

# NEWSLETTER

Issue: 480 - January 2019



TWENTY FIVE YEARS OF MACTUTOR LESS CLIMATE-IMPACTFUL CONFERENCES TRANSLATION SURFACES AND MODULI SPACES

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Images from MacTutor (see page 28). Names of the mathematicians shown can be found on MacTutor at tinyurl.com/ybylbo6h.

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News items should be sent to newsletter@lms.ac.uk.

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#### LMS NEWS

#### Forthcoming LMS Events

The following events will take place in the next four months:

Christopher Zeeman Medal Presentation: 5 March, Royal Society, London (tinyurl.com/y84gvbyk)

Hirst Lecture and Society Meeting: 21 March, De Morgan House, London (tinyurl.com/ybewfqz7)

**Mary Cartwright Lecture:** 5 April, ICMS, Edinburgh (tinyurl.com/ycv3ssfq)

LMS Meeting at the BMC: 10 April, Lancaster (tinyurl.com/yarpowdo)

A full listing of upcoming LMS events can be found on page 50.

### LMS Council 2018–19

The results of the 2018 LMS Elections to Council and Nominating Committee were announced at the LMS Annual General Meeting on 9 November 2018. Council membership is as follows:

#### PRESIDENT:

Professor Caroline Series FRS (University of Warwick)

#### VICE-PRESIDENTS:

Professor John Greenlees (University of Warwick) Professor Catherine Hobbs (University of the West of England)

TREASURER:

Professor Robert Curtis (University of Birmingham)

GENERAL SECRETARY: Professor Stephen Huggett (University of Plymouth)

PROGRAMME SECRETARY : Professor Chris Parker (University of Birmingham)

PUBLICATIONS SECRETARY: Professor John Hunton (University of Durham)

EDUCATION SECRETARY: Dr Kevin Houston (University of Leeds)

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MEMBERS-AT-LARGE OF COUNCIL: Professor Alexandre Borovik (University of Manchester) Dr Tara Brendle (University of Glasgow) \*Professor Mark Chaplain (University of St Andrews) \*Professor Andrew Dancer (University of Oxford) Professor David E. Evans (University of Cardiff) \*Dr Anthony Gardiner

\*Professor Brita Nucinkis (Royal Holloway) Dr Mariya Ptashnyk (Heriot-Watt University) \*Professor Gwyneth Stallard (Open University) Professor Anne Taormina (Durham University) \*Dr Alina Vdovina (University of Newcastle)

\*Members elected in 2017 who are continuing the second year of their two-year term.

#### LMS NOMINATING COMMITTEE:

Also at the AGM, Professor I. David Abrahams (Isaac Newton Institute for Mathematical Sciences) and Professor Elizabeth Winstanley (University of Sheffield) were elected to the Nominating Committee for threeyear terms of office. Continuing members of the Nominating Committee are: Professor Kenneth Falconer (Chair), Professor Roger Heath-Brown, Professor H. Dugald Macpherson, Dr Martin Mathieu, and Professor Ulrike Tillmann. Council will also appoint a representative to the committee.

The AGM also saw the following members retire from Council: Professor lain Stewart, Professor June Barrow-Green, Dr Francis Clarke and Dr Sarah Zerbes. The LMS is grateful for their contributions, details of which can be found on page 12.

### DeMorgan@21

On 23 October 2019 it will be exactly 21 years since the official opening of De Morgan House, the LMS's premises in London. It has been decided to make this the occasion for a gathering in De Morgan House for people to reminisce and to celebrate how far the London Mathematical Society has come since then. The date has been set as the afternoon of Saturday 19 October.

Buying De Morgan House was a major step which has clearly been an enormous success. Who would have imagined then the extent to which the LMS would expand its role, which has so much depended on the foresight in purchasing the premises?

The programme will include a talk by June Barrow-Green, "It is easier to square the circle than to get round a mathematician": The Wit and Wisdom of Augustus de Morgan, and John Ball, the President who oversaw the purchase, and Susan Oakes, long-time Administrator of the Society, will talk about some of their memories. Members are invited to send in their reminiscences and reflections which will be collated and shared. There will also be reminders of some the changes to and achievements of the LMS since the move as well as some plans for the future.



Augustus De Morgan's original design for an LMS badge

The event will include exhibits and material, including the photos and film of the opening event and poster boards on the history and purpose of the LMS. There will be plenty of time for conversation among participants and the afternoon will be rounded off by tea with a birthday cake and champagne toast.

Please contact Susan (Susan.Oakes@lms.ac.uk) if you have reminiscences or other material you would like to share. There will be room for an attendance of about 100 open to the general membership. Watch for further details in future issues of the *LMS Newslet*-ter.

DeMorgan@21 Organising Committee: Caroline Series, June Barrow-Green, Susan Oakes, Sarah Zerbes

### LMS Publications: Plan S

Readers may be aware that in September 2018 a group of 11 European research funders (including UKRI), 'cOAlition S' launched their drive to make publications of scientific research obtained via public grants be published in pure Open Access (OA) journals from 2020 onwards. Full details of their wishes ('Plan S') may be read at scienceeurope.org/coalition-s.

Details of the implementation of the group's principles are to be decided at the level of individual funding organisations. As of writing (November 2018), many details are unknown, in particular as to how UKRI intends to formalise this. For example, it is not yet certain if a funded researcher placing an accepted version of their paper on the arXiv (the 'Green OA route') will be accepted as meeting the Plan S aspirations. UKRI have already stated that any policy changes will only apply to the REF after REF 2021. Part of the long-term hope of the group is to jump-start a transition to open access journals where publication costs are met by alternatives to the traditional subscription model, which currently accounts for something like 85% of journals published. In particular, they wish to see the end of 'hybrid' models, journals that are sold as subscription journals but offer an option where authors can pay if they wish or need to have their article made available free to all readers.

