Oxford Mathematics
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UNIVERSITY OF OXFORD
Mathematical Institute

# Andrew Wiles awarded the Abel Prize

**The Norwegian Academy of Science and Letters has awarded the 2016 Abel Prize for Mathematics to Oxford's Sir Andrew Wiles FRS 'for his stunning proof of Fermat's Last Theorem by way of the modularity conjecture for semistable elliptic curves, opening a new era in number theory'. The prize was presented by H.R.H. Crown Prince Haakon of Norway at a ceremony at the University of Oslo on 24 May, attended by 400 guests.**

Photo: Audun Braastad

*Andrew Wiles receives the Abel prize from Crown Prince Haakon.*

There is no Nobel prize in mathematics, and the Abel prize was launched in Oslo in 2002, named after the 19th-century Norwegian mathematician Niels Henrik Abel. Established to recognise 'outstanding scientific work in the field of mathematics', it is awarded annually to one or more mathematicians. Its past recipients have included Oxford's Sir Michael Atiyah.

Andrew Wiles completed his proof of Fermat's Last Theorem in 1994 after several years of intense private study at Princeton University. As he later recalled: *Fermat did not leave any clues because he did not have a solution, but nature itself leaves clues. I just had to find them. There was never going to be a one-line proof. Nor do proofs come just because one has been born with mathematical perfect pitch. There is no such thing. One has to spend years mastering the problem so that it becomes second nature. Then, and only then, after years of preparation is one's intuition so strong that the answer can come in a flash . . . These eureka moments are what a mathematician lives for; the bursts of creativity that are all the more precious for the years of hard work that go into them. The moment in the morning of September 1994 when I resolved my last problem is a moment I will never forget.*

Martin Bridson FRS, Head of the Oxford Mathematical Institute, writes: 'No individual exemplifies the relentless pursuit of mathematical understanding in the service of mankind better than Sir Andrew Wiles. His dedication to solving problems that have defied mankind for centuries, and the stunning beauty of his solutions to these problems, provide a beacon to inspire and sustain everyone who wrestles with the fundamental challenges of mathematics and the world around us. His work will inspire mathematicians and scientists for centuries to come. We are immensely proud to have Andrew as a colleague at the Mathematical Institute in Oxford.'

Photo: Audun Braastad

*Andrew Wiles with Ole Sejersted, President of the Norwegian Academy of Science and Letters. Behind them is Torbjørn Røe Isaksen, the Norwegian Minister of Education and Research, and to the right is Rahul Pandharipande, a member of the Abel Committee.*

**We hope that you will enjoy this annual newsletter.**
We are interested to receive your comments, and also contributions for future newsletters. Please contact the editor, Robin Wilson, c/o *lumbard@maths.ox.ac.uk*

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*Andrew Wiles at the Mathematical Institute.*

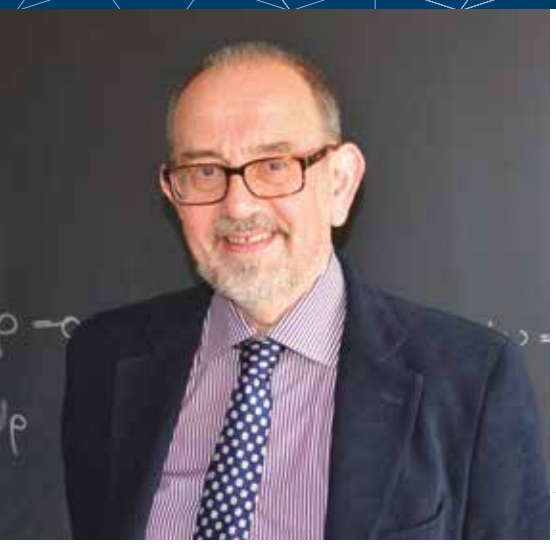


Photo: Elyce Winters

*Nigel Hitchin.*

# Nigel Hitchin wins the Shaw Prize

**Nigel Hitchin FRS retired from Oxford's Savilian Chair of Geometry last summer. Just before his retirement he was awarded the prestigious Shaw Prize in Mathematical Sciences. Here he looks back on a career spent mainly in Oxford.**

In September I retired from the Savilian Chair of Geometry. It has been a privilege to hold this position since 1997, and maybe now is an appropriate time to look back at my whole Oxford experience. In fact my first lecture as an undergraduate (in 1965) was delivered by a Savilian Professor, Michael Atiyah. Someone at the time had the bright idea of assigning the Mods Lectures to the statutory professors but it did not last long – tutors were ringing each other up to find out how to solve the problems on the question sheets. Only once did I teach a Mods course as a professor, so the experiment seems not to have been repeated.

