industry study group at Queensland University of Technology, Brisbane (MISG 2013). Such models could be useful for predicting the quality of cheese using initial measurements. This talk will consider the main results and ongoing investigation.

This project had a particular focus on cheddar cheese. The main ripening processes are modelled with chemical reactions governed by differential equations. These contain a number of unknown parameter values which are fitted using experimental data presented in the literature. Numerical integration is used for simulating the system represented by the equations. In general, the results of numerical fitting are in good agreement with experimental data.

152 A Model for Cell Proliferation in a Developing Organism

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In mathematical biology, there is much interest in producing continuum models by scaling discrete agent-based models, governed by local stochastic rules. We shall discuss a particular example: a model for the process that leads to Hirschprungs disease, a potentially-fatal condition in which the enteric nervous system of a new-born child does not extend all the way through the intestine and colon, as well as various other stochastic models for foetal tissue growth. We start with a simple discrete-state Markov chain model proposed by Hywood et al. in 2013 for the location of the neural crest cells that make up the enteric nervous system, and consider a variety of limiting regimes that lead to partial differential equation models that describe the dynamics of crest cell density as the whole gut grows. When a neural crest cell proliferates, the size of the whole lattice increases by one and a cell from the underlying domain is left behind the proliferating cell. Since tissue growth is a significant cellular transport mechanism during embryonic growth, it has an indispensable role in the derivation of the correct partial differential equation description. Therefore, we present a simple stochastic model of domain growth and work with a Partial Differential Equation to describe how the expected occupancy of each site moves with time. Moreover, we are able to derive a Partial Differential Equation for variance of occupancy of domain agents.

153 *Predicting channel bed topography in hydraulic falls

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We consider inverse methods for predicting the channel bed topography in experiments of hydraulic fall free surface flows. Two mathematical models are used to produce inverse solutions, both based on the potential flow model. Weakly nonlinear approximations are obtained using a forced Korteweg-de Vries equation, and fully nonlinear solutions are obtained using boundary integral methods. The inverse predictions are then compared with experiments. Accurate predictions are obtained for the maximum height of the topography and its constant horizontal level far downstream using the nonlinear method. The weakly nonlinear approximation is shown only to be a good predictor of the maximum height of the topography. The error in the inverse predictions is discussed.

154 Screen Deflection: A MISG 2015 problem

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The screen problem is from MISG 2015 at QUT in Brisbane and concerns modelling the wind deflection of very large sliding insect screens for living room french doors. Because of their size, the insect screens are designed to be as light as possible and so that they can be slid open and closed with minimal friction. Consequently there is a tendency for the screens to deflect significantly in windy conditions.

I'll briefly discuss the groups approaches to modelling these screens and give more details about my own continuum mechanics/calculus of variations approach.

155 Calculating optimal limits for transacting credit card customers

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Credit card users can roughly be dived into 'transactors', who pay off their balance each month, and 'revolvers', who maintain a substantial outstanding balance, on which they pay interest.

In this talk, we focus on modelling the behaviour of an individual transactor customer. Our motivation is to calculate an optimal credit limit from the bank's point of view. This requires an expression for the expected outstanding balance at the end of a payment period. We derive its Laplace transform, assuming that purchases are made according to a marked point process and that there is a simplified balance control policy which prevents all purchases in the rest of the payment period when the credit limit is exceeded.

We calculate optimal limits for a compound Poisson process example and show that the optimal limit scales with the distribution of the purchasing process, with the probability of exceeding the optimal limit remaining constant.

Furthermore, we establish a connection with the classic newsvendor model and use this to calculate bounds on the optimal limit for a more complicated balance control policy. Finally, we apply our model to real credit card purchase data.

156 Semiconductor laser with saturable absorber and delayed optical feedback: a bifurcation analysis

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Both experimentally and theoretically, semiconductor lasers have been shown to produce a wealth of interesting dynamics: this includes continuous-wave emission, self-pulsations, and excitability.

We consider here a semiconductor laser with saturable aborber subject to delayed optical feedback. The Yamada model with a feedback term — a system of three delay differential equations for the gain, the absorption, and the laser intensity — can be considered as the simplest mathematical model for such a laser. We perform here a numerical bifurcation analysis of this model, considering both the feedback strength and delay as bifurcation parameters. This allows to divide the parameter space into regions with different kind of solutions.