Relatively few mathematicians are funded directly by cOAlition S members. However in the UK at least it is possible that anyone at an institution which receives QR funding could fall under the UKRI implementation. Conceivably, as a worst-case scenario, most UK mathematicians may end up being seriously constrained as to which of the world's main mathematics journals they may publish in; of course that would also require institutions to be willing and able to support their staff submitting to OA titles instead, and would depend on the final decisions about what 'OA compliant' will actually mean. On the other hand, it is also clear that there is much opposition to the objectives of Plan S, both from large parts of the world and from academics from a multitude of disciplines. so how this will all play out is far from clear.

As readers will know, the LMS journals (including the Bulletin, Journal, Proceedings and Journal of Topology, which are each hybrid titles) use all surplus they make to fund the Society's charitable activities; publishing accounts for about two thirds of the Society's income. In the LMS publications group we continue to monitor developments to ensure that good publishing opportunities remain available to all researchers, irrespective of the requirements imposed on them or the funding they have available, while aiming to maintain the financial support our journals and books give to mathematicians and mathematics research. We will also continue to represent the interests of the discipline to the relevant policy makers and any significant developments will be posted on the LMS website when available.

> Professor John Hunton LMS Publications Secretary

### SASTRA Ramanujan Prize

LMS member Jack Thorne (University of Cambridge, UK) has been jointly awarded the 2018 SASTRA Ramanujan Prize along with Yifeng Liu (Yale University, USA). Jack, a member of the LMS Editorial Board for the journals and an LMS Whitehead Prize winner, has been awarded for 'far reaching contributions to number theory, representation theory and algebraic geometry'. SASTRA (Shanmugha Arts, Science, Technology & Research Academy) is located near Kumbakonam, India, Srinivasa Ramanujan's hometown. The age limit for the prize is 32 (the age at which Ramanujan died) and the current award is \$10,000.

#### MATHEMATICS POLICY DIGEST

### Harnessing Educational Research

The Royal Society, in collaboration with the British Academy, has published a report, *Harnessing Educational Research*, which assesses the current state of educational research about formal education in schools and colleges up to the age of 18 in the UK and its roles within the broader education system. The report considers the flows of people, funding and information through the education system and highlights areas where there are gaps or areas that need to be strengthened; uncovers tensions or barriers between key players; and identifies facilitators to enable improvements.

The report offers recommendations to the governments of the UK's four nations, UK Research and Innovation (UKRI) and its constituent bodies, universities and other higher education institutions, and education organisations such as learned societies, regulators, and professional bodies, to address the challenges and opportunities outlined in the report. Key recommendations include:

- creating an independent Office for Educational Research to bring together devolved governments, teachers, researchers and research councils;
- · securing the pipeline of researchers; and
- making teaching a research-literate profession.

More information is available at tinyurl.com/yd2hm4q7.

### Immigration proposal response

In its March 2018 Report: *Brexit, Science and Innovation* (tinyurl.com/yd6kgqvb) the House of Commons Science and Technology Select Committee made the recommendation that the Migration Advisory Committee (MAC) 'bring forward its conclusions in relation to the immigration arrangements needed to support science and innovation' in order for the government to 'build these into a science and innovation agreement with the EU by October 2018 or earlier if possible'. This recommendation was rejected by the government and the Select Committee decided to develop its own immigration proposal that works for the science and innovation community.

After consultation the report: An Immigration System that Works for Science and Innovation was published in July 2018. The report is available at tinyurl.com/yc36vgk3. The government response to this report is now available at tinyurl.com/yd2v6utc.

# Erasmus and Horizon 2020 after Brexit

The House of Lords EU Home Affairs Sub-Committee launched a call for evidence for its inquiry into Brexit: *EU Student Exchanges and Funding for University Research.* Erasmus and Horizon 2020 are two EU programmes that facilitate student exchanges and research funding and collaboration respectively. The government is committed to participation in these programmes until the end of their current phases in 2020, but after exiting the EU, the UK will no longer fulfil eligibility criteria for full membership.

The inquiry focused on the short- and long-term impact of leaving the EU on the UK's participation in both programmes. The Sub-Committee limited its focus on Horizon 2020 to the effect of Brexit on funding for university research. The deadline for submissions was 21 November 2018 and a report will be published in due course. More information is available at tinyurl.com/y9d54z64.

Policy Digest prepared by Dr John Johnston Society Communications Officer

Note: items included in the Mathematics Policy Digest are not necessarily endorsed by the Editorial Board or the LMS.

#### **EUROPEAN**

### EMS Statement on Open Access

In October 2018 the European Mathematical Society (EMS) issued this statement confirming its position on open access:

"Two months ago the EMS reiterated its position on open access: see tinyurl.com/yc9stjuk. While scientific publishing may move in this direction, any change of the system must be done in a balanced way taking into account the interests of all parties involved, in particular that of the scientific community. However, at the moment we are witnessing several disturbing developments. The European Commission (EC) announced its Plan S, which would make so-called Gold Open Access de facto obligatory from 2020 within the EU. The participation of big commercial publishers in formulating this plan was explicitly mentioned. Furthermore, the EC has selected Elsevier as a subcontractor responsible for monitoring the plan through the Open Science Monitor. In our view this is an obvious conflict of interests. The EMS is surprised that the EC, with its manifest willingness to fight big internet companies, should turn a blind eye to such a serious problem in its own backyard. This decision will have a serious and lasting impact on the future of Open Science and innovation in Europe, the livelihoods of European citizens, and even the legitimacy of the European Commission. A number of people have accordingly supported a complaint to the European Ombudsman, requesting that this decision be revoked. The European Mathematical Society shares these worries about the future of scientific publishing and strongly supports the complaint: see tinyurl.com/y8egw8hz."