In the following year our lectures began in the 'new' Mathematical Institute in St Giles. On the first day we piled into the common room with its coffee machine, only to be shooed out again by the receptionist – 'This is not for the use of undergraduates!'. But in subsequent years that building became my second home – first as a graduate student, then returning from three years' postdoctoral work in the US as a research assistant, research fellow, CUF lecturer, and for most of my time as Savilian Professor. It has now taken on a new role as the Department of Statistics.

As far as I recall, the Institute's mainstays in the early days were Jean Lewis the receptionist, and Frank Murray the caretaker, who dispensed gobbets of wisdom as he leaned on his broom and impossibly long ash drooped without falling from his cigarette.

In the 1970s Atiyah had returned to Oxford as a Royal Society Professor, and strange new words began to appear on the seminar board like 'solitons' and 'instantons'. This was the beginning of an interaction between physics and mathematics which is now a standard part of the landscape and formed a significant part of my own research. In 1990 I left Oxford to go to Warwick, and then Cambridge. By the time I returned to Oxford in my new role as Savilian Professor, the work of Simon Donaldson had turned those instantons into a major tool in differential topology, while other ideas from physics (and especially string theory) were permeating pure mathematics.

Just before my retirement I was honoured to receive in Hong Kong the 2016 Shaw Prize in Mathematical Sciences, for what were described as my 'far-reaching contributions to geometry, representation theory and theoretical physics'. Looking back on my career, it was the melting pot of ideas that were flying around in Oxford in the 1970s and 80s that was the primary source for this. Now, as I retire, it's clear that whole tracts of geometry, algebra and topology are influenced by ideas from quantum field theory which emanated from this particularly fertile period. ■

## The Shaw Prize

The Shaw Prize in the Mathematical Sciences was established by the Hong Kong philanthropist Sir Run Run Shaw in 2002, and was first awarded in 2004. It honours 'individuals who are currently active in their respective fields, and who have recently achieved distinguished and

Photo: The Shaw Prize Foundation

*Chun-Ying Leung, Chief Executive of Hong Kong, presents the Shaw prize to Nigel Hitchin.*

significant advances, who have made outstanding contributions in academic and scientific research or applications, or who in other domains have achieved excellence'. In 2013 the Shaw Prize in Astronomy was awarded to Oxford's Savilian Professor of Astronomy, Steven Balbus.

In awarding the Shaw Prize to Nigel Hitchin on 29 September 2016, the Prize Foundation commented that 'The fundamental and elegant concepts and techniques that he has introduced have had wide impact and are of lasting importance'.

His Oxford colleague Professor Frances Kirwan FRS writes: 'Nigel Hitchin has made fundamental contributions to the fields of differential and algebraic geometry and richly deserves the award of the Shaw Prize. His work has influenced a wide range of areas in geometry and mathematical physics.'

In celebration of Nigel Hitchin's 70th birthday and, in honour of his contributions to mathematics, Frances Kirwan and a group of his former students, in partnership with the Clay Mathematics Institute, organised a three-part conference in September 2016. It began in Aarhus, Denmark, with a workshop on differential geometry and quantisation, continued in Oxford with a meeting aimed at a general audience of geometers, and ended in Madrid with a workshop on Higgs bundles and generalised geometry. ■

# Head of Department's letter

**Martin Bridson** FRS

**When I wrote last year, I ended a short litany of the great strides that the Institute had made under my predecessors by invoking W. B. Yeats's antidote to complacency: *'What then?' sang Plato's ghost, 'What then?'*. 2016 provided a remarkably robust reply.**

