**Institution:** The Open University

**Unit of Assessment:** B10 Mathematical Sciences

## a. Overview

Research in mathematical sciences at The Open University is based in the Department of Mathematics and Statistics, one of three departments in the Mathematics, Computing and Technology (MCT) Faculty. Our main disciplines and key areas of expertise are

Pure maths (**Barrow-Green**, **Brignall**, **Gill, Gray**, **Rippon**, **Short, Širáň**, **Stallard**, **Webb**):
analysis, complex dynamics, geometry, combinatorics, graph theory, history of mathematics

Applied maths (**Grimm**, **Umerski**, **Wilkinson**):
theoretical solid state physics, statistical physics, mathematical physics, aperiodic order

Statistics (**Critchley, Farrington**, **Garthwaite**, **Jones, Queen**, **Trendafilov, Whitaker**):
multivariate statistics, Bayesian statistics, medical statistics, distribution theory.

## b. Research strategy

**Overall strategy** We have built on our research strength in statistics, which was acknowledged in RAE2008, and greatly strengthened mathematics, with much external evidence for this. Some particular achievements in the period are as follows:

- Our strength in medical statistics was recognised by the award to **Paddy Farrington** of a Royal Society Wolfson Merit Award and an RSS Bradford Hill Medal.
- Our strength in history of mathematics was recognised by the award to **Jeremy Gray** of the AMS Albert Leon Whiteman Prize, and his selection as a Fellow of the AMS.
- The appointment of **Robert Brignall** (from the University of Bristol), and his award of an EPSRC first grant, strengthens our combinatorics group, led by **Jozef Širáň**.
- The appointment of **Ian Short** (from NUI Maynooth) complements our strength in complex dynamics, led by **Phil Rippon** and **Gwyneth Stallard**.
- Our external research funding has more than doubled since RAE 2008 and is on an upward trajectory, with new research grants of more than £2.75 million awarded since 2008.
- We continue to have a strong group of postdoctoral researchers (PDRAs and PDRFs) and have almost doubled the number of full-time PhD students since 2008.
- There is a thriving research culture in the Department with many more seminars and study groups than formerly, and more conferences organised.

Our future vision is to build on these achievements even more vigorously, and so continue to make a major contribution to UK mathematics and statistics research, in terms of both excellent research and strong contributions to research infrastructure; see Section e. In particular, the Department is now seeking to appoint a new lecturer in applied maths to strengthen this area and work with our existing highly productive applied mathematicians.

There are many ongoing fruitful research projects and collaborations within and outside the Department in existing areas of strength, and promising new collaborations are emerging; see Section d. The process of bidding for external funding is strongly supported by a research bidding mentoring scheme, and by the sharing of successful experience.

**c. People, including:**

**Staffing strategy and staff development**

The staffing strategy of the Department is to recruit academics who do internationally excellent research and who will also make major contributions to our highly regarded distance teaching. Numbers of staff in mathematics and statistics are not large, so it is our policy to build strength in our key areas as listed in Section a.

**New appointments**
Following the retirements of several senior academics, mainly from pure mathematics, the Department has appointed two outstanding new lecturers, **Brignall** and **Short**.

**Brignall** joined the combinatorics group, a key UK group in this area, and he now has **Nicholas Korpelainen** as a PDRA and also a PhD student. Combinatorics has been further strengthened by the appointment of **Nick Gill** as a PDRF.

**Short** joined the analysis and geometry group, complementing our world-leading strength in complex dynamics, and now has two PhD students. With his arrival, and the appointments of **David Sixsmith** as a PDRA and **John Osborne** as a visiting research associate, we now have the largest group of complex analysts in the UK.