See page 5 for comments on Plan S by the LMS Publications Secretary.

#### **OPPORTUNITIES**

### LMS Grant Schemes

The next closing date for research grant applications (Schemes 1-5 and AMMSI) is 22 January 2019. Applications are invited for the following grants to be considered by the Research Grants Committee at its February 2019 meeting:

#### **Conferences (Scheme 1)**

Grants of up to £7,000 are available to provide partial support for conferences held in the UK, the Isle of Man and the Channel Islands. This includes a maximum of £4,000 for principal speakers, £2,000 to support the attendance of research students who are studying at universities in the UK, the Isle of Man and the Channel Islands, and £1,000 to support the attendance of participants from Scheme 5 eligible countries.

#### Visits to the UK (Scheme 2)

Grants of up to £1,500 are available to provide partial support for a visitor to the UK, the Isle of Man and the Channel Islands, who will give lectures in at least three separate institutions. Awards are made to the host towards the travel, accommodation and subsistence costs of the visitor. Potential applicants should note that it is expected the host institutions will contribute to the costs of the visitor.

#### Joint Research Groups in the UK (Scheme 3)

Grants of up to £4,000 split over two years (up to £2,000 a year) are available to support joint research meetings held by mathematicians who have a common research interest and who wish to engage in collaborative activities, working in at least three different locations (of which at least two must be in the UK, the Isle of Man and the Channel Islands).

Potential applicants should note that the grant award covers two years, and it is expected that a maximum of four meetings (or an equivalent level of activity) will be held per academic year. Grant applicants can apply for funds to host two meetings (or an equivalent level of activity) in a financial year, at a value of £500 per meeting. The Research Grants Committee will no longer require grant holders to hold four meetings per year (though they are still permitted to do so). It is anticipated that the award for each meeting will not exceed £500.

A grant may be used to support the activities of the group, and normally would be used to cover the expenses of speakers and or participants (e.g. travel, accommodation and subsistence).

#### Research in Pairs (Scheme 4)

For those mathematicians inviting a collaborator to the UK, the Isle of Man and the Channel Islands, grants of up to £1,200 are available to support a visit for collaborative research either by the grant holder to another institution abroad, or by a named mathematician from abroad to the home base of the grant holder. For those mathematicians collaborating with another UK, the Isle of Man and the Channel Islands-based mathematician, grants of up to £600 are available to support a visit for collaborative research either by the grant holder to another institution within the UK, the Isle of Man and the Channel Islands, or by a named mathematician from within the UK, the Isle of Man and the Channel Islands to the home base of the grant holder.

# Collaborations with Developing Countries (Scheme 5)

For those mathematicians inviting a collaborator to the UK, the Isle of Man and the Channel Islands, grants of up to £3,000 are available to support a visit for collaborative research, by a named mathematician from a country in which mathematics could be considered to be in a disadvantaged position, to the home base of the grant holder.

For those mathematicians going to their collaborator's institution, grants of up to £2,000 are available to support a visit for collaborative research by the grant holder to a country in which mathematics could be considered to be in a disadvantaged position. Applicants will be expected to explain in their application why the proposed country fits the circumstances considered eligible for Scheme 5 funding.

Contact the Grants team if you are unsure whether the proposed country is eligible, or check the IMU's Commission for Developing Countries definition of developing countries (tinyurl.com/y9dw364o).

# African Mathematics Millennium Science Initiative (AMMSI)

Grants of up to £2,000 are available to support the attendance of postgraduate students at conferences in Africa organised or supported by AMMSI. Appli-

cation forms for LMS-AMMSI grants are available at ammsi.or.ke.

#### **Research Workshop Grants**

Grants of up to £10,000 are available to provide support for Research Workshops held in the United Kingdom, the Isle of Man and the Channel Islands. Research Workshops should be an opportunity for a small group of active researchers to work together for a concentrated period on a specialised topic. Applications for Research Workshop Grants can be made at any time but should normally be submitted at least six months before the proposed workshop.

#### Computer Science Small Grants (Scheme 7)

Scheme 7 aims to provide support for visits to undertake collaborative research at the interface of mathematics and computer science. The deadline for applications is 15 April 2019 for the next round of Scheme 7 grants. Grants of up to £1,000 are available.

The next closing date for research grant applications (Schemes 8-9) is 22 February 2019. Applications are invited for the following grants to be considered by the Early Career Research Committee at its March 2019 meeting:

#### Postgraduate Research Conferences (Scheme 8)

Grants of up to £4,000 are available to provide partial support for conferences held in the UK, the Isle of Man and the Channel Islands, which are organised by and are for postgraduate research students. The grant award will be used to cover the costs of participants. The deadline for applications in the next round of Scheme 8 grants is 22 February 2019.

#### Celebrating new appointments (Scheme 9)

Grants of up to £600 are available to provide partial support for meetings held in the UK, the Isle of Man and the Channel Islands to celebrate the new appointment of a lecturer at a university in the UK, the Isle of Man and the Channel Islands. Potential applicants should note that it is expected that the grant holder will be one of the speakers at the conference. The deadline for applications in the next round of Scheme 9 grants is 22 February 2019.