Last June, as part of her 90th birthday celebrations, Her Majesty the Queen awarded a Regius Professorship of Mathematics to Oxford, the first Regius chair granted to the University since 1842. A gratifying feature of the award, which came hard on the heels of the announcements of Andrew Wiles's Abel Prize and Nigel Hitchin's Shaw Prize, is that it recognises the breadth and impact of Oxford Mathematics, as well as its depth: the criteria for the award of the chair demanded clear evidence of societal and economic benefits as well as academic excellence. Such recognition would surely have pleased Roger Bacon, whose view from Folly Bridge in the 13th century coincides with that from the Andrew Wiles Building in the 21st: *'He who knows not mathematics cannot know the other sciences nor the things of this world . . . a knowledge of this science prepares the mind and raises it up to a well-authenticated knowledge of all things'.*

When Nigel Hitchin spoke of his feelings on being awarded the Shaw Prize, he emphasised how much he has benefited throughout his career from the supportive and stimulating atmosphere in the Mathematical Institute. Everyone at the Institute, students and faculty alike, contributes to this atmosphere. It is what has drawn so many of us back to Oxford at different stages of our lives; it has attracted a steady influx of the most talented mathematicians from around the world, and it is what gives us confidence to face the great challenges of the future. *Louder sang that ghost, 'What then?'*

High on the list of the challenges that we face is the funding of doctoral students. Many of the brightest young mathematicians in the world want to study for a DPhil here, but we can only fund a small proportion of them. We're working hard on many fronts to remedy this situation, and hope that you, our alumni and friends, will see in this an opportunity to get involved in a crucial way in the life of the Institute: please think about making a regular contribution, however modest, perhaps co-funding a scholarship with a group of Oxford friends. And regardless of your ability to provide financial support, please visit our magnificent new building – perhaps you can refresh your well-authenticated knowledge of all things at one of our Public Lectures. ■

*Martin Bridson*

# Ehud Hrushovski
## Professor of Mathematical Logic

**Angus Macintyre** FRS

*Ehud Hrushovski*

**Ehud Hrushovski is Oxford's new Professor of Mathematical Logic, succeeding Boris Zilber who retired last summer. Known to his many friends and admirers as 'Udi', he comes to Oxford from the Hebrew University of Jerusalem, having previously spent time at Berkeley (where he gained his doctorate) and at Yale and MIT. He joins a group of quite exceptional researchers (Jochen Koenigsmann, Jonathan Pila, Alex Wilkie and Boris Zilber) who use ideas from mathematical logic in imaginative ways to reveal new structure and techniques in other areas of pure mathematics, such as algebra, number theory and geometry.**

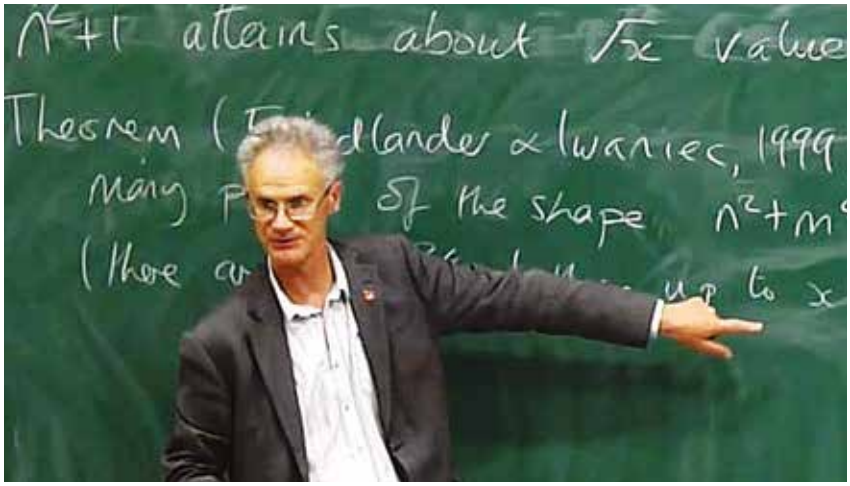
Udi is known as a model-theorist, though this description hardly does justice to his mathematical range. Model theory evolved from foundational work by Kurt Gödel and Alfred Tarski in the 1930s. Initially there was no thought that it might have mathematical significance for classical mathematical structures, but one of model theory's great achievements is that the general theory has undergone 'geometric' refinements (many due to Boris and Udi), so that it now provides powerful tools in many areas of modern mathematics.

