Oxford Mathematics
newsletter
Number 14 • Spring 2015

UNIVERSITY OF OXFORD

Mathematical Institute

Oxford tops the list

Our Mathematical Sciences submission to the 2014 Research Excellence Framework (REF), which covered all research in UK universities, was assessed as outstanding in every respect. We received the highest proportion of top grades across the whole UK for research publications and the impact of our research outside academia, and the equal highest proportion for our research environment. The results can be (and have been) turned into league tables in many ways, but they all put Oxford Mathematical Sciences at the top.

Every six years UK universities are assessed for the quality of their research, and funding is allocated accordingly. In the 2008 Research Assessment Exercise we also did very well, and this year's outstanding result reflects the continuing extraordinary quality of our faculty and research fellows, as well as the breadth, depth and impact of our core and interdisciplinary research, all underpinned by the University's investment in the mathematical sciences in the last decade.

Particularly noteworthy were our impact case studies. Here is an outline of five of them: further details can be found on the research page of the Institute's website *www.maths.ox.ac.uk*.

- *Influencing HIV/AIDS policy in India through mathematical modelling*, where Prof. Philip Maini's research team has played a significant role in shaping the Indian Government's response to the growing HIV/AIDS crisis.
- *Helping the 'Greeks' to run faster*, where mathematical techniques developed by Prof. Mike Giles have led to substantial reductions in the complexity of the Monte Carlo computer simulations run by large banks, cutting both computing costs and energy consumption. 'Greeks' is a term used by the industry for measures of risk that are used to minimise possible future losses due to fluctuations in the market.
- *Mathematics in the design and manufacture of novel glass products*. Glass is an unforgiving substance to make: flaws are very evident and hard to rectify, so precise control during manufacture is critical. A model developed by Prof. Peter Howell underpins software used by major glass manufacturers worldwide, enabling precise control in making the glass sheets and fibres that are ubiquitous in a wide range of products.
- *Finding moonshine.* 'Impact' included public engagement, as long as it stemmed from research. One of our case studies traced this kind of impact from Marcus du Sautoy's book *Finding Moonshine*, which describes the way that mathematicians go about solving their research problems. This book has had excellent reviews, leading to many TV, radio and online appearances by its author.
- *The HYDRA code*, pioneered by Prof. Mike Giles, is Rolls-Royce's standard computational tool to model and analyse the flow of air in their engines. It is sophisticated enough to enable the company to carry out extensive in silico design optimisation before actual engine trials, and has led to considerable savings and improvements in engine efficiency. ■

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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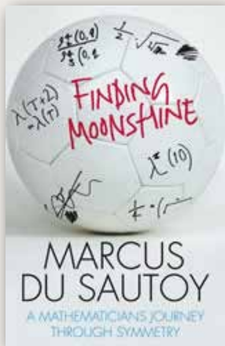
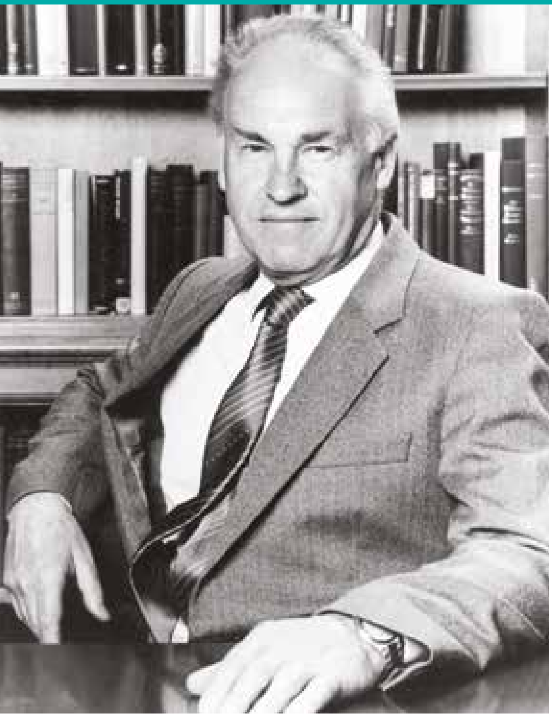


Rolls-Royce's Trent 1000 engine



Bryce McLeod

John Bryce McLeod FRS FRSE, 1930–2014

Sam Howison

Following a First Class BA degree in Mathematics & Natural Philosophy from the University of Aberdeen in 1950, Bryce McLeod was awarded a scholarship to Oxford University where he received another First Class BA degree in 1952. His tutor at Christ Church was T. W. Chaundy, a specialist in differential equations, who was influential in shaping Bryce's intellectual path and co-authored the first of his 150+ papers.