For full details of these grant schemes, and to find information on how to submit application forms, visit the LMS website: Ims.ac.uk/content/research-grants. Queries regarding applications can be addressed to the Grants Administrator Anthony Byrne (0207 927 0807, grants@Ims.ac.uk), who will be pleased to discuss proposals informally with potential applicants and give advice on the submission of an application.

### Spitalfields Day 2018-19

The London Mathematical Society is pleased to offer funding of up to £1,000 towards the cost of a Spitalfields Day. A Spitalfields Day is a one-day event at which selected participants, often eminent experts from overseas, give survey lectures or talks, which are accessible to a general mathematical audience. The Spitalfields Day is often associated with a longterm symposium and speakers will generally give lectures on topics of the symposium.

The name honours the Society's predecessor, the Spitalfields Mathematical Society, which flourished from 1717 to 1845, and Spitalfields Days have been held each year since 1987.

The funding of £1,000 is intended to cover actual supplementary costs for the event, e.g. subsidising the cost for a lunch for participants, and for small travel grants of £50 to enable LMS members and research students to attend the event.

If you are interested in organising a Spitalfields Day, please write to the Society (Imsmeetings@Ims.ac.uk). The format need not be precisely as described, but should be in a similar spirit. The next deadline for proposals is 31 January 2019. The subsequent deadline is 15 September 2019. Please note the Society cannot fund events retrospectively so applicants are advised to apply well in advance of the event.

Previously supported Spitalfields Days have included:

2015: York. Mathematics of Quantum Uncertainty: New Advances and Prospects. Speakers: Pekka Lahti (Turku, Finland), Reinhard Werner (Hannover, Germany), Madalin Guta (Nottingham) Paul Busch (York).

2014: INI, Cambridge. *Theory of Water Waves*. Speakers: Mark Groves (Loughborough, Saarland), Guido Schneider (Stuttgart), Steve Shkoller (Oxford), Eugene Varvaruca (Reading).

# LMS Prospects in Mathematics 2020

UK departments are invited to submit expressions of interest to host the LMS Prospects in Mathematics Meeting 2020 to the Prospects in Mathematics Meeting Steering Group by 1 March 2019.

Up to £7,000 is available to support the annual twoday events (usually taking place in September) for Finalist Mathematics Undergraduates who are considering apply for a PhD after they have completed their current studies. This includes funding to cover fares and accommodation for up to 50 students, travel and accommodation for speakers and subsistence for participants including a social event.

LMS Prospects in Mathematics Meetings should feature speakers from a wide range of mathematical fields across the UK who discuss their current research and what opportunities are available to prospective PhD students.

Prospective organisers should send an Expression of Interest (max. one A4 side in length) to the Prospects in Mathematics Steering Group (Imsmeetings@Ims.ac.uk) by 1 March 2019 with the following details:

- Department's confirmation of support to host the LMS Prospects in Mathematics Meeting.
- Reasons to host the LMS Prospects in Mathematics Meeting.
- A provisional list of speakers who are representative of the UK research landscape both geographically and scientifically.
- Speakers from under-represented groups should be included and women speakers should account for at least 40% of the invited speakers.
- Confirmation that prospective organisers have read and understood the terms and conditions in the Guidelines for Organisers (available from tinyurl.com/y9yn2ryo).
- Willingness to attend the upcoming LMS Prospects in Mathematics Meeting in Lancaster (6–7 September 2019) to get an idea of the event.

For further details about the LMS Prospects in Mathematics Meetings, please visit: tinyurl.com/y9yn2ryo.

### Call for Bids for the 9ECM

Outline bids from mathematicians to organize the 2024 European Congress of Mathematics are now invited, and should reach the EMS Secretariat by 28 February 2019. These bids need only be outline bids giving a clear idea of the proposal and possible sources of financial and local support. The Executive Committee of the EMS will consider the bids received, and it will invite one or more of the bids to be set out in greater detail so that it can decide which bids are sufficiently serious options to be considered further. The deadline for such "worked up" bids, which will include a draft budget and a commitment to follow the conditions set up by the Executive Committee, is 31 July 2019. In 2020, at the EMS Council held at Bled prior to 8ECM, a decision will be reached.

### LMS Summer Schools

The London Mathematical Society has held an annual Summer School, aimed at introducing enthusiastic undergraduate students to modern mathematical research, since 2015. The Summer Schools take place for a two-week period in July and have proved very popular. The Society now seeks expressions of interest in hosting the Summer School in 2020 and 2021.

A grant of up £31,000 plus income from registration fees (£250 per registered student) is available to support the costs of the Summer School that can accommodate at least 50 undergraduate students.

Departments interested in hosting the School in 2020 or 2021 are now asked to send a short (two sides maximum) expression of interest to Elizabeth Fisher (Imssummerschool@Ims.ac.uk) by 22 February 2019. Whilst the expression need not be detailed it should include the name of the person in the department who would act as local organiser. The expression of interest should be signed by the head of department. At this stage, interested departments are asked to provide an approximate budget, outline the facilities, catering and accommodation available and talk about their experience in hosting other similar events.

We hope that departments will be interested in working with the LMS to continue the level of success that the Summer School programme has enjoyed in previous years.

For further details, including the requirements to host a Summer School, support from the Society and the selection process, visit the website at tinyurl.com/ybhd8llx. Contact Elizabeth Fisher (Imssummerschool@Ims.ac.uk) or 020 7291 9973 with any queries.

### 7th Heidelberg Laureate Forum

Applications are open for participation at the 7th Heidelberg Laureate Forum, to be held 22–27 September 2019 in Heidelberg, Germany. There are three categories for candidates: undergraduates, PhD students, and postdocs. Mathematical organisations in the UK are encouraged to make nominations. See tinyurl.com/y83xdlzs for details and an online nomination form. The Heidelberg Laureate Forum serves as a great platform for interaction between the masters in the fields of mathematics and computer science and young talents.

