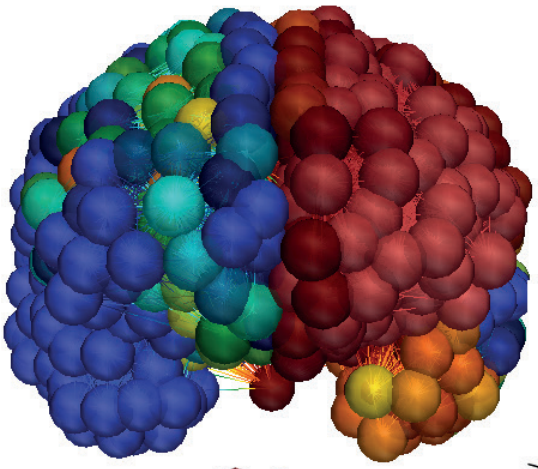
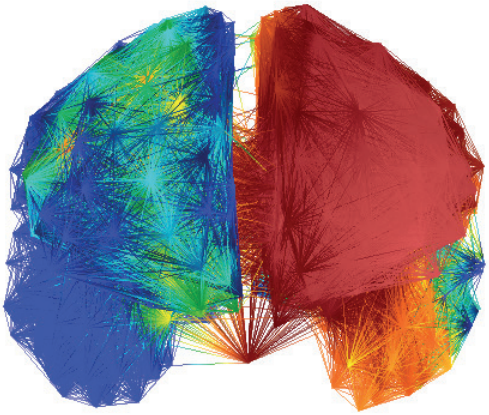
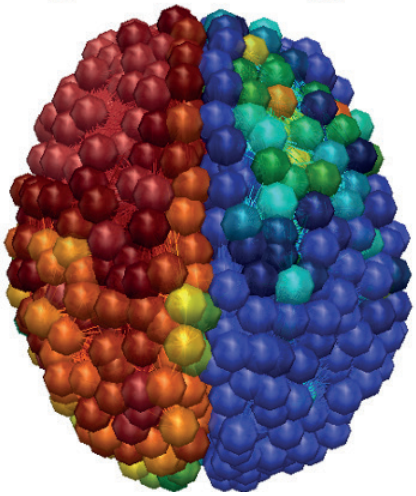
Bulletin16

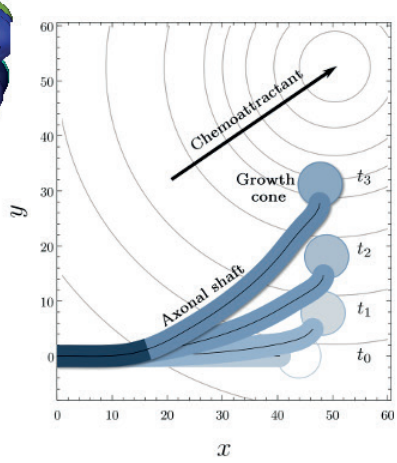
MT 2019

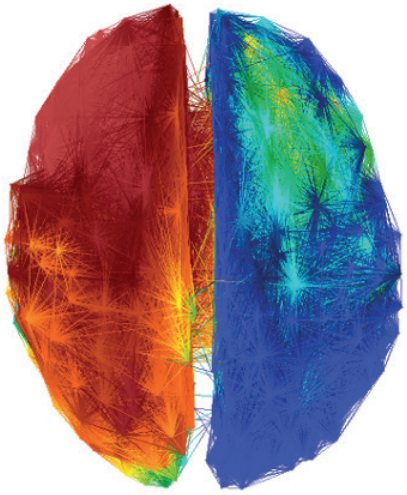
OXFORD CENTRE FOR INDUSTRIAL & APPLIED MATHEMATICS
University of Oxford
Mathematical Institute, Andrew Wiles Building











Welcome

Ian Griffiths

Ian needs no introduction. As a Royal Society Research Fellow his principal research agenda concerns hydrodynamical challenges in industrial situations,. This work has included water purification for the developing world, the manufacture of star-shaped Cheerios, the manufacture of glass screens for smartphones and tablets, the fabrication of LCD screens, and the manufacture of effective filters for Dyson vacuum cleaners and air purifiers. Ian now has a permanent appointment as Professor of Industrial Mathematics. He is also a Tutorial Fellow at Mansfield College.