**PDRAs and PDRFs**
During the period, many of our PDRA/Fs moved to positions in other universities, including:

**Casper Albers** (to the University of Groningen), **Karim Anaya** (to the London School of Hygiene and Tropical Medicine and then the University of Bath), **Gabriel Autès** (to École Polytechnique Fédérale de Lausanne), **Doyo Enki** (to the University of Plymouth), **Edmund Harriss** (to the University of Arkansas), **Mounia Hocine** (to the Conservatoire National des Arts et Métiers, Paris), **Christian Huck** (to the University of Bielefeld), **Dan Nicks** (to the University of Nottingham) and **Steffen Unkel** (to Justus-Liebig-University, Giessen).

Current PDRA/Fs are **Fadlalla Elfadaly**, **Nick Gill**, **Nicholas Korpelainen**, **Angela Noufaily** and **David Sixsmith**.

**Career development**
The OU's Research Career Development Team works with academic units to support researchers at each stage of their careers, with an extensive programme of activities. New staff and career-young researchers have mentors and thorough induction, as well as priority in the allocation of certain departmental and University research funds. The OU is a signatory to the Concordat to Support the Career Development of Researchers and actively works to implement its seven principles. Our commitment to the Concordat has been recognised with the European Commission HR Excellence in Research Award.

The Career Development and Staff Appraisal scheme for all academics covers an annual review of performance, the planning of training and development, and a research and scholarship plan. Academics are entitled to two months study leave per year, which can be accumulated up to one year, and an annual allowance of around £1000 for research-related expenses.

**Personal fellowships**
In 2011 **Paddy Farrington** was appointed to a prestigious Royal Society Wolfson Merit Award position. The aim of this award is to 'attract to this country or to retain respected scientists of outstanding achievement and potential'.

In 2012 **Jeremy Gray** was made a Fellow of the AMS for his 'outstanding contributions to the creation, exposition, advancement, communication, and utilization of mathematics'.

In 2009 Prof. Michael Baake (Bielefeld) held a Leverhulme Visiting Fellowship in the Department.

**Visitors**
The eminent statistician **John Gower**, and the highly productive combinatorialists **Terry Griggs** and **Mike Grannell**, have strong long-term links with the Department as Visiting & Emeritus Professors – all three were submitted to RAE 2008.

Notable short-term visitors include:

Prof. Michael Albert (University of Otago), Prof. Dan Archdeacon (University of Vermont), Prof. Michael Baake (University of Bielefeld), Prof. Karl Barth (Syracuse University), Prof. Shinto Eguchi (Institute of Statistical Mathematics, Tokyo), Prof. Lars Elden (Linköping University), Prof. Paul Marriott (University of Waterloo), Prof. Anthony O'Farrell (NUI Maynooth), Prof. Hannu Oja (University of Tampere, Finland), Prof. Bruce Richter (University of Waterloo) and Prof. Vincent Vatter (University of Florida).

**International staff appointments**
These all concern our PDRA/Fs – some of these were recruited from abroad, specifically from France, the Netherlands and Mexico, and others have moved to jobs abroad; see above.

**Equality and diversity**
The Department has a very strong record on equality and diversity. The proportions of female academics are well above the national average at all levels of seniority. The Department has been chosen to be one of the first at the OU to submit an application for an Athena SWAN award (November 2013), following a university-level Bronze Award in April 2013.

In 2012 the Department participated in a national benchmarking survey of good practice in UK mathematics departments, commissioned by the LMS. It received very positive feedback, obtaining scores that were at least the national average on each of the ten areas under consideration. In many areas, the scores were well above the national average, most notably in the areas of 'flexibility and sustainable careers' and 'levelling appointment and promotion playing fields' where the Department received the highest possible grading of 'very good'.

Working practices within the Department are highly conducive to flexible working, both formally and informally. Meetings are always scheduled for the middle of the day and arrangements made for staff to access meetings and some seminars remotely. In the current REF period, three members have taken full paternity leave and two have taken maternity leave. Several women have worked part-time and gradually increased their hours of work over many years, following earlier periods of maternity leave. Part-time working and maternity leave is carefully taken into account when considering promotions (and inclusion in the REF), and women have been promoted to senior lecturer and professor while working part-time.