After a year as a Rotary Foundation Fellow in Vancouver and two years' National Service, Bryce returned to Oxford to complete a DPhil degree with E. C. Titchmarsh in 1958. Following two years as a mathematics lecturer at Edinburgh University, Bryce returned to Oxford in 1960, with a Fellowship at Wadham College, and remained there until 1988, becoming a University Lecturer in 1970.

Throughout his early career, Bryce maintained regular contact with applied analysts in the US, especially in Madison, Wisconsin, where he spent a number of sabbatical years, greatly expanding his range of contacts. He had many offers to cross the Atlantic and in 1988, facing imminent mandatory retirement in the UK and feeling that (unlike today) applied analysis was not properly appreciated at Oxford, he moved to Pittsburgh. He remained there until 2007 when he returned to the UK, basing himself in Oxford's Centre for Nonlinear PDEs for the remainder of his career.

Bryce was elected FRSE in 1974 and FRS in 1992. He received the Whittaker Prize of the Edinburgh Mathematical Society in 1965, the Keith Medal and Prize of the Royal Society of Edinburgh in 1987, and the Naylor Prize and Lectureship in Applied Mathematics of the London Mathematical Society in 2011.

Considering himself a problem-solving mathematician rather than a builder of general theories, he liked to focus on a specific hard problem and to find something new to say about it that was rigorous, interesting and useful. He solved problems with consummate skill across an extraordinary range of areas, including fluid mechanics, general relativity, plasma physics, mathematical biology, superconductivity, Painlevé equations, coagulation processes, nonlinear diffusion and pantograph equations. He had long-lasting and productive collaborations with many distinguished mathematicians, both applied analysts like himself and modellers whose differential equations had caught his interest: he often looked at new problems unearthed by colleagues working in a more applications-focused way. His work was characterised by great lucidity of thought and ingenuity of argument.

Although he worked on many different problems, some general themes emerged – in particular, the importance of similarity solutions as indicators of more general behaviour, and the development of powerful techniques for 'shooting' methods, especially with several parameters. A McLeod lecture was a model of clarity: as the subject unfolded, the board was filled with economical spare notes in his characteristic hand, and the audience invariably left feeling that they had witnessed a tour de force of applied analysis.

Many throughout the mathematical community remember Bryce with great fondness: for his kindness and support for students and colleagues, for his intensely amused laughter, for his rapt concentration on an explanation, and for his zest for life and for mathematics.

Let the last word be Bryce's: when asked what advice he would give a young mathematician, he replied simply: 'Have fun'.* Bryce certainly did that.

* Interview with John Ball, *http://www.maths.ox.ac.uk/node/24862*

A version of this obituary appeared in the LMS Newsletter in November 2014, and is reproduced with permission of the London Mathematical Society. ■

DAME KATHLEEN OLLERENSHAW, has died at the age of 101. A former undergraduate at Somerville College, she wrote her Oxford doctoral thesis on 'Critical lattices' under the supervision of T. W. Chaundy before moving to the University of Manchester. She later became President of the Institute of Mathematics and its Applications and Lord Mayor of Manchester, and was a government advisor on educational matters. In her 90s she wrote a prizewinning article on pandiagonal magic squares. ■

SANDY GREEN FRS has died at the age of 88. A distinguished algebraist who worked at Bletchley Park during World War II and later taught at the Universities of Manchester, Sussex and Warwick, he was awarded the London Mathematical Society's Senior Berwick Prize and De Morgan Medal for his work in group representation theory. He retired to Oxford, where he participated in the mathematical life and served on a committee reviewing the mathematics curriculum. ■

Jacqueline Anne Stedall, 1950–2014

Peter Neumann

Jackie Stedall came to Oxford in October 2000 as Clifford Norton Student in the History of Science at Queen's College. In due course she became Senior Research Fellow in the Oxford Mathematical Institute and at Queen's College, posts from which, knowing that she had incurable cancer, she took early retirement in December 2013.