Bernadette Stolz

Bernadette is a PDRA in the Centre for Topological Data Analysis. She is interested in applying ideas from topology to study the shape of biological data. For example, she is using persistent homology to spatially characterise the unique features of tumour blood vessel networks in experimental data. She will further use this approach to compare different mathematical models, producing these networks. She is collaborating closely with researchers from mathematics, oncology, and industry.

OCIAM's new graduates

Calum Braham joins OCIAM from the University of Western Australia, where he previously studied a BPhil in mathematics and physics. His thesis analysed the passing strategies of Australian football teams. His MPhil in mathematics researched systems of particles undergoing aggregation and breakage in the context of mine wastewater treatment. He has applied mathematical modelling to problems from several organisations, including the Perth Festival, King Edward Memorial Hospital, Hockey Australia and Fisher & Paykel Appliances. More recently he has been working with the ARC Offshore Research Hub at UWA. At OCIAM he will work with Professor Jon Chapman on multi-scale models of cell biology. **Gonzalo Gonzalez De Diego** studied aerospace engineering in Madrid, where during his final year he developed an interest in numerical analysis and PDEs, an interest that would lead a few years later to complete the MSc in Mathematical Sciences in Oxford. His DPhil programme, working

Anna Seigal

Anna Seigal is a Hooke Research Fellow and a Junior Research Fellow at Queen's College. She did her PhD at the University of California, Berkeley. The topic of her research is applied algebra - the use of algebraic methods to tackle applied problems. Anna uses tensors and algebraic tools to understand statistical models, and for algorithms to analyse biological data.

Priya Subramanian

Priya's research focus since her PhD has been on the formation of complex spatio-temporal patterns in diverse physical systems such as fluid flows, soft matter and active systems. After post-doctoral work at MPI for Dynamics and Self-Organization (Germany) and University of Leeds (UK), she joins us as a Hooke Research Fellow. Her current interest is modelling self-assembly during soft matter crystallisation using tools from computational algebraic geometry and topological data analysis.

Kelly Spendlove

Kelly joins us from Rutgers as a PDRA in the Centre for Topological Data Analysis. He is interested in applied algebraic topological approaches to dynamical systems, and applications to systems/synthetic biology and high-dimensional data