**i. Research students**
The OU recruits full-time PhD students and also part-time ones, a few of whom are based outside the UK. Currently we have 11 full-time PhD students registered or doing corrections, recruited from UK universities, including Oxford and Warwick, the OU's MSc in Mathematics programme, and other countries, as well as 5 part-time PhD students. In the period 25 students were awarded PhDs by the Department, and 11 of these went on to academic or research positions. The OU provided fees and full stipends for about 75% of our full-time students, others being funded from external research grants, including DTG funding from the EPSRC.

Our students are members of the University's Research School, which is responsible for student recruitment and progression, the appointment of supervisors and examiners, and the provision of extensive university-wide training. Within the Faculty, an Associate Dean (currently **Uwe Grimm**) has overall responsibility for research policy, and day-to-day management is devolved to the Department's Research Director and Research Committee.

All students have at least two supervisors, with experienced supervisors lending support to less experienced colleagues. Students have an induction scheme, substantial research training, and an

independent third-party monitor. Their progress is formally reviewed every six months and a probation assessment is undertaken within the first year (the first two years for part-time students), including a skills audit, an oral presentation, a mini viva and a formal summative report. All students have full access to library facilities. Full-time students have their own desk and networked PC in a shared office, and further computing facilities as required.

Annual events provide students with an opportunity to present their research in a supportive environment, and students are funded (up to £1250 per year for full-time students) to attend appropriate national and international conferences, including the BMC and BAMC, and conferences for young mathematicians and statisticians.

Full-time statistics students participate in the EPSRC-supported Academy for PhD Training in Statistics of which the OU is a sponsoring member. In 2013 full-time mathematics students began to attend lectures (some given by OU academics) at the London Taught Course Centre, of which the OU is a full member. All PhD students are supported by the Department to join the LMS, IMA or RSS.

The Department has received DTG funding within the period, and in the most recent EPSRC Mathematical Sciences DTG allocation exercise, the Department's research student provision was judged sufficiently strong to be allocated 1.3% of the total funding.

**d. Income, infrastructure and facilities**

**Infrastructure**

The Mathematics and Statistics Department occupies two floors of the Alan Turing Building on the OU's central campus in Milton Keynes. The offices were refurbished in 2008 in line with the Department's requirements. Members of staff have good working conditions, mainly individual offices with good levels of equipment. There is a well-used common room area and a seminar room suitable for up to about thirty people. This facilitates our regular seminar programmes of external speakers in mathematics and in statistics.

The seminar room has blackboards and whiteboards, including a 'smart' whiteboard, so that seminars can be delivered remotely using an online synchronous conferencing system; the remote participants receive the audio component, the slides and any handwritten annotations via the web. In particular, our regionally based staff and our remote MSc students can attend expository seminars, aimed at sharing research topics of wider interest. We also use this system to deliver occasional research-based e-Colloquia to our mathematics MSc students (usually at least fifty attend), with a range of international speakers.

Staff and students have access to the extensive facilities of a modern research library, with most key mathematics and statistics online journals and databases available via the University network and a large, up-to-date collection of books and reference works. They also have access to all the mathematical and statistical software packages they require. The University also has a parallel computing facility with more than 750 CPU's and 2.8TB of RAM that is used exclusively to support STEM research, including several projects within the Department.

**Research portfolio**

Some significant examples of externally funded projects during the period are given below. The outcomes of several further bids to the EPSRC are currently awaited.

**Stallard** was awarded grants by the EPSRC in 2009, 2012 and 2013, totalling over £700k, with **Rippon** as co-investigator, to work on a new unified approach to two conjectures in transcendental dynamics (50% FTE each for five years in total), and to support a PDRA working on Hausdorff dimensions of subsets of the escaping set.

**Brignall** was awarded £92k in 2012 under the EPSRC's first grant scheme to support a PDRA

working on 'Infinite antichains of combinatorial structures'.