This analysis highlights that, despite its simplicity, the delayed-feedback Yamada model displays complex dynamics, such as coexistence of several stable periodic orbits and quasiperiodic solutions on tori. The comparison between bifurcation analysis and time-domain simulations allows a better understanding of complex dynamics observed experimentally. Specifically, we discuss a possible interpretation for the mechanism leading to pulse trains featuring different amplitudes and multipulses before the intensity drops back to zero.

157 Wilmore energy for joining of carbon nanostructures

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Numerous types of carbon nanostructure have been found experimentally, including nanotubes, fullerenes, nanocones and graphene. These structures have received much attention for their potential application in various nanoscale devices; the joining of these structures may lead to further new structures with more remarkable properties and more potential applications. Using the calculus of variations we may approximate the profile at the join between different types of carbon nanostructure in a rotationally symmetric configuration, including a piece of a carbon nanocone joined to a fullerene, two nanocones, graphene and a nanocone, a fullerene and graphene, and a nanocone and two parallel sheets of graphene. In previous studies, carbon nanostructures were assumed to deform according to perfect elasticity, thus the elastic energy, which depends only on the axial curvature, was used to determine the join profile consisting of a finite number of discrete bonds. However, one could argue that the relevant energy should also involve the rotational curvature, especially when its size is comparable to the axial curvature. In this talk, we adopt a different model namely the Willmore energy which depends on the axial and rotational curvatures. Catenoids are absolute minimizers of the Willmore energy and pieces of these may be used to join various nanostructures. By comparing the results based on the two energies for joining carbon nanocones with carbon nanotubes, two carbon nanocones and two fullerenes, we find for each case that both energies give similar joining profiles.

158 *Simulations of a Jet in Crossflow

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A Jet in Crossflow (JICF) is a jet of fluid that enters a uniform stream at right angles. This flow has applications in many fields, from fuel injection and mixing in scramjets to modelling the spread of volcanic ash plumes. As such, it is an important flow to understand both qualitatively and quantitatively. In this talk I will present the direct numerical simulation of a 2D JICF, for a variety of flow conditions, as the first step in the development of a fully 3D simulation. As will be seen, the 2D simulation gives a good qualitative picture of the flow. I will also discuss the shortcomings of 2D simulation, and the need for a 3D investigation.

159 *Dynamic fire behaviour and fire line geometry

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Dynamic fire behaviour may be defined as changes in the behaviour of a fire that are not the result of changes in ambient conditions. For example separate fires, or different parts of the one fire, can interact to produce dynamic and, in some cases, extreme fire behaviour. Thus the geometry of the evolving fire line can substantially affect the behaviour of a wildfire. This may occur, for example, during the coalescence of spot fires or when separate fire fronts merge. Possible mechanisms for such effects include pyro-convective coupling between different parts of the fire lines and geometric effects relating to the radiative and convective transfer of energy. In this study we model numerically the dynamic fire behaviour associated with various simple fire line configurations, such as V-shaped fire lines and circular fires. The dynamics of the fire spread in these cases is examined using a coupled fire-atmosphere model (WRF-Fire), which accounts for the influence of pyro-convection but not explicitly for the radiative transfer of heat. The observed behaviour is analysed in terms of the geometry of the evolving fire line, with fire line curvature a primary focus.

160 *An empirical approach for determining the state of charge of a battery

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State of charge (SoC) is an operational definition used to quantitatively describe the remaining amount of useful energy within the battery. This variable is analogous to the fuel gauge reading of a gasoline powered vehicle. An accurate estimation of the SoC is important in improving the effectiveness of a battery management system (BMS) to manage a rechargeable battery (eg lithium ion battery). In this presentation a new approach for estimating the battery's SoC will be presented. The method uses the measurement of current and voltage to directly calculate the SoC of the battery. In addition, the method to calculate the parameters of the model will also be discussed.

161 *Deformations in Preform Extrusion

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A microstructured optical fibre consists of a thin thread of material containing a number of air channels that run along its length. Such fibres may be fabricated by first extruding molten material from a die to form a macroscopic version of the fibre known as a preform; however, the resulting fluid flow leads to deformations in the geometry that may render the preform useless. A model of this process is developed using a slenderness approximation in which the molten material is considered to be a very viscous Newtonian fluid deforming due to surface tension and gravity. The model predictions are compared with experimental observations of an archetypical preform design with three internal boundaries. A hypothesis to explain the origin of large-scale deformations in the outer boundary is presented and examined using the model.