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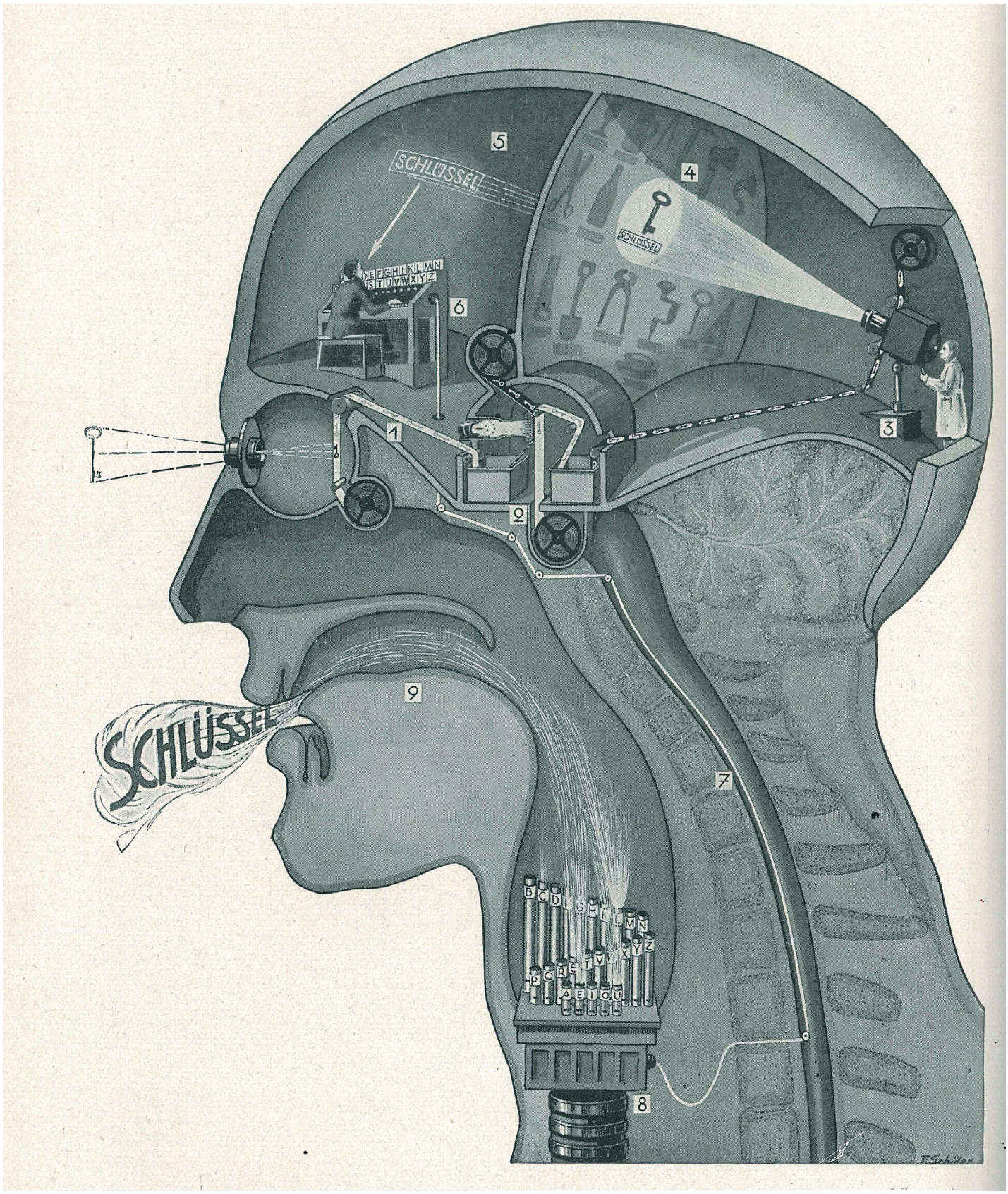
with Professors Patrick Farrell and Ian Hewitt with focus on the construction of robust preconditioners for problems in glaciology modelled with the Stokes equations.
David Beers has joined the Mathematical Brain Modelling group of Prof. Goriely as a DPhil student (see P6). **Amy Kent** completed her undergraduate in physics at the University of Oxford where her Masters' project involved developing new detection techniques for viruses. Starting on the Interdisciplinary Bioscience Doctoral Training Programme in 2018, Amy completed one project in theoretical physics working on evolution of cell lineages before joining maths for her DPhil. She will be working with Sarah Waters and Jim Oliver, modelling the fluid flow in a humanoid robotic bioreactor designed to grow tendon tissue. **Prama Putra** has joined the Mathematical Brain Modelling group of Prof. Goriely as a DPhil student (see p.6). **Jamie Rees** was awarded a Natural Environment Research Council scholarship to research Geophysical Fluid Dynamics.He will be working with the Met Office to investigate the stability of continuously stratified zonal jets over the equator, with particular interest into Tropical Instability Waves.
At Durham, **Philip Winchester** studied Physics and Mathematics. His Masters dissertation is entitled, "The Theoretical Formulation of the Magnetics Monopole". Philip will be conducting research into the dynamo instability supervised by Prof. Peter Howell and Dr Vassilios Dallas.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F. Schiller

Mathematics of the brain

The last few years have seen a tremendous increase of interest in brain research. While large research programmes attempt to enhance our understanding of small-scale influence, at the cellular or protein scale, the role of mechanics in these studies has been largely ignored.

Professor Alain Goriely has advanced the understanding of brain tissue mechanics by exploring their role in predicting growth and development. For instance his work has exposed the involvement of wrinkling instabilities in elastic bilayers and how they thicken gyri in the developing cortex. His work has also provided clinical insight into the mechanics of craniectomies; showing, mathematically, where and how neurosurgeons can cut into the skull to minimise proximal brain-tissue damage.

Der Sehakt "The Act of Speech." Illustration by Fritz Kahn, Das Lieben des Menschen IV, 1929

Now Prof Goriely turns his attention towards a brain modelling issue recognised as centrally important to our ageing population: understanding dementia. With a large ageing population dementia is a pressing health and economic crisis. According to a report from the Alzheimer's society it is projected that 1 in 79 persons living in the United Kingdom, and 1 in 14 over the age of 65, will suffer from some form of dementia.