**Gray** was awarded £45k in 2011 by the Leverhulme Trust to work on a 'Scientific biography of Poincaré'.

**Grimm** was awarded £216k in 2006 by the EPSRC to support PDRAs and a PhD student until the end of 2009, and £25k in 2008 by the Leverhulme Trust to support an eight month visit to the OU by Prof. Michael Baake (Bielefeld).

**Umerski** was awarded £129k in 2008 by the EPSRC to support a PDRA working on 'Solving the fundamental limitations for RT spintronics - the role of interfaces in electron spin detection and injection'.

**Critchley** was awarded £284k in 2006 by the EPSRC to support a PDRA working until 2010 on 'A computational information geometry approach to sensitivity analysis in statistical science'.

**Farrington** was awarded £236k in 2006 by the EPSRC to support a PDRA working until 2009 on 'New statistics for the case series method: weakening the assumptions', £300k in 2010 by the MRC to work on 'Inference for infectious diseases from multivariate serological survey data', and £500k in 2011, also by the MRC, to support two PDRAs working on 'Statistical outbreak detection methods for large multiple surveillance systems'.

**Garthwaite** was awarded £332k in 2012 by the MRC, with **Jones** as co-investigator, to support a PDRA working on 'Development of statistical methods for the analysis of single patient data', and is co-investigator on Farrington's third grant above.

**Trendafilov** was awarded £173k in 2013 by the Leverhulme Trust to support a PDRA working on 'Sparse factor analysis with application to large data sets'.

**Consultancies and professional services**
Several members do consultancy work, mainly on a small scale. Two significant examples are:

**Farrington** was appointed in 2012 as one of three expert statistical witnesses to the Tribunal de Grande Instance de Paris, to advise the court in the high-profile 'Affaire Médiator'; their 700 page report for the court took many months to produce.

**Brignall** works as a consultant for the Heilbronn Institute, University of Bristol.

Our Statistics Discipline interacts directly with OU staff and students in other disciplines via a Statistics Advisory Service, which offers free advice to research students and staff, and a Statistical Consultancy Service, which performs work for staff remunerated from grants.

An important example of professional service is **Whitaker**'s maintenance of a website for epidemiologists on the self-controlled case series method; see http://statistics.open.ac.uk/sccs.

**e. Collaboration and contribution to the discipline or research base**

**Research collaborations and interdisciplinary research**
Some indicative examples of our many research collaborations and interdisciplinary projects, some supported by the Department's research budget and some by external funding, are listed below:

**Rippon** and **Stallard** have collaborated with world leader Prof. Walter Bergweiler (Kiel) on two major papers in transcendental dynamics, visiting Kiel in 2009, funded by the EPSRC.

**Grimm** collaborates regularly with Prof. Michael Baake (Bielefeld) on the theory of aperiodic order. In the period they worked together at the OU or Bielefeld several times a year on research projects, and also to complete their book *Aperiodic Order, Volume 1* (CUP, 2013), the first of a

series of definitive texts that they are preparing on this subject.

**Jones** leads a collaboration with Dr Arthur Pewsey (University of Extremadura, Cáceres, Spain) and Dr Shogo Kato (Institute of Statistical Mathematics,Tokyo) on distribution theory, with particular reference to circular data**;** all possible pairwise and triangular meetings have occurred once or more during the period.

**Farrington** has a long-standing and fruitful collaboration with the PHE (Public Health England, previously HPA), which has generated numerous methodological innovations. His other current and recent collaborations include ones with the Institut National de la Santé et de la Recherche Médicale (Inserm) in Paris and the Robert Koch Institute (RKI) in Berlin.

**Garthwaite**'s single-case study research involves close collaboration with Prof. John Crawford, a neuropsychologist at the University of Aberdeen, and he is also co-investigator on the multi-million euro EU project ERITAGE, based at the OU, which is studying climate change.

In collaboration with UCL, Birkbeck and Edinburgh University, our applied mathematicians are working on a £1 million grant from the BBSRC to create online mathematical modelling training for research biologists entitled 'Systems Training in Maths, Informatics and Computational Biology'. The first cohort started the training in January 2013.