But it is not only to modern mathematics that Udi's model-theoretic insights have been dramatically applied. He first achieved international acclaim in mathematics, and selection as a plenary speaker at the International Congress of Mathematicians in Berlin in 1998, with his proof of a recalcitrant conjecture of Mordell and Lang in finite-characteristic diophantine geometry. More recently he has worked in the area where model theory meets the famous Weil Conjectures proved by Pierre Deligne, and has used his results to give a rigorous derivation of some bounds in difference algebra analogous to those in a still unproved conjecture in differential algebra, first formulated in an 1865 publication of Carl Jacobi. Recently, his model-theoretic ideas have been crucial in an important part of modern combinatorics, the work of Oxford's Ben Green and others on approximate groups.

This is not Udi's first appearance as a member of the Oxford mathematical community. He was here for a year as a visiting student when he was 16, and his potential was spotted even then by Oxford mathematicians. ■

# Cryptography in the Mathematical Institute

**Roger Heath-Brown** FRS




*Roger Heath-Brown*

**Mathematicians have always played an important role in cryptography. In our internet age much of our security depends ultimately on ideas from number theory, such as the *RSA* system, which is based on the fact that we can discover large primes and multiply them together, whereas splitting large numbers into their prime factors is extremely difficult.**

With *RSA*, someone wishing to receive coded messages publishes a large composite integer $N$, and senders use this integer to encrypt their messages. However, to *decrypt* a received message the recipient or any eavesdropper needs to know the prime factorisation of $N$. This is not an issue for an authorised recipient, who has constructed $N$ by choosing two large primes and multiplying them. However no-one else can easily factor $N$ and discover its prime divisors.

All this might change if, and when, quantum computers become available. Quantum computers would tackle factorisation easily, as well as many other mathematical problems that underpin our current *cryptographic* methods. This should be a matter for real concern for all of us: our banking details, our NHS records, and our social security information, are all protected by encryption that would readily be overcome by a quantum computer.

Post Quantum Cryptography looks for methods that would be secure against quantum attack. As a simple example, consider the following situation, which concerns an identification issue rather than an encryption problem. Suppose I deposit a package at the bank, and to identify it as mine I write a large composite number $N$ on the outside. When I return to claim it, I give the prime factorisation of $N$ to confirm that it's mine. Anyone else trying to claim the package would also have to give the factors of $N$. As with the *RSA* system, it's relatively easy for me to construct a suitable number $N$, but hard for anyone else to factor $N$ – unless they have a quantum computer.

However, instead of using factorisation, I could sign my package with an *NP-complete problem*. Very crudely, a class of problems is in NP if we can easily check any solution that is given to us – for example, it is easy to check whether a given factorisation is correct, so the factorisation problem is in NP. A class of problems is *NP-complete* if it is in NP, and if all other NP problems can be quickly reduced to it. Surprisingly, many classes of NP-complete problems are known – for example, in the *subset sum problem* we are given a list of integers, such as {−1027, −529, −343, −17, 8, 13, 227, 889, 1045}, and asked to find a subset that sums to 0 (the answer is given below). This class of problems is known to be NP-complete, whereas the factorisation problem is expected not to be.

At present we don't know whether a quantum computer might easily solve the subset sum problem – but if it could, then it can easily solve all NP problems, by the defining property of NP-completeness. So, either the subset sum problem will provide a secure identification scheme in the post-quantum age, or no system will be secure.

Thus, one line of research looks at security methods based on NP-complete problems, since the above identification situation is much simpler than the problem of encryption. But there are a great many other aspects to cryptography: we need systems that are practical and secure against all sorts of threats. It's not only eavesdroppers that we need to protect against!

*Christophe Petit*

*Ali El Kaafarani*

The Mathematical Institute has a research group in Cryptography. Although it's currently rather small, consisting principally of two post-docs, *Christophe Petit* and *Ali El Kaafarani*, the group is supported by faculty in other research groups, most notably number theory.