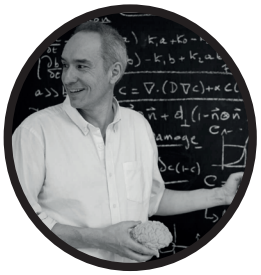
The study of dementia dynamics is multi-scaled and complex; involving coupled biological systems at the molecular, cellular, and organ level. The fact that some fundamental clinical questions about the basic function of the brain remain open further confounds the issue, and clinicians are in dire need of data biomarkers for early clinical diagnosis. Once the disease state reaches critical levels any hope for intervention becomes unlikely.

Clinicians are in dire need of data biomarkers for early clinical diagnosis.

The occurrence of various dementia is strongly correlated with the spread of toxic proteins in the brain. With a recent EPSRC fellowship, Prof Goriely is developing mathematical models describing the genesis and spreading of the toxic proteins characterising various dementia and their related tissue damage. Central to these models are the axons; small fibrilar structures inside the brain that connect neurons to one another. Axons provide a path for the electrical signals that give rise to our thoughts as well as a superhighway for the spread of toxic proteins in the dementia-addled mind. Prof Goriely is scrutinising every mechanism of this critical highway: How do axons grow? Can toxic protein migration models posed on axon highways explain clinical data? Can mathematical models of the diseased protein kinetics, and the damage they do to the axons, explain disease progression and provide useful clinical biomarkers for early detection?

Dementia is a challenging problem with fundamental, open, clinical questions; we are limited in our ability to explore these questions experimentally. Mathematical models are central to computational investigations of clinical hypotheses and for harnessing big data methods to discover effective diagnostic biomarkers. Prof Goriely and his team are developing the mathematical models that enable a fundamental understanding of the dynamics characterising dementia formation, tissue damage, and spread. Alain's team is also leading the development of open source research software based on his models; this software can be used to study clinical hypotheses in simulated human environments and provide data scientists a platform to find life-saving early detection biomarkers.

Brain Modelling in OCIAM



Professor Goriely and his team are devising mathematical models and leading open source software development that enable the study of clinical hypotheses in simulated human environments This also provides data scientists a platform to find life-saving early detection biomarkers.

Here are some recent publications relevant to current brain modelling research:

L. Angela Mihai. Silvia Budday, Gerhard A. Holzapfel, Ellen Kuhl, Alain Goriely. **A family of hyperelastic models for human brain tissue**. *Journal of the Mechanics and Physics of Solids*. 2017. 106. 60-79
DOI: 10.1016/j.jmps.2017.05.015

Johannes Weickenmeier, Pablo Saez, Alain Goriely, and Ellen Kuhl. **Bulging Brains**. *Journal of Elasticity.* 129 (1-2): 197–212.
DOI: 10.1007/s10659-016-9606-1

Johannes Weickenmeier, Ellen Kuhl, and Alain Goriely. **The multiphysics of prion-like diseases: progression and atrophy**. *Physical Review Letters*. 2018. 121, 158101.
DOI: 10.1103/PhysRevLett.121.158101

Sveva Fornari, Amelie Schäfer, Mathias Jucker, Alain Goriely, Ellen Kuhl. **Prion-like spreading of Alzheimer's disease within the brain's connectome.** *Journal of the Royal Society Interface.*
DOI: 10.1098/rsif.2019.0356

Sveva Fornari, Amelie Schäfer, Ellen Kuhl, Alain Goriely. **Spatially-extended nucleation-aggregation-fragmentation models for the dynamics of prion-like neurodegenerative protein-spreading in the brain and its connectome.** *Forthcoming.*
DOI: 10.1101/692038

M. Holland, S. Budday, A. Goriely, E. Kuhl. **Symmetry breaking in wrinkling patterns: Gyri are universally thicker than sulci**. *Physical Review Letters*. 2019.
DOI: 10.1103/PhysRevLett.121.228002

Johannes Weickenmeier, Mathias Jucker, Alain Goriely, Ellen Kuhl. **A physics-based model explains the prion-like features of neurodegeneration in Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis.** *Journal of the Mechanics and Physics of Solids*. 2019.
DOI: 10.1016/j.jmps.2018.10.013

Hamza Alawiye is a final year DPhil student, working with Alain Goriely and Patrick Farrell. He works on elastic surface instabilities which are believed to be responsible for the formation of the characteristic shape of the mammalian brain. He is also interested in finite element simulations of this and other problems in solid mechanics.