Jackie Stedall and Peter Neumann, 2008

This was her fifth career. Following studies at Cambridge and Canterbury she had been a statistician, Overseas Programmes Administrator for War on Want, a full-time parent, and a schoolteacher, before she became a historian of mathematics. Although her career as a full-time researcher, scholar and university teacher spanned less than fourteen years, it was greatly influential. Her nine books, more than twenty articles, and major contributions (transcriptions, translations, commentary) to the online edition of the manuscripts of Thomas Harriot cover a wide range of scholarship. They are cogently argued and written in a lucid and attractive style. She was as comfortable with the fine detail of textual analysis and reconstruction (Harriot, Brouncker, Wallis) as with synoptic studies of individual authors (Harriot, Pell, Wallis) or of large areas such as algebra or the history of mathematics itself. She gently challenged traditional orthodoxies. She earned an international reputation – twice, for example, she received invitations (courteously declined) to lecture at the International Congress of Mathematicians.

Her Oxford teaching was equally successful. She moulded the course on History of Mathematics to her perceptions of what teaching and learning at third-year undergraduate level should be. Students were led to handle evidence in the context of history of mathematics and how to use sources, both primary and secondary, effectively. She supervised many third- and fourth-year dissertations. In a very different area, jointly with Cath Wilkins, she designed and managed the Part B Structured Projects in applied mathematics. This third-year course has some highly innovative features that have proved a great success. She won awards for teaching excellence on two separate occasions.

Jackie was exceptionally well organised. She never missed a deadline. University lectures and classes, seminar and conference papers, all were prepared months ahead, never more than a few weeks after she had accepted a commission. Book manuscripts, copy for journals she edited, all reached the publisher safely before the contract date.

She was a great scholar, teacher, editor and organiser. More than that: to very many of us she was a great colleague and friend. ■

Head of Department's letter

Sam Howison

We are delighted with the outcome of the REF (page 1), which testifies to the quality of Mathematical Sciences research at Oxford, as well as to a great deal of hard work in preparing the submission. It is a fantastic springboard for the next few years. I do wonder, however, whether these assessments end up dictating our behaviour: certainly there is now a six-year hiring cycle, and there are less obvious impacts as well. We must never forget our main goal, to pursue mathematics at the highest level with all its infinite variety and connections.

A surprising connection arose the other day. Ulrike Tillmann (Topology), Samson Abramsky (Computer Science) and Heather Harrington (Mathematical Biology) are organising a course on Computational Algebraic Geometry. Topological ideas find applications in data science; this is just one manifestation of the ubiquitous impact of 'Big Data'. By the time you read this, the national Alan Turing Institute will have been launched (see page 8), with Oxford as a founding partner. Mathematics is central to its work, and data science will be of increasing importance for mathematicians worldwide.

Another vitally important topic for us is the area of 'Good Practice'. How do we create and sustain a working environment to match the quality of our mathematics? The 'gender gap' is a huge issue for mathematics, highlighted by the award of a 2014 Fields Medal to Maryam Mirzakhani, the first to be awarded to a

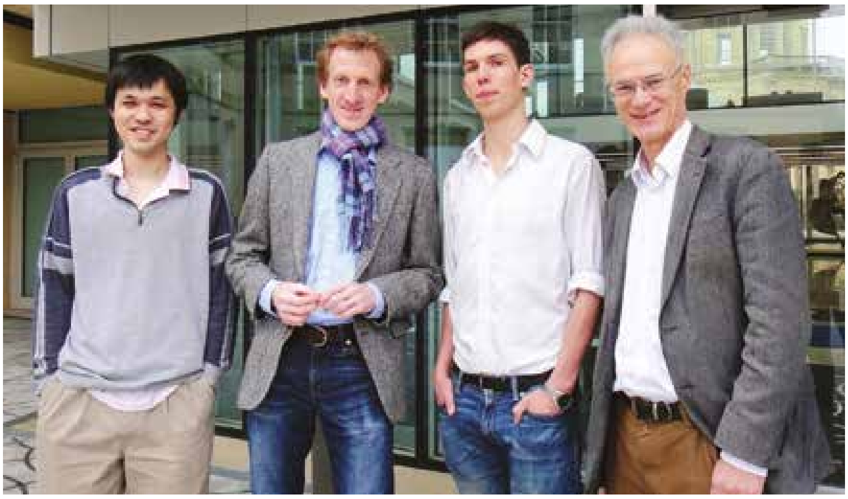
woman. The imbalance runs deep: for example, fewer than 1000 girls get A* in Further Maths A-level, compared with over 2400 boys. You can help us by convincing all the clever girls you meet that maths is a wonderful subject for them. To see what we are doing in this sphere, please visit the Good Practice pages on our website, *www.maths.ox.ac.uk.*

This is my fifth and last letter as Head of Department; next year you will hear from my successor, Martin Bridson. It has been an honour and a privilege to be Head of our wonderful department at this exciting period in its history, and to work with present and former members alike. ■

Prime-time mathematics

Ben Green FRS, Waynflete Professor of Pure Mathematics

In the last 18 months there has been a great deal of progress in the study of prime numbers, and four Oxford mathematicians have been involved in various aspects of this work.