What is the group hoping to achieve, and why is it a priority for government funding? As well as its research goals, the Oxford cryptography group tries to promote the study of mathematical post-quantum cryptography in general. The group currently teaches two MSc courses per year, and we hope to re-introduce cryptography into the undergraduate syllabus. The Institute is looking at various ways to continue the good start made by our two post-docs. It is an area of real practical importance, and one whose development we watch with interest. ■

*Answer to subset sum problem:*
(−529) + (−343) + (−17) + 889 = 0.

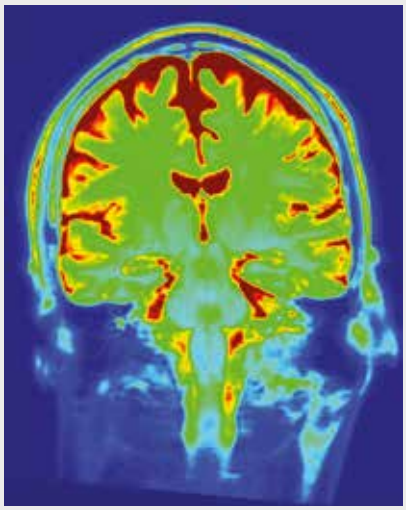
# Applied mathematics: don't think twice, it's all right

**Alain Goriely,** Director of OCCAM

**In an interview with *Rolling Stone Magazine* in 1965, Bob Dylan was pushed to define himself: *Do you think of yourself primarily as a singer or a poet?* To which, Dylan famously replied: *Oh, I think of myself more as a song and dance man, y'know*. Dylan's attitude to pigeonholing resonates with many applied mathematicians. I lack the coolness factor of Dylan, but if pushed about defining what kind of mathematician I am, I would say: *Oh, I think myself more as an equation and matrix guy, y'know.***

*Alain Goriely*

One of the greatest strengths of applied mathematics is that it has established itself by defying simple categorisation. Applied mathematics, be it an art, a craft, or a discipline, is not bound to a particular scientific application, a particular mathematical universe, or a well-defined university department. The drawback is that applied mathematics usually gets no mega-funding or the limelight associated with big scientific breakthroughs. But its biggest advantage is that it can insert itself into all scientific disciplines and easily reinvent itself by moving fluidly from one field to the next, guided only by methods, theory, and applications: it is all equations and matrices. Many applied mathematicians see new challenges as an opportunity to expand their mathematical horizons, and in our rapidly changing modern new society such new challenges abound. Here are three of these.



*My feet are so tired, my brain is so wired'. Will collaborative applied mathematics untangle the mystery of the author's brain, mathematical or otherwise?*

Major scientific efforts are required for major society challenges. These include fighting climate change, optimising new renewable energy sources, developing new medical treatments, and understanding the brain. Traditionally, applied mathematicians involved with these collaborative efforts were considered a useful but small cog in a huge scientific machine, but it is now appreciated that quality science requires clever modelling, state-of-the-art numerical methods, and fundamental theoretical insights from simplified models. This is the realm of applied mathematics, and accordingly our role in these endeavours is bound to increase. By the end of the day we may not get the fame, but we'll certainly have the fun.

A second relatively recent development of applied mathematics is the theory of networks. Networks represent connections between multiple physical or virtual entities. They are found in information theory (web links, social connections), biological systems (gene regulatory networks, metabolic networks, evolutionary trees), and physical systems (axon connections, electric grid). Regardless of their origin, these networks share common mathematical features. Their analyses span many different fields of study, and network theory has now established tentacular connections to various parts of pure and applied mathematics, a network of its own.

For about five years there has been much excitement about BIG DATA. The initial hope was that one could go straight into data and use empirical methods to unravel the mysteries of the universe. Quite the opposite is happening. The success of many methods has shed a bright light on the need to understand the underlying mathematical structure of both data and methods. The subject now presents a rich field of study that brings all mathematical sciences together, including statistics and computer science.

These examples share a common thread that highlights a new trend in mathematical and scientific discoveries: beyond inter-, multi-, and supra-disciplinarity, we live in a post-disciplinary world. Things have changed, and Oxford University with its collegiate system, and the Mathematical Institute with its collegial atmosphere, are particularly well equipped to thrive in this new scientific world. But despite all the hype, we're also fully aware that there's nothing wrong with the old world, the old problems, or the old conjectures. We have an intellectual responsibility to promote and cherish these areas of knowledge defined by the great thinkers, past and present, especially if they are believed to be useless or irrelevant.