# LMS Early Career Fellowships: 2018–19 awards

To support early career mathematicians in the transition between PhD and a postdoctoral position, the London Mathematical Society offers up to eight Fellowships of between three and six months to mathematicians who have recently or will shortly receive their PhD. The award will be calculated at £1,200 per month plus a travel allowance. The fellowships may be held at one or more institutions but not normally at the institution where the fellow received their PhD.

For further details, including how to apply, visit the Society's website at tinyurl.com/y7npy2q7. Contact Elizabeth Fisher (Ims.ecf@Ims.ac.uk or 020 7291 9973) with any queries. The deadline is 14 February 2019.

### Reminders

LMS Prizes: call for nominations Details at tinyurl.com/Imsprizes2019. Deadline for nominations is 25 January 2019.

**Research Schools 2020: call for proposals** Details at https://tinyurl.com/ybora298. Deadline for proposals is 31 January 2019.

Nominations for Hardy Lectureship Tour 2020 Details at tinyurl.com/h5ql729. Deadline for proposals is 31 January 2019.

Undergraduate Research Bursaries in Mathematics 2019: call for applications Details at tinyurl.com/ya5stelx. Deadline for applications is 1 February 2019.

**Invited Lecture Series 2020: call for proposals** Details at tinyurl.com/y98espkj. Deadline for proposals is 1 February 2019.

**Crighton Medal 2019: call for nominations** Details at tinyurl.com/y9jtpa8n. Deadline for nominations is 28 February 2019.

**Early Career Researchers LMS Travel Grants** Details at tinyurl.com/y7b8ouo3. Deadline for applications is 28 February 2019.

**Applications for Cecil King Travel Scholarship** Details at tinyurl.com/yarns982. Deadline for applications is 31 March 2019.

### Visit of Sylvain Carpentier

Dr Sylvain Carpentier (Simons Postdoctoral Research Scientist at Columbia University, NYC) will visit the University of Kent from 31 March to 6 April 2019. He works in the field of infinite dimensional integrable systems. During his visit he will give a talk on *The Role of PreHamiltonain Difference Operators in Integrable Systems of Differential-Difference Equations.* For further information contact J.Wang@kent.ac.uk. The visit is supported by an LMS Scheme 4 Research in Pairs grant.

### Visit of Alberto De Sole

Professor Alberto De Sole (University of Rome 'La Sapienza', Italy) will visit the UK from 22 April to 2 May 2019. His research involves W-algebras, Hamiltonian and bi-Hamiltonian formalism and Integrable Systems. He will give lectures at Glasgow (23 April), Leeds (26 April), Loughborough (29 April) and Kent (30 April). For further details contact V.Novikov@lboro.ac.uk. The visit is supported by an LMS Scheme 2 grant.

### Visit of Gaurav Dhariwal

Dr Gaurav Dhariwal (Institute of Analysis and Scientific Computing, TU Wien, Austria) will visit University College London 4-8 February and 8-12 April 2019. He works in the field of stochastic partial differential equations. During his visit he will give talk on *Stochastic cross-diffusion equations: Existence of a martingale solution.* For further information contact e.zatorska@ucl.ac.uk. The visit is supported by an LMS Scheme 4 Research in Pairs grant.

### Visit of Andrey Dorogovtsev

Professor Andrey Dorogovtsev (National Academy of Sciences of Ukraine) will visit the School of Mathematical Sciences at Queen Mary, University of London from 4 to 16 February 2019. His recent research activity concerns measure-valued processes and stochastic flows. He will give lectures at Leeds (7 February), Queen Mary (13 February) and Warwick (14 February). For further details contact a.gnedin@qmul.ac.uk. The visit is supported by an LMS Scheme 2 grant.

### Visit of Christian Fonseca-Mora

Dr Christian Andrés Fonseca-Mora (Department of Mathematics, University of Costa Rica) will visit Professor Markus Riedle at King's College London from 19 February to 9 March 2019. During his stay, he will give talks at Imperial College (26 February), Swansea University (28 February) and the University of Sheffield (7 March). Dr Fonseca-Mora works in the area of stochastic analysis. The visit is supported by an LMS Scheme 5 grant.

### Visit of Valery Gaiko

Dr Valery Gaiko (National Academy of Sciences of Belarus) will visit the University of Warwick from 24 February to 31 March 2019, under an LMS Scheme 5 grant, to collaborate with Professor MacKay on global bifurcations of vector fields, with particular attention to planar and three-dimensional polynomial systems and applications to models for the dynamics of diabetes. He will give an *Ergodic Theory and Dynamical Systems* seminar on 26 February. For further information email R.S.MacKay@warwick.ac.uk.

### Visit of Sat Gupta

Professor Sat Gupta (University of North Carolina at Greensboro, USA) will visit the Department of Mathematical Sciences, Durham University, from 24 March to 7 April 2019. He is particularly known for his contributions to randomised response techniques. He will give lectures at City University London (25 March), Newcastle (29 March) and Durham (4 April). For further details contact frank.coolen@durham.ac.uk. The visit is supported by an LMS Scheme 2 grant.

### Visit of Yuri Latushkin

Professor Yuri Latushkin (University of Missouri-Columbia) will visit the University of Surrey from 2 to 9 March 2019. He works in the field of infinite dimensional dynamical systems. During his visit he will give a talk on *The Maslov Index and the Spectrum of Differential Operators*. For further information contact c.wulff@surrey.ac.uk. The visit is supported by an LMS Scheme 4 Research in Pairs grant.