Four Oxford number-theorists: Xiannan Li, Ben Green, James Maynard and Roger Heath-Brown, 2014

In May 2013, previously unheralded mathematician Yitang Zhang of the University of New Hampshire caused a sensation by proving that there are infinitely many pairs of consecutive prime numbers differing by at most 70 million. While this may sound like an enormous number – indeed it is conjectured that infinitely many pairs of consecutive primes differ by 2 (the *twin prime conjecture*) – no-one had previously been able to establish any finite bound at all.

Zhang's work set off a feverish effort to reduce the number 70 million as far as possible. An online collaborative project called *Polymath* explored a variety of different avenues, some of them very technical and computational, and succeeded in reducing the gap from 70 million to 4680.

Meanwhile, recently graduated Oxford DPhil student James Maynard, in Montreal for a year as a postdoc, was pursuing his own approach to the problem. This paid spectacular dividends when, in November 2013, he announced a relatively short argument reducing the gap still further to around 600. Unlike Zhang's argument, Maynard's argument has the virtue that one could teach it in its entirety in a one-term graduate course. Moreover, Maynard (and independently Terry Tao) have obtained a result significantly stronger than Zhang's – that one can find infinitely many triples of consecutive primes, all contained in an interval of length bounded by some constant C – and similarly for quadruples, quintuples, and so on. Using Maynard and Tao's ideas, a further Polymath project has succeeded in reducing Zhang's 70 million to 246, the best bound currently known.

Consecutive primes lying close together constitute an unusual situation. The number of primes less than X is around $X / \log X$ (this is the *prime number theorem*) and so the *average* gap between a prime of size around X and the next prime is $\log X$, which tends to infinity as X does (and, in particular, is eventually much larger than 70 million). So, what about the question opposite to that studied by Zhang, of finding consecutive primes much *further* apart than the average?

This question was studied in several papers in the early part of the 20th century, culminating in work of Robert Rankin from 1938 showing that, amongst the primes less than X, there are two consecutive primes differing by at least $\log X$ times $f(X)$, where

$$f(X) = c \log\log X \log\log\log\log X / (\log\log\log X)^2$$

for some constant c; this function $f(X)$ tends to infinity with X. Over the last 75 years it had become a notorious problem to improve this function f by more than a constant factor. Indeed, the late Hungarian mathematician Paul Erdős offered 10,000 dollars for doing precisely this.

Remarkably, in August 2014 the problem was solved twice, independently, at almost precisely the same time – by James Maynard, and by myself in collaboration with Kevin Ford, Sergei Konyagin and Terry Tao. Maynard uses methods related to his work on *small* gaps, but the connection between the two problems is by no means obvious – and is in fact very surprising. My coauthors and I rely in part on work done by Tao and myself over the last ten years on arithmetic progressions of primes, such as 5, 11, 17, 23, 29; again the nature of the link between this and large gaps between primes is far from self-evident.

One of the attractions of working in prime number theory is the profusion of easily-stated unsolved problems. Quite a famous one is the question of showing that there are infinitely many squares which, when increased by 1, are prime: for example, $6^2 + 1 = 37$ is prime. This problem remains beyond reach, but this year Roger Heath-Brown (Professor of Pure Mathematics at Oxford) and his postdoc Xiannan Li proved a highly non-trivial result on a similar kind of problem. They showed that there are infinitely many squares to which one may add the fourth power of a prime in such a way that the resulting number is still prime (for example, $5^2 + 2^4 = 41$ and $4^2 + 3^4 = 97$).

James Maynard has recently been awarded a Clay Research Fellowship for three years. With him back in Oxford as a Fellow by Examination at Magdalen College, Oxford's research in prime number theory has never been in such good shape. ■

Chebfun and dolfin-adjoint

Nick Trefethen FRS, Professor of Numerical Analysis

Most problems of continuous mathematics cannot be solved analytically – just look at almost any partial differential equation, nonlinear system of equations, or optimisation problem. Numerical analysts develop algorithms to solve them numerically, and for generations Oxford's Numerical Analysis Group has been the UK leader in this area.