Bob Dylan, in the same interview, foresaw yet another possible application of mathematics: *What would you call your music?* His reply: *I like to think of it more in terms of vision music – it's mathematical music.*

For more discussion on these hot topics, you can watch the author's video via the Oxford Mathematics YouTube page. ■

## Appointments...

**We are delighted to welcome the following new Faculty members.**

**Chris Beem** (*Princeton*): Associate Professor of Mathematical Physics, and Tutorial Fellow at St John's College: *Research interests:* exact operator algebras in supersymmetric quantum field theory and conformal field theory.

**Sam Cohen** (*Oxford*): Associate Professor in the Mathematical and Computational Finance Group, and Senior Research Fellow of New College. *Research interests:* methods of understanding uncertainty, probability models and statistics, and decision-making patterns.

**Ehud Hrushovski** (*Jerusalem*): Professor of Mathematical Logic and Fellow of Merton College. *Research interests:* connections of logic with mathematics, including algebraic geometry, number theory and additive combinatorics (see page 3).

**Abdul-Lateef Haji-Ali** (*Saudi Arabia*): Hooke Research Fellow. *Research interests:* numerical methods for uncertainty quantification, sparse, multilevel and multi-index methods, and stochastic particle systems.

**Patrick Farrell** (*Oxford*): Associate Professor of Numerical Analysis and Scientific Computing, and Tutorial Fellow at Oriel College. *Research interests:* numerical solution of partial differential equations, particularly bifurcation analysis and optimisation problems.

**Sakura Schäfer-Nameki** (*King's College London*): Professor of Mathematical Physics, and Tutorial Fellow at Wadham College. *Research interests:* supersymmetric gauge theories and string theory and their relation to geometric structures.

**Philippe Trinh** (*Oxford*): Departmental Lecturer in Mathematical Modelling. *Research interests:* singular perturbation theory and exponential asymptotics, applied complex analysis, and general fluid/continuum mechanics.

## Retirements and departures...

Academics have never taken retirement very seriously, regarding it more as an asymptotic state, but while the formal stage exists we mark it.
This year we saw the retirement of several long-standing members of the department.

**Roger Heath-Brown** FRS was Professor of Pure Mathematics with interests in number theory, and a Fellow of Magdalen and Worcester Colleges.

**Nigel Hitchin** FRS was Savilian Professor of Geometry (see page 2) and a Fellow of New College.

**Andrew Hodges** was a Senior Research Fellow of Wadham College, and is best known for his biography of Alan Turing.

**Mason Porter**, Professor of Nonlinear and Complex Systems in OCIAM, has moved to the University of California, Los Angeles (UCLA).

**Ian Sobey** was an Associate Professor in Numerical Analysis and a Fellow of St John's College.

**Paul Tod** was a Professor of Mathematical Physics with interests in general relativity and twistor theory, and a Fellow of St John's College.

**Xunyu Zhou**, Nomura Professor of Mathematical Finance, has moved to Columbia University, USA.

**Boris Zilber** was Professor of Mathematical Logic with interests in model theory, and a Fellow of Merton College.

## Fellows of the Royal Society...

**Congratulations to the following who have been elected Fellows of the Royal Society:**

**Martin Bridson** is Whitehead Professor of Pure Mathematics, Head of the Mathematical Institute, and a Fellow of Magdalen College. He has played a leading role in establishing geometric group theory as a major field, and was elected for his distinguished contributions to group theory and topology.

**Marcus du Sautoy** OBE is Simonyi Professor for the Public Understanding of Science and a Fellow of New College. He has been elected for his outstanding achievements in communicating mathematics to the general public worldwide and for his research in pure mathematics, in particular on zeta functions of groups.

**Artur Ekert** is Professor of Quantum Physics at the Mathematical Institute and a Fellow of Merton College. He has been elected for his work on quantum physics, quantum computation and cryptography.

## Achievements...

**This has been another excellent year for awards and achievements.**

**Dominic Joyce** FRS has been awarded the 2016 London Mathematical Society Fröhlich Prize for his 'profound and wide-ranging contributions to differential and algebraic geometry'. Here he receives the award from LMS President Simon Tavaré.