162 *Image registration under conformal diffeomorphisms

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Image registration is a process in which we apply transformations to an image so that it looks “similar” to the other image. In this talk I will discuss about image registration under conformal diffeomorphisms.

163 *Free boundary PDE models of atherosclerotic plaque formation

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Atherosclerosis is among the leading causes of death worldwide due to its implication in heart attacks and strokes. The disease is characterised by the localised thickening of artery walls due to the buildup of fatty cholesterol-filled streaks. Specifically, atherosclerotic plaques form as an inflammatory response to the presence of cholesterol-carrying low density lipoproteins (LDL) inside artery walls. The presence of LDL stimulates the recruitment of macrophages from the bloodstream to consume the LDL. These macrophages become lipid-engorged foam cells that eventually break down to release free lipids and cellular debris into the surrounding plaque. Plaque dynamics consist of many nonlinear interactions between various cellular and biochemical species besides the recruitment and consumption of LDL by macrophages. In particular, recent biological studies suggest that the majority of active macrophages found in established atherosclerotic plaques derive from local proliferation of existing macrophages rather than recruitment from the bloodstream.

In this talk, we present a partial differential equation model for an early stage atherosclerotic plaque. The model accounts for interactions between macrophages, LDL, foam cells, cytokines, and chemoattractants, modelling the plaque space as a 1D domain with a moving boundary. In contrast to previous models, our model has the capacity to account for active macrophage proliferation, and also incorporates the effects of cell crowding by having the domain expand according to the total cell number. We discuss how this model gives insight into how early plaque development depends on the rates of LDL influx, macrophage recruitment, and macrophage proliferation.

164 Blast from the Past: (A taste of DDDEs)

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A widely accepted model of coexisting cultures of pasture-growth, which incorporated delay-mechanisms over an interval of prior time, revealed the existence of periodic solutions, not prevalent in a purely local model-formulation, see Louie et al (2002). This served to suggest that even a mono-culture (with only one compartment) could also exhibit this largely unexplored phenomenon. In this talk we investigate this for the simple very common equation: the logistic equation, albeit with a distributed-delay mechanism incorporated. It is shown that there is a super-critical Hopf bifurcation, when we use the delay-time T as a distinguished parameter. The equation is

$$\frac{\mathrm{d}x}{\mathrm{d}t} = rx\left(1 - \frac{1}{KT}\int_{t-T}^{t} x\left(s\right)\mathrm{d}s\right).$$

Here the Malthusian growth parameter r and the carrying capacity K are, for simplicity, taken to be constant. This illustrates the fact that delays can easily be used to explain unusual experimental outcomes in a relatively straightforward manner.

Reference: K Louie, GC Wake, MG Lambert, A McKay & D Barker "A delay model for the growth of rye-grass-clover mixtures: Formulation and preliminary simulations", *Ecological Modelling,* 155, **2002**, pp31–42.

165 Mystic Canberra: Distance sampling for lines of supernatural power

Edward Waters

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Canberra, designed on occult principles, sits upon lines of supernatural power, and is one of Australia's most mystically significant and active sites. Our ancient ancestors understood that to avoid negative consequences, such as being haunted, it was best not to build dwellings on lines of power. In the modern era, when traditional knowledges are forgotten, mathematics and statistics must take their place. A line-intercept sampling scheme, utilising a zig-zag configured sampler, is presented for solving the binary classification problem of whether a building site in Canberra disturbs a line of occult power. Use of the sampler is validated by computer simulations and results presented in terms of Type I and II error rates, accuracy and positive predictive value. A sampler length of 17km is shown to achieve acceptable Type II error rates, and is presented as a suitable tool for avoiding supernaturally unfavourable building sites in the ACT.

166 The role of cell volume changes in normal and pathological dynamics of the brain

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Cell volume changes are ubiquitous in normal and pathological activity of the brain. Nevertheless, we know little of how cell volume affects neuronal dynamics.

In this talk, I will discuss the role of cell volume on neural dynamics by incorporating cell volume changes together with dynamic ion concentrations and oxygen supply into Hodgkin-Huxley spiking dynamics. I will highlight the underlying multiple time-scales structure in these extended conductance based neural models and show how transitions from normal to pathological states arise by employing geometric singular perturbation theory. This dynamical systems approach provides an explanation of the observed spontaneous transition between epileptic seizure and spreading depression states as the cell swells and contracts in response to changes in osmotic pressure.