This is a field with *users*! Our end-product is numerical software relied on by scientists and engineers around the world. How does anybody compute the eigenvalues of a matrix? Almost certainly by calling a computer code with a name like **eig** which is descended from Fortran programs written in the 1970s.

2014 was a year of two memorable software achievements for the NA Group. One was the release of a completely rewritten Version 5 of Chebfun, a MATLAB package whose vision is 'numerical computation with functions'. Scientists may traditionally be interested in working with continuous functions, but numerical algorithms force them to deal with approximating discrete vectors. The Chebfun project takes the view that scientists shouldn't have to pay attention to these matters in the 21st century. In MATLAB or Python, you might type **sum**(***v***) to add up the entries of a vector ***v*** or **max**(***v***) to find the maximum. In Chebfun, such commands are overloaded to give analogous results for continuous objects. Thus **sum**(***f***) gives the definite integral of a function *f*, and **max**(***f***) gives its maximum. In MATLAB, you solve a system of equations $Ax = b$ by typing ***x=A\b***; in Chebfun you solve an integral or differential equation $Lu = f$ by typing ***u=L\f***. All this is made possible by algorithms based on approximation of functions by Chebyshev polynomials. I started the project in 2003, and now we have a team of ten.

Chebfun has thousands of users around the world, and its impact seems to be doubling roughly every two years: the number of Google scholar hits for 2005–2006, . . . , 2013–2014 were 5, 14, 58, 104 and 186. Look at our online examples at *www.chebfun.org* to see how much fun hands-on mathematics can be these days!

Patrick Farrell, EPSRC Early Career Research Fellow

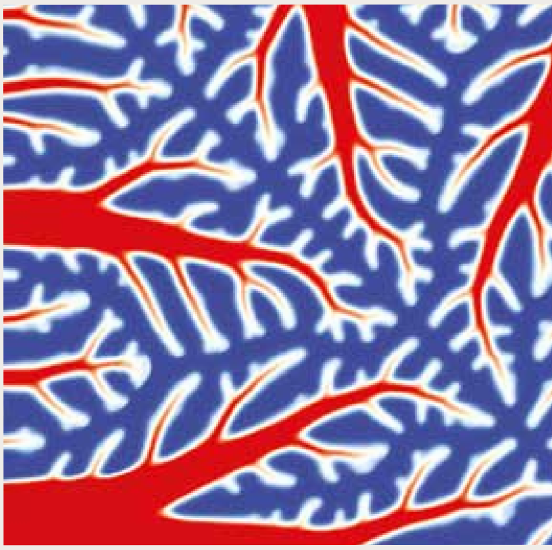
If Chebfun started with a white-haired professor, dolfin-adjoint comes from a blue-eyed boy. Patrick Farrell grew up in western Ireland and completed his PhD degree at Imperial College before joining the Mathematical Institute two years ago. In 2014 he began to get world-wide recognition for the Python software project he created called dolfin-adjoint (*www.dolfin-adjoint.org*).

Like Chebfun, dolfin-adjoint is all about computing at a higher level of abstraction than was usual in the last century: the key word is *adjoint.* In the 20th century, advances and algorithms and hardware enabled us to solve all kinds of 'forward problems' on computers, such as determining the flow around an aeroplane or the force distribution in a solid structure. Ultimately, however, we would like to solve inverse problems: what structure gives us the behaviour we want? The mathematics of such problems is fascinating. Whenever you have one operator that carries information forward, there is a dual *adjoint operator* that carries information backward. Optimisation becomes feasible if you can realise the adjoint computationally. Dolfin-adjoint is based on a method that Farrell devised to do this automatically in the context of the FEniCS finite-element software. Given a FEniCS high-level specification of a problem, dolfin-adjoint elegantly constructs the dual at the same high level.

Nick Trefethen meets Leonhard Euler

Applications of dolfin-adjoint are taking Farrell places. As he remarked:
One day you can be working on problems in generating electricity from tidal turbines, the next you're solving problems in cardiac electrophysiology for diagnosing damage to the heart, the third in elastic imaging of cancerous tissue. While I was a postdoc I went to sea for a month with the oceanographers, sailing across the Atlantic, gathering data that lets us deduce the transport of heat in the ocean. Become an applied mathematician, and see the world!