Finally, there are numerous collaborations between Department members and other OU academics. For example:

**Grimm** has co-supervised PhD students working on topics such as biology, including malaria control.

**Ben Mestel** (Applied Maths) has joined Prof. William Nuttall (OU, Professor of Energy) to lead an inter-departmental 'energy research group', to work on problems such as modelling smart grids, storage, and demand forecasting, and is co-supervising a PhD student working in this area.

**Kevin McConway** (Statistics) is working on problems in ecology and evolution with Prof. Jonathan Silvertown (OU, Environment, Earth and Ecosystems) and colleagues from several European countries and South Africa, partly funded by grants from DEFRA, the Royal Society and the British Council, and also with Prof. Maureen Mackintosh (OU, Economics) and NHS colleagues on socio-economic status in relation to care needs, funded by the NHS.

**Exemplars of leadership**
Department members make very wide and influential contributions to the mathematics and statistics research base. Amongst the most public recognition of these contributions are:

**Paddy Farrington** received the highly prized Bradford Hill Medal of the RSS (2013), awarded only once every three years, for 'outstanding or influential contributions by a Fellow of the RSS to the development, application or exposition of medical statistics'.

**Jeremy Gray** received the Albert Leon Whiteman Prize of the American Mathematical Society (2009) in recognition of 'the value of his many historical works, which have not only shed great light on the history of modern mathematics but also have given an example of the ways in which historical scholarship can contribute to the understanding of mathematics and its philosophy'.

**June Barrow-Green** was appointed International Research Professor at Nancy University (February to July 2010) to work on 'George Birkhoff and Dynamical Systems Theory'.

Department members also make many long-term contributions to research in mathematics and statistics through their leadership roles within the LMS, the RSS, the CMS, the IoP and the Athena Forum, and through conference organisation, journal editing, PhD examining, and invited talks.

**External leadership roles and responsibilities**
We list a number of the most important roles that Department members have held in the period on national and international mathematics and statistics bodies.

**Barrow-Green**: member of LMS Council and LMS Librarian (2008–present), and member (currently Vice-chair) of the Executive Committee of the International Commission on the History of Mathematics (ICHM) (2010–present).

**Katie Chicot** (Pure Maths): Director of the UK Mathematics Trust.

**Farrington**: member of RSS Council (2008–2011), RSS Vice-president, Academic Affairs (2011), member of the WHO Advisory Committee on serological responses to EPI vaccines in infants receiving 'Intermittent Preventive Treatment for malaria' (2008–2010), and member of the Council for the Mathematical Sciences (2011).

**Grimm**: member of the International Union of Crystallography's Commission on Aperiodic Crystals, member, Vice-chair and Chair of the Mathematical and Theoretical Physics Group Committee of the Institute of Physics (2008–2013), and member of the IoP's Conferences Committee (2013).

**McConway**: member of the RSS Council (2012–present), RSS Vice-president, Academic Affairs (2012–present), Council for the Mathematical Sciences (2012–present).

**Mestel**: Deputy Director (50% FTE), Isaac Newton Institute (2008–2011).

**Rippon**: LMS representative on the BMC Scientific Committee (2011–present).

**Širáň**: member of the Slovak Committee for Awards in Science (2008–2010).

**Stallard**: LMS Women in Mathematics Committee Chair (2006–present), member of LMS Prizes Committee (2010–2011), LMS representative on the Athena Forum (2010–present), member of the LMS Good Practice Steering Committee (2009–present), member of an EPSRC Postdoctoral Research Fellowships panel (2011).

**Umerski**: member of an EPSRC and National Natural Science Foundation of China, UK/China Nanospintronics panel (2009) and an EPSRC Research Fellowships panel (2010).

**Conferences at the OU**
There is an annual OU Winter Combinatorics Meeting (now in its fourteenth year), with about forty participants and an annual Open Statistical Physics meeting, with about thirty participants.