David Beers received his bachelor's and master's degrees from Boston University and is currently a D.Phil. student under the supervision of Prof. Goriely and Prof. Harrington. He is interested in network evolution arising from dynamical processes taking place on graphs. In particular, he is studying bifurcations in the underlying topology induced by these networks.

Hadrien Oliveri completed a D.Phil. in Computer Science in May 2019 at the French National Institute for Research in Computer Science and Automation (Inria). Hadrien is generally interested in the morphogenesis of biological systems; more specifically in the dynamic interaction between mechanics, growth and active regulation processes. Hadrien is studying the mechanical effects involved in the control of axonal development and pathfinding.

Prama Putra has joined the Mathematical Brain Modelling team of Prof. Goriely as a D.Phil student. While at at the Institut Teknologi Bandung in Indonesia Prama published work in the mathematical modelling of epidemiological problems; including the evolution patterns of diseases on network systems. Prama will use his expertise in exploring the graph-based evolution of toxic protein propagation in the brain. Such models may offer promise in elucidating key mechanisms of neurodegenerative disease formation; including Alzheimer's disease.

Travis Thompson holds a D.Phil. in Mathematics from Texas A&M University. Travis' research interests are in numerical analysis, scientific computing and the mathematical modelling of biological soft-tissue systems. Travis is researching network-based models reducing the continuum and protein kinetics of disease propagation in the brain to a coupled high-dimensional system of nonlinear ordinary differential equations.

ECMI

European Consortium for Mathematics in Industry

European Consortium for Maths in Industry Modelling Week, Grenoble, 2019

Each year OCIAM funds several graduate students (DPhil or MSc) who are selected based on their application, to attend the ECMI Summer Modelling week. The funding covers registration, accommodation, subsistence and travel costs.

The annual ECMI modelling weeks introduce students to devising mathematical models of real-world problems. Participants work in groups, under the guidance of a mentor/instructor who has proposed the problem. At the end of the week, each group presents to the other groups, instructors and ECMI members.

Kristian Kiradjiev writes about his experience at this summer's modelling week in Grenoble.

The ECMI Modelling Week was an amazing experience for me, both academically and socially. It attracted numerous students from all over Europe to undertake one of seven challenges inspired by various real world problems. The project I chose concerned modelling an eye implant, which is a new treatment for glaucoma, a condition involving an increased pressure in the eye that can damage the optical nerve. The team I was part of was very multi-national: apart from me, there was a student from Austria, Finland, and Spain. We worked together in a very efficient way splitting our tasks and working in parallel. We managed to come up with a detailed mathematical model that linked glaucoma to the change in porosity in an internal part of the eye where liquid is drained. We obtained a simplified model and compared it with a full three-dimensional model that we solved numerically. In addition, we identified key parameters that control the dynamics of the system and describe the effect of changing certain material properties of the implant on its effectiveness. This work is novel, and we are planning on publishing our results soon. On the whole, the modelling week greatly expanded my knowledge horizon.

A call for applications to attend the ECMI Modelling Week in St.Petersburg 5th - 12th July 2020 will be sent in the New Year.

Study Groups

Initiated in Oxford in 1968, Study Groups with Industry provide a forum for industrial scientists to work alongside academic mathematicians on problems of direct industrial relevance. They are an internationally recognised method of technology and knowledge transfer between academic mathematicians and industry, usually lasting one week.

The success of the (now called) ESGI: European Study Groups with Industry, in which problems presented by industry are used as a basis for mathematical research, is demonstrated by the extent to which the unique format has been propagated internationally and in the UK has evolved to become an important and flexible intervention tool to engage mathematical sciences in topics of key importance; from energy systems, to agriculture.