The software scene these days is very different from in the 1970s. It's all about online collaboration, files stores in the cloud, issue trackers readable by the world, Skype video-calls to South Africa and Delaware and Norway. And what we do with our mathematics keeps on getting more remarkable. ■



Approximation to an optimal heat-conductor computed with dolfin-adjoint

Appointments...

We are delighted to welcome the following new Faculty members of the Mathematical Institute.

Dan Ciubotaru (*University of Utah, USA*): Associate Professor of Pure Mathematics and Tutorial Fellow at Somerville College. *Research interests*: Representation theory of reductive groups, unitary representations, Hecke algebras, reflection groups.

Radek Erban (*Oxford / Royal Society University Research Fellow*): Professor of Mathematics and Tutorial Fellow at Merton College. *Research interests*: Mathematical biology, multiscale modelling, partial differential equations, stochastic simulation algorithms, molecular dynamics, gene regulatory networks, chemotaxis, collective animal behaviour.

Vicky Neale (*Cambridge*): Whitehead Lecturer at the Mathematical Institute and Balliol College. Public understanding and communication of mathematics (see page 7).

Robert Style (*Yale, USA*): Departmental Lecturer in Mathematical Modelling. *Research interests*: Soft matter, elasticity, fluid dynamics, capillarity, geophysics, and general problems involving modelling of physical and industrial processes.

Andrew Thompson (*Duke University, USA*): Departmental Lecturer in Computational Mathematics. *Research interests*: analysis of high-dimensional data, with particular interests in compressed sensing, optimisation and image processing applications.

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 three long-standing members of the department:

Karin Erdmann was University Lecturer in Pure Mathematics, with particular interests in representation theory and homological algebra, and Tutorial Fellow at Somerville College.

Richard Haydon was Professor of Mathematics, with interests in functional analysis and topology, and Tutorial Fellow at Brasenose College.

David Stirzaker was Research Fellow in Mathematics, with particular interests in probability and its ramifications, and Tutorial Fellow of St John's College.

Achievements...

This has been another excellent year for awards and achievements.

At the 2014 International Congress of Mathematicians in Seoul, Korea, **Ben Green** FRS and **Jonathan Pila** gave invited plenary lectures, while **Konstantin Ardakov**, **David Conlon**, **Terry Lyons** FRS and **Tom Sanders** gave invited section lectures. Dame **Frances Kirwan** FRS was a member of the ICM Fields Medal Committee.

Ruth Baker was awarded a London Mathematical Society Whitehead Prize for her outstanding contributions to mathematical biology.

Martin Bridson, Whitehead Professor of Mathematics, has been elected a Fellow of the American Mathematical Society for his contributions to geometric group theory.

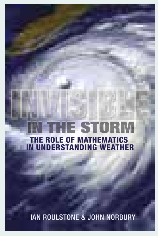
Marcus du Sautoy OBE, Simonyi Professor for the Public Understanding of Science, has been awarded the Sir George Thomson Gold Medal by the Institute of Measurement and Control; awarded quinquennially it recognised 'his considerable efforts to promote a positive public perception of mathematics' and cited in particular his BBC television programmes on *Precision: The Measure of All Things*. He was also awarded the Christopher Zeeman Medal for the Promotion of Mathematics to the Public by the Institute of Mathematics and its Applications and the London Mathematical Society.

Ben Green FRS, Waynflete Professor of Pure Mathematics, has been awarded the Royal Society's biennial Sylvester Medal (named after Oxford's former Savilian Professor J. J. Sylvester FRS) for his work on primes in arithmetic progression and other recent results in number theory (see page 4).

Nigel Hitchin FRS, Savilian Professor of Geometry, has been awarded an Honorary Doctorate of Science by the University of Warwick.

Terry Lyons FRS has continued as President of the London Mathematical Society.

James Maynard has won the 2014 SASTRA Ramanujan Prize, awarded annually to a mathematician below the age of 32, for his contributions to number theory (see page 4).



John Norbury and his co-author Ian Roulstone have won the Louis J. Batten Author's Award by the Council of the American Meteorological Society for their recent book *Invisible in the Storm* on the role of mathematics in understanding weather.

Ebrahim Patel has won the IMA's Early Career Mathematician Catherine Richards Prize 2014 for his article 'Pendulum pattern perception'.

Kishan Patel was awarded the 2014 Kansjoerg Wacker Prize of the European Consortium for Mathematics in Industry for a Master's thesis on Industrial mathematics.