There is also a long-standing programme of statistics conferences (the latest was the twenty-fifth) with typically about sixty participants. Since 2008, they have been on the following topics:

2008 'Statistics for Public Health Surveillance'
2009 'Workshop on Geometric and Algebraic Statistics'
2009 'Traffic Modelling'
2009 'Statistics for Health Registers and Linked Databases'
2010 'Statistical Methods for Outbreak Detection'
2010 'The Geometry of Data Analysis', in honour of the 80$^{th}$ birthday of Prof. John Gower
2011 'Visualisation and Presentation in Statistics'
2012 'Statistical Methods for Infectious Diseases'

The Department also hosted:

2008 'One Day Function Theory Meeting', funded by the LMS
2009 'Combinatorial, Dynamical and Harmonic Aspects of Aperiodic Order'

2011 'Complex Analysis and Geometry', a one day meeting funded by the LMS

**Conference organisation elsewhere**
Department members are heavily involved in organising meetings elsewhere. For example:

**Grimm**: APERIODIC'09, the sixth International Conference on Aperiodic Crystals, at the University of Liverpool (2009) and an EPSRC-funded workshop on Aperiodic Order at the University of Leicester (2009).

**Stallard**: an Oberwolfach workshop (2009) and two two-day LMS Women in Mathematics meetings (2010, 2013) at the Isaac Newton Institute.

**Širáň**: 'Graph Embeddings and Maps on Surfaces', Slovakia (2009 and 2013) and 'International workshop in optimal network topology', Indonesia (2012).

**Rippon** and **Stallard**: a one-week meeting on 'Transcendental Dynamics' at the Stephan Banach Centre, Warsaw (2010) with forty participants, and a workshop on 'The Role of Complex Analysis in Complex Dynamics' at the International Centre for Mathematical Sciences, Edinburgh (2013) with fifty participants.

**Barrow-Green**: the first International Conference on the History of Modern Mathematics, Xian, China (2010), an Oberwolfach workshop (2011), and a forthcoming three-week workshop on the history of mathematics at the Mittag-Leffler Institute (January 2014).

**Barrow-Green** and **Gray**: an LMS Society Meeting, marking the 100th anniversary of Poincaré's death, at De Morgan House (2012) with seventy participants.

**Rosie Cretney** and **Mairi Walker** (OU PhD students): the twenty-fourth Novembertagung, an annual international conference for PhD students and PDRAs in History of Mathematics with twenty participants, held at De Morgan House (2013), and funded by the LMS and the ICHM.

**Plenary lectures**
Invited main lectures by Department members at international meetings since 2008 include:

**Barrow-Green** (Brazil, China, India), **Critchley** (Poland), **Farrington** (Algeria, Denmark, Ireland, France, Germany, Norway), **Garthwaite** (Malta), **Gower** (Italy), **Gray** (France), **Grimm** (France, Germany, Poland), **Jones** (Canada, Hong Kong, USA), **Rippon** (Poland, USA), **Širáň** (Canada, China, India, Japan, Mexico, New Zealand), **Stallard** (Poland, USA), **Trendafilov** (Japan), **Webb** (Australia) and **Wilkinson** (Germany).

Other significant examples are two main talks at the BMC (**Barrow-Green** and **Stallard**), one at an AMS meeting (**Gray**), and one at an EMS meeting (**Gray**, as 'Distinguished speaker').

**Journal and book series editing**
Since 2008 Department members have spent time as editors, members of editorial boards, associate editors or guest editors of about thirty journals and book series, including the main LMS journals, and the LMS/AMS History of Mathematics book series.

**Barrow-Green** was the managing editor of *Historia Mathematica* (2007–2012) and co-edited (with Prof. Tim Gowers and Prof. Imre Leader) the *Princeton Companion to Mathematics*.

**Farrington** and **Jones** have both served actively on the RSS Research Section Committee, which acts as an editorial panel for the most prestigious 'read' papers published by the RSS.