# **Retiring Members of Council**

#### IAIN STEWART Programme Secretary

After four years Professor lain Stewart, Professor in the Department of Computer Science, Durham University, has retired as Programme Secretary. Professor Stewart has provided effective leadership across the Society's meetings and lectures programme and will continue to input to the Society's work as Chair of the newly formed Society Lectures and Meetings Committee (SLAM).

Professor Stewart has been involved in a number of LMS activities over the years. He has been the LMS Programme Secretary since 2015 and was previously a member of the LMS Council 1997–99; a member of the LMS Computer Science Committee 1996–99 and 2015–current (and Chair 1999–02); a member of the LMS Publications Committee 1997–99 and an Editorial Advisor of LMS Journal of Computation and Mathematics from its inauguration until 2012. He was also Coordinator of the joint LMS/EPSRC Mathematics for IT (MathFIT) initiative 2000–02. Professor Stewart's input has led the development of the Society's programme of meetings and lectures over the past four years and the LMS thanks him for his previous work in this area and his continuing leadership of SLAM.

#### JUNE BARROW-GREEN LMS Librarian and Member-at-Large

After 10 years June Barrow-Green, Professor of History of Mathematics, Open University has retired as LMS Librarian and Member-at Large. Professor Barrow-Green served from 2008 to 18 and has played an influential role in the Society's activities for a number of years. Her expertise as the LMS Librarian and as a member of LMS Council has been invaluable. In particular her position as a renowned member of the history of mathematics community and her extensive historical knowledge has been at the heart of many important projects for the LMS.

During her time as Librarian, Professor Barrow-Green set up the Library Students scheme where students gain work experience in the LMS Archive. She also helped set up the UCL Library exhibition *Queen of the Sciences; A Celebration of Numbers and the London Mathematical Society* during the Society's 150th Anniversary celebrations. More recently, she curated two displays on Augustus De Morgan and the Society from 1865 to the present day as part of the *Sublime Symmetry* Exhibition at the Guildhall Art Gallery, London. She also oversaw the return to the LMS of the Plücker models from the Science Museum, London.

Professor Barrow-Green's contributions to the LMS 150th Anniversary celebrations included the production of the LMS infographic 'from 1865 to the present day' and also organising and hosting a De Morgan Day at the Society's headquarters, celebrating the life and work of the first LMS President, Professor Augustus De Morgan.

Professor Barrow-Green has been a member of the Website Development Group, Personnel Committee, Prizes Committee and Zeeman Medal Committee, and has also been the LMS Council Diarist. The LMS is extremely grateful to her for the support she has given to the Society and the wider mathematical sciences community.

Although Professor Barrow-Green is standing down as LMS Librarian and as a Member of LMS Council, the Society will continue to benefit from her expertise as part of the 21st DMH Anniversary Celebrations Working Group, and as a member of the Standing Orders Review Group and the *LMS Newsletter* Editorial Board.

#### FRANCIS CLARKE and SARAH ZERBES Members-at-Large

Dr Francis Clarke has served the LMS in a number of areas over the years, including LMS Council 2013–18; Programme Committee 2013–17, being Deputy Programme Secretary 2015–17; Chair of Research Grants Committee 2018; Computer Science Committee 2013, Publications Committee 2014–18. He also served on the Euromath Committee in the 1980s; the BMC Scientific Committee, 2004–07; and as an organiser of the LMS/EPSRC Short Course on Algebraic Topology, 2005.

Dr Clarke has made notable contributions to Council business and to the wider activities of the LMS over the years and the LMS thanks him for his broad and varied support of the Society in achieving its charitable aims and supporting the wider mathematical community. Dr Sarah Zerbes was elected to Council in 2016 and stepped down as Member-at-Large of Council at the 2018 AGM. Dr Zerbes will continue to be involved with Society activities as part of the 21st DMH Anniversary Celebrations Working Group. The LMS thanks her for her contributions on Council and her continuing support for LMS activities.

# Longstanding LMS Members

The following is a list of members who in 2019 will have completed 50 years or more of membership of the London Mathematical Society.

76 years: Freeman J. Dyson

**71–74 years:** Bernard Fishel, Walter K. Hayman, Eric L. Huppert, Godfrey L. Isaacs.

70 years: David Borwein.

**66-67 years:** John M. Marstrand, Margaret E. Rayner, John R. Ringrose, Paul A. Samet, H. Peter F. Swinnerton-Dyer.

**61–65 years:** John C. Amson, J. Vernon Armitage, Michael Atiyah, Bryan Birch, John F. Bowers, Ronald Brown, Aldric L. Brown, Daniel E. Cohen, Gearoid De Barra, David E. Edmunds, David A. Edwards, Hanafi K. Farahat, Ioan M. James, Donald Keedwell, Lionel W. Longdon, I.G. Macdonald, Ismail J. Mohamed, David Monk, Brian H. Murdoch, Michael F. Newman, Roger Penrose, Roy L. Perry, Francis Rayner, Dennis C. Russell, S. James Taylor, G.E. Wall.