A report from academics and KTN's Industrial Mathematics expert has looked at the impact of study groups on industry Authored by Dr Martine Barons, director of the Applied Statistics & Risk Unit (AS&RU) University of Warwick, Chris Budd OBE, Professor of Applied Mathematics at the University of Bath, Dr Joanna Jordan, freelance mathematics knowledge exchange specialist and Matt Butchers, KTN's Knowledge Transfer Manager. The report can be found at:
https://ktn-uk.co.uk/news/study-groups-with-industry-what-is-the-value

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Fontys in Tilburg, Netherlands
27 - 31 January 2020

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Centre de Recerca Matemàtica, Barcelona
27 - 31 January 2020

MISG

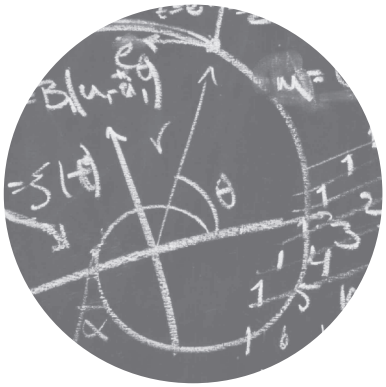
University of Newcastle, Australia
28 January - 1 February 2020

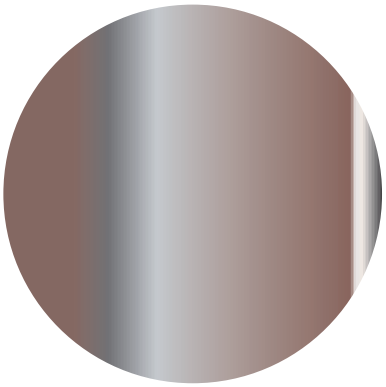
MISG

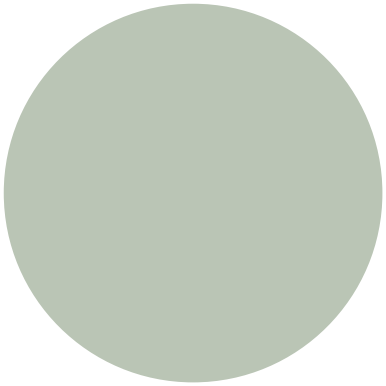
University of Zululand, South Africa
13 - 31 January 2020

OCIAM-relevant seminars, talks and colloqiua are listed here.

Events







OCIAM Seminars

24 Oct Linda Cummings
New Jersey Institute of Tech
31 Oct Prof. Garegin Papoian
University of Maryland
7 Nov Andrew Archer
University of Loughborough
14 Nov Priya Subramanian
Oxford, Hooke Fellow
21 Nov Yuichi Togashi
Hiroshima University
28 Nov Megan Davies Wykes
University of Cambridge
5 Dec Scott Mccue
University of Queensland
12 Dec Saleh Tanveer
University of Ohio

Talks take place on Thursdays at 4pm in L3. Titles and abstracts can be found on the **website**.

Computational Maths
Seminars

24 Oct Fredrik Johansoon
University of Bordeaux
31 Oct Niall Bootland
University of Strathclyde
7 Nov Simon Taverner
Colorado State University
14 Nov Massimiliano Ferronato
University of Padua
21 Nov Karl Meerbergen
Catholic University of Leuven
28 Nov Philippe Toint
University of Namur
5 Dec Clarice Poon
University of Bath

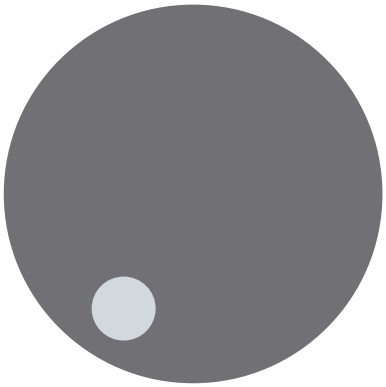
Talks take place on Thursdays at 2pm in L4. Titles and abstracts can be found on the

Math Bio & Ecology
Seminars

25 Oct Stanislav Shavrtsman
Princeton
1 Nov Anna Seigal
University of Oxford
8 Nov Simon Taverner
Colorado State University
15 Nov Neil Dalchau
Microsoft Research, Cambridge
22 Nov Marketa Tomkova
Nuffield Dep. of Medicine
29 Nov Rachel Bennett
University of Bristol
6 Dec Aleksandr Sahakya
University of Oxford

Talks take place on Fridays at 2pm in L3 Titles and abstracts can be found on the **website**

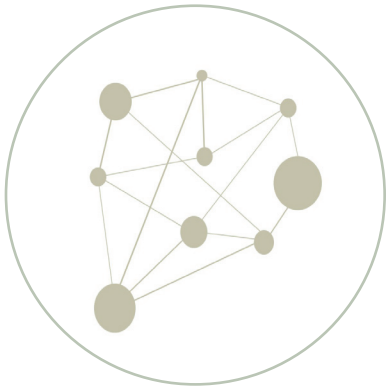
If you would like your event listed please get in touch.