**Maria Bruna** has been awarded a L'Oréal–UNESCO UK & Ireland Fellowship for Women in Science for her research in the stochastic modelling of interacting particle systems. She has also won the annual Women of the Future Science award.

**Gui-Qiang Chen** has been elected a Fellow of the American Mathematical Society for his contributions to partial differential equations, nonlinear analysis and other areas.

**Alison Etheridge** FRS has been named a Fellow of the Institute of Mathematical Statistics for her research on measure-valued stochastic processes and applications to population biology. She is also its President-Elect.

**Heather Harrington** has been awarded a Royal Society University Research Fellowship and gave two London Mathematical Society Popular Lectures on 'The shape of data in biology'.

**Jake Taylor King** was awarded the Society for Mathematical Biology's annual Lee Segel Prize for Best Student Paper, for his paper 'From birds to bacteria: generalised velocity jump processes with resting states'.

**Frances Kirwan** FRS has received a Suffrage Science Award, at the Clinical Sciences Centre at Imperial College, London.

**James Maynard** was awarded a European Mathematical Society Prize at the 7th European Congress of Mathematics in Berlin for his work in analytic number theory.

**Peter Neumann** OBE has completed his term as President of the Mathematical Association.

**Linus Schumacher** has received the 2016 Reinhart Heinrich Doctoral Thesis Award for the best thesis in any area of Mathematical and Theoretical Biology.

**Brigitte Stenhouse** was awarded a prize by the British Society for the History of Mathematics for an undergraduate essay on Mary Somerville.

**Rob Style** has been awarded the 2016 Adhesion Society Young Scientist Award for his fundamental contributions to our understanding of the coupling of surface tension to elastic deformation.

**Endre Süli** and **Xunyu Zhou** have been elected Fellows of SIAM, the Society for Industrial and Applied Mathematics.

**Robin Wilson** has been awarded an Honorary Doctorate of Education by the University of Bradford.

**OXFORD AWARDS**:

**Vicky Neale** has won a Mathematics, Physics and Life Sciences (MPLS) Division individual teaching award.
**Zubin Siganporia** has won the MPLS Outstanding Tutor award.

Lifetime teaching awards by the Department were given to **Roger Heath-Brown** and **Paul Tod**.

The Mathematical Institute has received a Gold 'Green Impact Award' for achievements in a number of environmental areas, adding to the bronze and silver awards received in the preceding two years. ■

# InFoMM

**Chris Breward** and **Colin Please**
InFoMM Co-Directors

Providing critical insight into processes, developing novel methods to speed up software, and understanding structures in data are all mathematical research endeavours that are undertaken by our students at the EPSRC's Centre for Doctoral Training in Industrially Focused Mathematical Modelling (InFoMM). Set up in 2014 as a partnership between EPSRC, the University of Oxford, and 36 partner companies, and building on OCIAM's long tradition of industrial mathematics, InFoMM harnesses the Mathematical Institute's collective talent to address challenges facing companies, while training the next generation of mathematicians to work effectively at the interface between academia and industry.

InFoMM recruits its students from all over the world and has a yearly intake of around 12. After six months of intensive training in mathematics and people skills, delivered by academics and company staff, the students embark on two short research projects, followed by the three-year project that forms their DPhil; all projects focus on the development of novel mathematics to address company challenges. Short projects provide a vehicle for the students to immerse themselves in a company and tackle a focused mathematical investigation.

Here are some examples:
In collaboration with Tesco, Fabian Ying built a probabilistic model to describe how shoppers move around supermarkets; this topic has been taken forward in an open-ended DPhil project.
With the US Army Corps of Engineers, Niall Bootland developed and tested 'preconditioning' matrices to speed up calculations of wave break up.
Caoimhe Rooney has worked with SharkNinja on predicting the size of particles during blending.

The students enjoy the deep involvement of companies in the programme, and the outcomes of their early work have been well received. For example, Tim Lunn from PA Consulting commented 'We have enjoyed working with the students and have had brilliant work carried out', while NAG's website says 'Such sponsorship benefits NAG by giving access to the expertise of Oxford academic staff as well as students, and has already borne fruit in the form of new software which will add derivative-free optimisation techniques to the NAG library'.