Jonathan Pila has won a Carol Karp Prize, awarded every five years by the Association for Symbolic Logic for an outstanding book or paper on the subject.

Mason Porter has won the 2014 Erdős–Rényi Prize, awarded annually to a young scientist for research achievements in network science.

Angkana Ruland has won the University of Bonn's Hausdorff prize for a thesis on partial differential equations.

Iain Smears, a DPhil student, won a SIAM Student Paper prize for an article published in the *SIAM Journal on Numerical Analysis*.

Miguel Walsh has won the 2014 Ramanujan Prize for his outstanding contributions to ergodic theory and number theory.

Kit Yates has won a Silver Award in the mathematics category of the *SET for Britain Awards* for his work on the swarming of locusts.

OTHER AWARDS:

Mathematical Institute teaching awards were given to **Karin Erdmann**, **Peter Howell**, **Colin Macdonald**, **Michael Monoyios**, **Oliver Riordan**, **Jackie Stedall**, **David Stirzaker** and **Paul Tod**.

Fernando Alday received OUSU's 'Most Acclaimed Lecturer' award in the Mathematical, Physical & Life Sciences Division.

The Andrew Wiles Building was one of eleven buildings to win a South Regional Award by the Royal Institute of British Architects (RIBA).

The Mathematical Institute has received a University Green Impact Award for achievements in a number of environmental areas. ■

Institute outreach

Rebecca Cotton-Barratt

Saturday morning may not seem the most natural time to do mathematics. Nevertheless, the enthusiastic descriptions from Year 9 Oxfordshire school students of our Royal Institution Mathematics Masterclasses suggests that early starts are no barrier for budding mathematicians. The five masterclasses covered such topics as measuring symmetry, Efron's dice, the king chicken theorem, and binary encoding, giving the students an opportunity to explore maths beyond the school curriculum. As summed up by one participant at the end of the course: *There is so much you don't even know that you don't know – it is endless.*

Infinity was also the theme of several group presentations by participants on the University of Oxford's UNIQ Summer Schools. Aimed at students from areas and schools with low progression to higher education, these week-long courses give students a chance to experience life as an Oxford Maths undergraduate. During these weeks it was a pleasure to have mathematics alumni joining us for formal dinners and question-and-answer sessions with the students. Linking graduates and possible graduates breaks down barriers, allowing students to see what they can do with their degrees, and is only possible thanks to alumni who are willing to give their time and energy to talk to these brilliant young people.

Marcus du Sautoy's 'Marvellous Mathemagicians' (see *Newsletter* 10) continue to visit schools around the country and further afield. During the past year they have visited dozens of schools, inspiring students of a wide variety of ages and ability to engage with and enjoy maths. They now do an annual tour in March to visit the Dulwich Colleges in China, Singapore and South Korea, and continue to support the local Oxfordshire Science Festival. Their mathematical walking tours in Oxford and London are still available (see *www.mathsinthecity.com*), and are ideal for those curious about the mathematics around us – in buildings, patterns and people. ■

Public engagement with mathematics

Vicky Neale

I am very fortunate to be the first holder of the Whitehead Lecturership at the Mathematical Institute, which combines undergraduate teaching at Balliol with public communication of mathematics.

Since arriving in Oxford I've been 'spreading the word' by appearing in BBC Radio 4 programmes on the beauty of mathematics, one of which also featured Oxford mathematicians Ben Green and Peter Neumann. I also appeared on *Start the week* and Melvyn Bragg's *In our time* discussing 'Euler's number, e'.

For much of my time I give talks to the public and to school students around the country, and I have contributed to several UK Maths Trust events. Indeed, part of my role is to develop a programme of residential maths summer schools for teenagers (the sort of students who might one day become Oxford maths students), building on the Institute's successful UKMT summer camps and our links with PROMYS, the American programme for budding mathematicians which is now expanding into Europe. We're looking for ways to expand the department's activities in this area – for example, by seeking funding for undergraduates to work on their own summer research projects, while also inspiring the younger students at the summer schools.

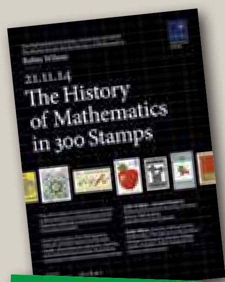
On a less serious note, I was delighted to be involved with the Institute's first 'Mathematical Bake-Off', in which staff and students showed huge creativity and baking flair, and we even had a mathematical craft afternoon towards the end of Michaelmas term. There's no boundary that maths cannot cross! ■

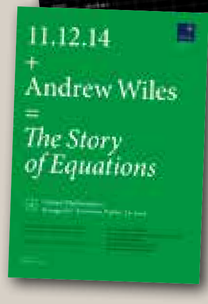
Public lectures and interviews

Dyrol Lumbard

Telling the world about the pleasures (and very rare pains) of mathematics has been a highlight of our recent activities.