Data Science
Seminars

25 Oct Gard Spreeman
École Polytechnique Fédérale de Lausanne
15 Nov Pascal Frossard
École Polytechnique Fédérale de Lausanne
15 Nov Chad Topaz
Williams College

Talks take place on Fridays at 12pm in L3. Abstracts can be found on the **website**



Networks
Seminars

29 Oct Matthew Garrodl
Imperial College London
5 Nov Takaaki Aoki
University of Oxford
12 Nov Barbara Mahler
University of Oxford
22 Nov R. Maria del Rio-Chanona
Institute for New Economic Thinking
26 Nov Ambrose Yimt
University of Oxford
3 Dec Javier Pardo Diaz
University of Oxford

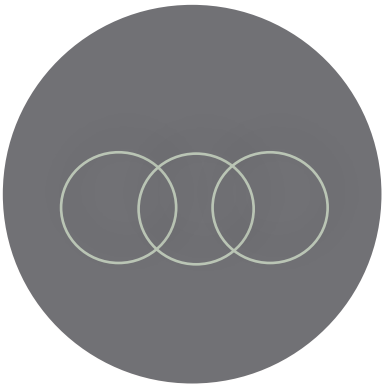
Talks take place on Tuesdays at 12pm in C1 Titles and abstracts can be found on the **website**

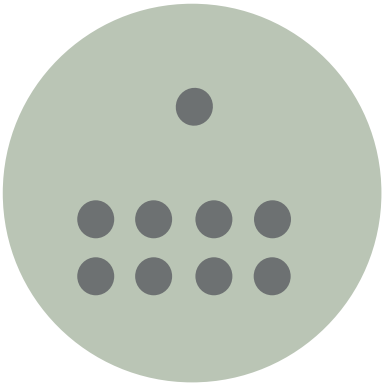
Numerical Analysis
Seminars

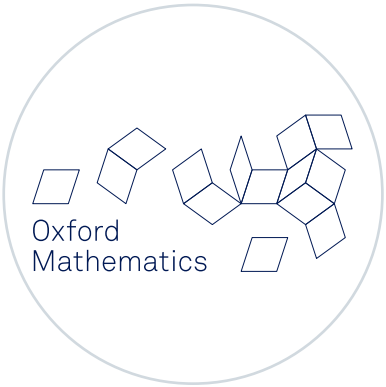
29 Oct Zen Shao & Priya Subramanian
University of Oxford
5 Nov Maha Kaouri & Sophy Oliver
University of Reading / Oxford
12 Nov Ioannis Papadopoulos & Nick Trefethen
University of Oxford
19 Nov Caroline Urzua Torres & Charles Millard
University of Oxford
26 Nov Constantin Puiu & Nikitas Rontsis
University of Oxford
3 Dec Mikael Slevinsky & Takeru Matsudar
University of Manitoba / University of Tokyo

Talks take place on Tuesdays at 2pm in L2. Titles and abstracts can be found on the **website**

Events







Industrial & Interdisciplinary
Seminars

25 Oct Wayne Arter
Culham Centre for Fusion Energy

1 Nov Laurence Cook
ARRIVAL

15 Nov Michael Hirsch
Science and Technology Facilities Council

Talks take place on Fridays at 10am in L3. Abstracts can be found on the **website**

Colloquia

David Gabai, Princeton
The Four Dimensional Light Bulb Theorem
25 October 2019
16:00, Mathematical Institute, L1
Title TBC

Doug Arnold, University of Minnesota
Talk title TBC
15 November 2019
16:00, Mathematical Institute, L1

Talks take place on Fridays at 4pm in L1. Abstracts can be found on the **website**

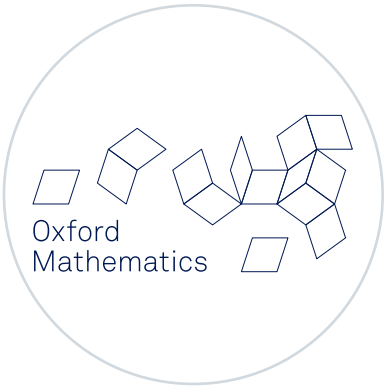
Oxford Mathematics
Public Lecture

Jon Chapman, University of Oxford
Waves and resonance: from musical instruments to vacuum cleaners, via metamaterials and invisibility cloaks.