167 *Modelling and simulation of electromagnetic emission during crack propagation in epoxy resin materials

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The failure of a brittle dielectric material under mechanical load generates acoustic emission (AE) and electromagnetic emission (EME). Detection and analysis of the AE are commonly used for the investigation of failure in solid materials. However, the origins of the emitted electromagnetic fields are still highly debated. We model and simulate three-point flexure tests, which induce mode-1-fracture of epoxy resin specimens, and compare these to experimental data investigating the influence of the electronic measurement devices on the EME, the influence of distance and orientation of the crack surfaces, the basic characteristics of the emitting source as well as the origins of the electromagnetic signals. Experimental data to be presented and comparison with simulation results substantiate our hypothesis that the obtained EME signals consist of two parts: one part results from separation of charges during the crack progress and subsequent charge relaxation and the other part is a superimposed small oscillation induced by vibrations of the charged crack surfaces.

168 A Tale of Two Ponds or Simulation Serendipity

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Flinders University Environmental Heath researchers have been at the forefront of the development wastewater treatment using High-Rate Algal Ponds (HRAP) to replace traditional Waste Stabilisation Ponds. One of the main advantages of HRAP over WSP is the order-of-magnitude reduction in treatment times. However, the accepted sterilisation mechanisms did not lead to useful models of their operation. A serendipitous failure in the experimental HRAP pond situated at Kingston-on-Murray in the South Australian Riverland showed an agreement with a simple simulation that allowed the use of laboratory-measured sterilisation rates to accurately predict the performance of the pond in-situ. In turn this lead to a major rethink of the sterilisation mechanisms in the HRAP which helped in the approval of their use in South Australia.

169 *A non-Hebbian learning model for some periodic activities with synchronizations of phase oscillators

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Phase oscillators have been used for modelling a neural network of brains. A key point of the structure of well-known brain model is synaptic plasticity. People say that Hebbian law, which means the strength of synapse become higher when post-synaptic neuron and pre-synaptic neuron active at the same time, is one of the most important property in brain memory. In other word, a key point of the structure of well-known models is how to define the strength of each synapse. We note that Hebbian memory is not the whole brain but just a port of its structure. Actually other experimental result said that the region of memory in brain can change, so there may exist some types of memory systems in one organism. For example, anticipation of amoeba indicates that a neuron can memorize a periodic event without synaptic plasticity. In this talk, I will introduce a developed amoebae leaning model and expand it. First, I will explain the amoebae model briefly. Next, I will rewrite the output function in amoebae model to embed memories in the spike timing of neuron. Finally, I will propose a phase oscillators system for memorizing some periodic stimuli.

170 *On the extinction probability in models of within-host infection: the role of latency and immunity

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When a susceptible individual is exposed to a small amount of virus such as influenza, infection is not guaranteed. This is because the virus could become extinct due to stochastic events. The extinction probability can be altered by the host immune response, leading to the possibility of using antiviral treatment to prevent infection.

Viral infection in its early stages can be modelled as a multi-type continuous time branching process. Previous studies on calculating the extinction probability have concentrated on models of infection within the host where the immune response and/or treatment effect are either time-independent, or explicitly a function of time, in which case the extinction probability can be found by analysing the backward ChapmanKolmogorov differential equation for the model. We show that for a mechanistic model of the immune response, the extinction probability depends on the chosen form of the model, such as the lifetime distribution of infected cells and the existence of a latent period during which the infected cells cannot produce virus. We apply the method to a model of re-infection, where ferrets are exposed to different strains of influenza with varying intervals between the two exposures. Our model not only explains the observation that a second infection is prevented in a proportion of animals, but also show why this temporary immunity is dependent on the time between exposures. Our findings enable a better understanding of how the immune response blocks infection, with potential applications in vaccination and preventative treatment.

171 *Investigating preferences in university collaboration networks

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The Revealed Comparative Preference (RCP) is a measure used to study collaborations within groups of universities and research institutes, and is done by analysing real-world bibliometric data.

The networks formed by the collaborations between these institutes are visualised with a force-directed layout and we present different groups of institutes that vary in characteristics such as size and geographic distribution. We discuss findings from these different groups and speculate on possible causes of collaboration preference.

In addition to collaboration, we briefly discuss other publication statistics such as subject matter, as well as shortcomings in the data obtained and how these may impact results.