A series of public lectures has taken place in the Andrew Wiles Building, and several are available online. Lectures have ranged from Jim Murray on how mathematical biology can explain the lack of three-headed monsters and prevent marriage breakdown, via a talk on mathematical stamps and Alain Goriely talking about how mathematical modelling can move between the climate and the brain and many points in between, to Cédric Villani on the 'Birth of an Idea' that led to his award of a Fields Medal in 2014.





A highlight of the year was our Inaugural Christmas Lecture by Andrew Wiles, whose *The Story of Equations* attracted over 700 requests for places. The Public Lecture series is targeted at anyone with an interest in the subject, from sixth-formers to the wider general public. Please keep an eye on our website, *www.maths.ox.ac.uk*, for details. The website also includes interviews with a number of prominent Oxford mathematicians, including Jim Murray, Bryce McLeod, Michael Atiyah and Roger Penrose. ■

Mathematics is a piece of cake: the Mathematical Bake-Off.

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 Sir Roger Penrose FRS.

This year's lecture will be given by Prof. Ben Green FRS and will take place on 19 September. You can book on *www.maths.ox.ac.uk/about-us/alumni/alumni-garden-party.*

In addition to the annual Garden Party we held a successful alumni evening last November at Staple Inn Hall in London. We plan to hold more such evenings as we invite alumni to share their thoughts and ideas about Oxford Mathematics.

Celebrating Sir Michael Atiyah

A one-day conference was held last year to celebrate the 85th birthday of Sir Michael Atiyah, OM, FRS, FRSE, Fields Medal winner and former Oxford Savilian Professor of Geometry. Guest speakers included Oxford mathematicians Nigel Hitchin and Graeme Segal. The meeting also marked the publication by Oxford University Press of the seventh volume of his *Collected Works*.

Mathematical sculpture

The entrance lobby of the Institute now displays *Axiom*, which combines the mathematical ideas of symmetry, asymmetry and entropy. The sculpture was created in cast aluminium by artist Mat Chivers, using a combination of hand-made and contemporary digital envisioning and fabrication processes.

Mathematical posters

Posters featuring mathematicians are displayed in the basement of the Andrew Wiles building. A new series of historical posters features *G. H. Hardy's Oxford Years*, and it is intended to follow these with posters on *John Wallis*, *Charles Dodgson* (Lewis Carroll) and other Oxford-based mathematicians. The posters can be viewed on the Institute's website at *www.maths.ox.ac.uk/about-us/history*.

Quillen notebooks

Daniel Quillen (1940–2011) moved from MIT to Oxford in 1984 to succeed Graham Higman as the Waynflete Professor. His standing as one of the leading mathematicians of his time had already been recognised by the award of a Fields Medal in 1978 for his foundational work on *K*-theory.

During his long career, Quillen kept a detailed record of his mathematical research. The 30,000 pages of notes left on his death give a fascinating insight into the working of a great mathematical mind. They show how he tackled problems, often reworking the ideas of other researchers as he sought a way into a problem or sought new productive areas for research. They also contain many unpublished results and observations that are still relevant to the active areas of current research that he pioneered.

Under the aegis of the Clay Mathematics Institute, Glenys Luke and Graeme Segal have led a project to make the notes available online. This work in progress can be seen on the CMI website: the scans are complete and accessible, and Glenys is working on the index which had reached 1992 at the time of writing.

Alan Turing Institute

Oxford University is one of five universities involved with the creation and the activities of the new **Alan Turing Institute**. The new Institute focuses on the analysis and application of big data and algorithm research, and will be based in London.

The Penrose paving

The paving in front of the Andrew Wiles building is constructed from just two different diamond-shaped granite tiles, each adorned identically with stainless steel circular arcs. There are many ways of covering the infinite plane with these tiles, matching the arcs as we go. Every such pattern is non-repetitive and contains infinitely many exact copies of the pattern in the picture. The non-repeating arrangement was discovered by Roger Penrose in 1974. This version, with its circular adornments, was designed by him in 2012.