25 October 2019
5.30pm-6.30pm
Mathematical Institute, L1
Please email **external-relations@maths.ox.ac.uk** to register.

Watch live:
https://facebook.com/OxfordMathematics
https://livestream.com/oxuni/chapman

The Oxford Mathematics Public Lectures are generously supported by XTX Markets.



Oxford Mathematics
Public Lecture

Chris Budd
Univeristy of Bath
Friday 10 December 2019
5.00pm-6.00pm
Mathematical Institute, L1

For our popular Christmas lecture this year Chris Budd will give a seasonal talk with a number of light hearted applications of mathematics to the festive season.

Chris is currently Professor of Applied Mathematics at the University of Bath, and Professor of Geometry at Gresham College. He is a passionate populariser of mathematics and was awarded an OBE in 2015 for services to science and maths education..

Please email **external-relations@maths.ox.ac.uk** to register.

ECMI 2020
Limerick

The 21st ECMI Conference on Industrial and Applied Mathematics
22 – 26 Jun 2020
University of Limerick, Ireland
The series of ECMI conferences are devoted to enforcing the interaction between academy and industry, leading to innovations in both fields.

DEADLINES
MINISYMPOSIA
Monday 13th January 2020

CONTRIBUTED TALKS / POSTERS
Friday 6th March 2020

PRESENTATION ABTRACTS
14th March 2020.

ECMI Member Early Bird - €440.00
ECMI Non Member Early Bird - €520.00
Student Early Bird - €290.00

Details on the ECMI2020 website

OCIAM Dinner
Christ Church

The annual OCIAM dinner will be held on 4/5 March 2020.

The guest speaker is Oliver Jensen, Sir Horace Lamb Professor & Head of Department of Mathematics, University of Manchester.

Look out for your invitation.

Congratulations

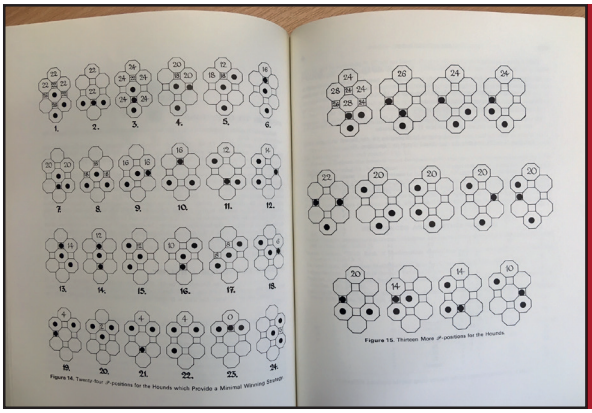
Jess Philips has submitted her DPhil thesis supervised by Sarah Waters, Derek Moulton, and Ben Turney, on mathematical modelling of fluid flows during ureteroscopic kidney stone removal. She has now started a six-month PDRA, funded by the EPSRC doctoral prize scheme, focusing on redesigning the ureteroscope tip.

Michael McPhail submitted his DPhil thesis which investigates the extrusion of vapour-expanded snack-food products. His supervisors were Ian Griffiths and Jim Oliver. He will soon begin work as a PDRA with Ian Hewitt modelling meltwater—ice sheet interactions.

Caoimhe Rooney has been awarded a NASA Postdoctoral Program Fellowship. She will be working on the characterisation of exoplanet atmospheres with the goal of identifying those that could harbour life. Using mathemats to produce a model that captures essential atmospheric microphysics while maintaining an appropriate level of simplicity to allow for feasible computational solutions.

Tori Pereira has submitted her DPhil thesis. In it she looks at bubble dynamics in flow regime transitions working with Andrew Fowler. She has now started a PDRA with Ian Griffiths studying ceramic filtration membranes in collaboration with Smart Separations Ltd.

Did you know



OCIAM has a library. **The Fox-Tayler Library** in (and just outside of) S2.37.

Use it (or lose it).

The OCIAM desk at Graduate Open Day needs **half an hour of your time** on Wednesday 6th November between 2-5pm.

Please sign up.

No.17

The next Bulletin will go out in January. Please send any contributions, news, articles or information about events relevant to OCIAM to:

ociam-admin@maths.ox.ac.uk

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