172 *Influenza forecasting with a seasonally informed model

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Each year temperate climates witness a seasonal influenza epidemic. However, there is considerable variation in their timing and severity. Accurate forecasts of these epidemics have the potential to reduce the burden placed on the health care system and save lives. Previous work has modelled the transmission of influenza in Melbourne using a hidden Markov model. The hidden state is modelled using a system of stochastic differential equations along the lines of the susceptible-exposed-infectious-recovered (SEIR) model. A classic of mathematical epidemiology, the SEIR model partitions a population into four classes based on disease status. Members of the population transition between classes following mass action kinetics. The (time series) data for this model consists of noisy measures of incidence; i.e., the number of people who visit the doctor for influenza. Within the SEIR model this corresponds to transitioning from the exposed to the infectious class. Experimental work has shown the influenza virus' ability to spread is influenced by temperature and humidity. Building on previous work we included seasonal forcing, allowing the rate of infection to vary as a function of temperature and humidity. Rather than attempt to forecast the weather and influenza simultaneously we have treated the weather as a known signal, the average of previous years. This work was motivated by a specific problem, the need for timely prediction of an epidemic's peak incidence and when this will occur. Here, I will present the findings of our study and discuss the potential for using temperature and humidity data to improve forecasting skill as measured by real world utility.

173 *Numerical comparisons in two-state regime-switching model

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In this talk, we present a comparative study of the Monte Carlo simulation (MC hereafter) and the finite difference method (FD hereafter) for pricing European options under a two-state regime-switching (TSRS hereafter) model. Since one extra dimension of randomness, the hidden Markov chain, is introduced in the TSRS model, computational cost of both of the two methods increase in different ways. The numerical performance shows that even for one single underlying asset, the MC is more efficient than the FD in the parameter space where the transition rate λ and the time to maturity T are small. However, the efficiency of the MC declines as λ and T increase. To overcome this shortcoming, we propose a new Monte Carlo simulation (NMC) which simulates the total occupational time. Our NMC proves to be much faster than both MC and FD in the entire parameter space.

174 *The Combination technique applied to QoI computed from the GENE code of gyrokinetic equations

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More and more challenging problems today in Physics are high-dimensional and require exascale computing. The simulation of microturbulences in hot fusion plasma is among these challenging topics. The microturbulences can be described by five-dimensional gyrokinetic equations. Estimating QoI from the simulation is crucial for us to understand the whole problem. The sparse grid combination technique has been successfully applied to solve many high-dimensional problems. It allows us to reduce the curse of dimensionality by combining several low resolution solutions derived from many anisotropic grids, that is with different mesh sizes. In this work, we first compute QoI for a smooth Maxwell-Bolzmann distribution function and analyse the error of our combination technique in this case. Then we show some first results to apply our combination technique to compute QoI generated by the GENE code.

175 Pricing European options with stochastic volatility under the minimal entropy martingale measure

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In this talk, a closed-form pricing formula in the form of an infinite series for European call options is derived for the Heston stochastic volatility model under a chosen martingale measure. A great advantage of our newly-derived pricing formula is that the convergence of the solution in series form can be proved theoretically; such a proof of the convergence is also complemented by some numerical examples to demonstrate the speed of convergence. To further show the validity of our formula, a comparison of prices calculated through the newly derived formula is made with those obtained directly from the Monte Carlo simulation as well as those from solving the PDE (partial differential equation) with the finite difference method.

176 Modelling noise in competing sense/decision-making networks

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The Kuramoto model of network synchronisation of coupled oscillators — long used for physical and biological systems — has in recent years been adapted for modelling socio-technical systems. For example, the phase of an oscillator at the nodes of a network may be used to represent the point in a continuous loop of sensing (perception-orientation), decision-making and action. This then models how groups of humans undertake sense- and decision-making activities in organisational networks. If a competitor or adversary organisation is also involved, as occurs in military or business contexts, the model is particularly useful. Proponents of such an approach to analysing decision-making argue that success is based on competing agents getting inside the loop of the adversary. Previous study of such a model has focused on deterministic behaviours. In this presentation we incorporate Gaussian noise into the model in order to provide better fidelity of modelling of human agents in such an approach. We show how noise changes predictions from fixed point stability analysis, enabling understanding of where in the various networks decision-making becomes incoherent or fragmented. We test analytical solutions against numerical computations.

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