Would your company benefit from working with us? If you'd like to explore this with us, please get in touch by phone or e-mail through our industry facilitator, Jonathan Mason (masonj@maths.ox.ac.uk; 01865 280615). ■

# PROMYS Europe

**Vicky Neale** and **Nick Woodhouse**

The PROMYS summer school for high school students was set up by Glenn Stevens in Boston, USA, in 1989. It has been the starting point for many a stellar career in mathematics.

A mirror programme, PROMYS Europe, was launched in Oxford in 2015, as a partnership between PROMYS, the Mathematical Institute, Wadham College, and the Clay Mathematics Institute, with the support of Oxford alumni. It ran successfully for the second time last summer: 24 students and 7 counsellors from some 15 countries spent six weeks in Oxford, tackling challenging number theory problems, formulating and proving their own conjectures, and really getting a taste for what it is to work as a mathematician. Selection is highly competitive, but is needs-blind, with costs covered for those who would otherwise be unable to attend. ■

## Alumni events

Last year's Mathematical Institute Garden Party was held in the Andrew Wiles Building during the University's Alumni weekend. The speaker was Jon Chapman, Director of OCIAM, who lectured on 'The mathematics of M. C. Escher'.

This year's Garden Party will take place on 16 September in the Andrew Wiles Building during the Alumni weekend. You can book online on the Institute's website, *www.maths.ox.ac.uk*.

## Oxford Mathematics merchandise on sale

We are delighted to say that our wide range of merchandise will be available soon to alumni via the University shop (*www.oushop.com*). Featuring the unique Penrose tiling and hugely popular around the department, we have t-shirts, hoodies, bags, notebooks, mugs and more all at reasonable mathematical prices.

## History of Oxford mathematics

The series of posters illustrating the history of Oxford mathematics has now been completed by Raymond Flood and Robin Wilson, with six posters on each of the following topics:

- Early mathematics in Oxford
- John Wallis
- Oxford mathematics: Halley to Hornsby
- Oxford's Victorian Professors of Geometry
- Lewis Carroll, Oxford mathematician
- G H Hardy's Oxford years

These posters can all be viewed or downloaded from the Institute's website.


## Public lectures

**Dyrol Lumbard**

Over the past year Oxford Mathematics Public Lectures have flexed their geographical and intellectual muscle with our first alumni London Lecture given by Marcus du Sautoy in November 2016, and with Oxford lectures on crime, mathematical toys, economic prediction, and the importance of statistical truth filling our lecture theatres with a broad audience of all ages and backgrounds. A Christmas lecture was given by Ian Stewart.


In recognition of a lifetime's contribution across the mathematical sciences, the Institute has initiated an annual public lecture in honour of Sir Roger Penrose. The inaugural lecture will be given by his long-term collaborator and friend Stephen Hawking. Further lectures in Oxford, London, and beyond will follow. Please keep an eye on our website for more details.

## The Mirzakhani Society

The Mirzakhani Society is the society for women and non-binary undergraduates and postgraduates studying mathematics at Oxford. Named after Maryam Mirzakhani, who in 2014 became the first woman to win a Fields Medal, it aims to address the significant gender gap in degree performance and to encourage more women to stay on for a fourth year and proceed to graduate study.

Our support network provides an invaluable way of broadening contacts. With over 100 active members we hold weekly 'Sip and Solve' meetings (with tea and cake), and socials and talks. Through attending our events and getting to know other female and non-binary mathematicians, our members gain confidence in their own ability, feel more as though they belong in the Mathematical Institute, and make the most of the fantastic education available to them at Oxford.

Last year we paid a visit to Cambridge (funded by the London Mathematical Society) for a joint meeting with our Cambridge counterparts, the Emmy Noether Society. Other recent successful events have included a 'Freshers' Elevenses' for new students and an information event promoting the fourth year and graduate study.

## Lewis Carroll in Numberland

A dramatic presentation of C. L. Dodgson's mathematical activities was held in the Mathematical Institute last year, with Roger Penrose playing the Mock Turtle, Vicky Neale as Alice, Frances Kirwan as the White Queen, Ursula Martin as Queen Victoria, Sam Howison as Tweedledee, Cameron Hall as the Hatter, and Robin Wilson as Dodgson.