**60 years:** David A. Burgess, Roger W. Carter, Roland F. Hoskins, Glenys Ingram, Joseph F. Manogue, Alan West.

56-59 years: J. Clifford Ault, Patrick D. Barry, Benjamin Baumslag, Alan F. Beardon, Homer Bechtell, Simon J. Bernau, Thomas S. Blyth, Lilian G. Button, John H.E. Cohn, Hallard T. Croft, Charles W. Curtis, Roy O. Davies, Ian M.S. Dey, Vlastimil Dlab, J. Keith Dugdale, Peter L. Duren, L.C. Eggan, David Epstein, James O.C. Ezeilo, Matthew P. Gaffney, David J.H. Garling, Richard K. Guy, Desmond J. Harris, Robin E. Harte, Philip Heywood, A. Howard M. Hoare, John F.C. Kingman, J. David Knowles, Peter G. Lowe, Alun O. Morris, Albert A. Mullin, Alan R. Pears, John E. Peters, Frederick C. Piper, John S. Pym, Frank Rhodes, Joseph B. Roberts, Stewart A. Robertson, W. John Robinson, H. Peter Rogosinski, John W. Rutter, Arthur D. Sands, Eira J. Scourfield, Abe Sklar, Ernst H. Sondheimer, Dona Strauss, Wilson A. Sutherland, Anthony C. Thompson, Ronald F. Turner-Smith, C. Terence C. Wall, Eric W. Wallace, John F. Watters, Alfred Weinmann, David J. White, Joyce E. Whittington, Sheila O. Williams.

51-55 years: Irene A. Ault, Anthony D. Barnard, John C.R. Batty, M.C. Bramwell, William Brown, Roger M. Bryant, Allan G.R. Calder, Sheila Carter, Munibur R. Chowdhury, Michael J. Collins, Donald J. Collins, Bruce D. Craven, P. Laurie Davies, M.A.H. Dempster, M.M. Dodson, Patrick Dolan, Martin J. Dunwoody, Roger H. Dye, Barry G. Eke, K. David Elworthy, John Erdos, Edward A. Evans, W. Desmond Evans, Roger A. Fenn, Colin R. Fletcher, James W.M. Ford, Cyril F. Gardiner, Peter Giblin, Charles Goldie, William J. Harvey, Keith E. Hirst, Wilfrid A. Hodges, Terence H. Jackson, Graham J.O. Jameson, Michael E. Keating, Otto H. Kegel, Thomas J. Laffey, E. Christopher Lance, David G. Larman, Earl E. Lazerson, Ronald Ledgard, David W. Lewis, W.B. Raymond Lickorish, Bernard L. Luffman, Bob Margolis, Malcolm T. McGregor, John McKay, Peter McMullen, Ian M. Michael, William Moran, Hugh Morton, Robert Moss, Roy Nelson, Peter M. Neumann, Kung-Fu Ng, David R. Page, Oliver Pretzel, George A. Reid, John F. Rennison, Derek J.S. Robinson, James Edward Roseblade, Colin P. Rourke, Keith Rowlands, Stephan M. Rudolfer, Philip Samuels, Rodney Y. Sharp, Bruce L.R. Shawyer, David Singerman, Brian F. Steer, Nelson M. Stephens, Bill Stephenson, W. Brian Stewart, Anthony E. Stratton, David Tall, Brian Thorpe, David Tipple, Graham F. Vincent-Smith, Rabe R. von Randow, Grant Walker, Martin Antony Walker, Bertram Wehrfritz, Thomas A. Whitelaw, Christopher M. Williams, Geoffrey V. Wood, Douglas R. Woodall.

**50 years:** R.B.J.T. Allenby, Mark A. Armstrong, Nicholas H. Bingham, Peter J. Bushell, H. Dales, Richard Delanghe, Peter Dixon, John Duncan, John B. Fountain, Jonathan Hodgson, David L. Johnson, Peter J. Nicholls, Fredos Papangelou, Jon V. Pepper, Hilary A. Priestley, Peter Rowlinson, John Silvester, Gabrielle A. Stoy, R.F. Streater, Jeffrey R.L. Webb, Dominic J.A. Welsh, Christopher Wensley, J.D.M. Wright, Abraham Zaks.

# LMS Library at UCL: Member Benefit



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Members of the Society can register as users of the UCL Library, where the London Mathematical Society Library is held. The LMS Library contains a collection of:

- periodicals published by other mathematical societies which are received in exchange for the Society's publications
- copies of books and journals published by the Society
- items acquired by the Society as review copies or gifts.

#### **UCL Library Privileges**

- Use of all the material available in the reading rooms and stores of the UCL family of libraries.
- · Borrowing up to ten items at any one time.
- Placing up to three concurrent reservations on material already on loan.
- Borrowing books by post without service charge (costs for returning the books must be covered by the user).
- Access to MathSciNet and specific electronic journals from designated terminals in the Science Library.
- Use of the *Explore* access points to search for and view electronic publications and save single copies of articles (no more than one article per journal issue) for your own personal use. You can save articles to standard USB sticks, note that USB sticks containing encrypted software do not work on the Explore access points.

- Use of photocopying facilities at UCL libraries (charged at the same rate as UCL staff).
- Rapid photocopying service by post.

For licensing reasons, remote electronic access to journals and articles is not included in UCL Library membership. To check the listings of electronic journals available to visitors, before your visit to the Library, use Explore (tinyurl.com/ybm887s7).

#### **Registering and Renewing**

For details on how to register/renew your UCL Library card visit tinyurl.com/ybxlzavw. No charge is made is made for the initial registration or for renewing expired library cards or cards which are within one calendar month of expiring. Library cards are valid for 12 months from date of issue and should be renewed each year.



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#### Visiting the Library

- Opening hours can be found at tinyurl.com/ybja2tmu.
- During the weekends and evenings, the Library is open principally to offer book loans and to handle related queries. For all other queries contact a member of staff during office hours at tinyurl.com/ycqizxjt.
- Check seat availability in the reading rooms and computer cluster at the Science Library at tinyurl.com/y7b8vu5v.

For further information about the Society's Library visit Ims.ac.uk/library/Ims-library.

# Update from the Computer Science Committee

#### Call for New Committee Members

The Computer Science Committee advises Council on all matters at the interface of mathematics and computer science. The Committee meets twice annually in April/May and in October/November. The committee currently consists of six members plus representatives from BCS (British Computer Society), EPSRC, and IMA (Institute of Mathematics & its Applications). There will be openings for committee members in 2019. We invite researchers to join the committee. Expression of interest should be sent to Imscomputerscience@Ims.ac.uk by 31 January 2019.

#### Activities

The CS Committee (co)-organises two annual events: the LMS/BCS-FACS (BCS-Formal Aspects of Computing Science) Evening Seminar and the LMS Computer Science Colloquium. This year's LMS/BCS-FACS Evening Seminar was held on 1 November 2018. The speaker Professor Bill Roscoe (Oxford) gave a talk titled Verifying CSP and its offspring. The CS Colloquium is an annual day of themed talks on a topical issue at the interface of mathematics and computer science. This year's topic was Quantum Computing: Unique Mathematical Perspectives and five talks were held on 8 November 2018. See the report on this meeting on page 18. We would like to ask for suggestions of topics for CS Colloquium 2019, which can be sent to Imscomputerscience@Ims.ac.uk.

#### Grants

The CS Committee oversees the Scheme 7 grants programme to support a visit for collaborative research at the interface of Mathematics and Computer Science. The maximum award is £1,000. There are two rounds of applications, with deadlines in April and October. See tinyurl.com/scheme-7-grants for details and to download an application form.

### 2019 HEILBRONN FOCUSED RESEARCH GRANTS



#### Call for proposals

The Heilbronn Institute for Mathematical Research is offering a number of grants of up to  $\pm$ 7.5K to fund focused research groups to work on adventurous and challenging mathematical problems, or to discuss important new developments in mathematics.

These grants will support travel and local expenses for groups to come together to focus intensively on a problem or to discuss a significant new development in mathematics. We expect these groups to be normally 12 or fewer people. Groups are encouraged to include international participants, but should also involve a substantial UK-based component.

Open to all mathematicians and to any department in the UK.

Proposals from these areas of research, interpreted broadly, will be given priority: Pure Mathematics, Probability and Statistics, and Quantum Information.

Proposals of no more than one page of A4 should be sent by **9am, 1 February 2019** to: <u>heilbronn-manager@bristol.ac.uk</u>

For further particulars and additional information, please visit our website: <a href="http://heilbronn.ac.uk/opportunities/">http://heilbronn.ac.uk/opportunities/</a>

# LMS Council Diary — A Personal View

Council met at De Morgan House on Friday, 19 October 2018 for its first meeting of the academic year. One of the main issues was the discussion of the updated version of the revised Standing Orders Document, which has by now been opened up for consultation with the membership. A number of key issues for agreement had been highlighted for discussion. These included a proposed change in the procedure for the requisition of a Special General Meeting, an amendment to the quorum of Council, and new rules to allow eight one-year terms of office for Officers with a two-year gap between terms. We also discussed the merits of revising removal procedures relating to Trustees or members in cases of misconduct.

Just before lunch we also had a visit from David Abrahams, Director of the Isaac Newton Institute (INI), who gave a presentation to Council about the Institute, its current work and future plans. The Society, which has supported the INI since its foundation, at present awards a grant of £35k per annum to the INI. The INI requested further funding for the next five years to enhance funding for the following: provision of family and/or personal care support packages; continued support for early career researchers; and support for visitors from the Development Assistance Committee (DAC) List of Official Development Assistance (ODA) Recipient Countries.

As usual, we also heard a report from the President on her activities since the last meeting, which included the following: She attended the International Congress of Mathematics and the International Mathematics Union (IMU) General Assembly. She had also been working on setting up an LMS working group to develop the Society's views in relation to the Bond Review recommendations.

Chris Parker provided the Early Career Research Committee's annual report to Council. He reported that there had been a strong demand for the LMS Travel Grants for Early Career Researchers, and that the Celebrating New Appointments Scheme was also oversubscribed, so that some proposals had to be deferred with the aim of eventually supporting all. He informed Council that the Heilbronn Institute would not be supporting any of the Research Schools in 2018-19. However, the new Early Career Fellowship scheme will be launched in 2018–19.

We also considered the Trustees' Report and Annual Accounts for the year 1 August 2017–31 July 2018, and heard updates from the Education, Publication, and Women in Mathematics Committees. Council agreed that Andrew Dancer would be appointed Chair of the Research Grants Committee subsequent to the end of Francis Clarke's term of office this November. It was also agreed that the Council amend its policy so that it would clearly state that people based in the Channel Islands or the Isle of Man would be eligible to submit grant applications. Finally, Council agreed 222 applications for membership to be proposed to the Annual General Meeting to be held on 9 November 2018.

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#### REPORTS OF THE LMS

### Report: LMS Computer Science Colloquium



Speakers (I to r): Viv Kendon, Ashley Montanaro, Richard Jozsa, Earl Campbell, Mark Howard

This colloquium, titled *Quantum Computing: Unique Mathematical Perspectives*, was held on Thursday 8 November 2018 at De Morgan House. A full house, primarily of postdocs and PhD students, enjoyed a compelling series of talks.

The first speaker was Professor Richard Jozsa, from the University of Cambridge, who spoke on *Foundations of Quantum Computation and Complexity*. Richard gave a beautiful and elegant introduction into the fundamental mathematics behind quantum computation. His exposition was such as to take the audience from the foundations of the subject through what can and cannot be done within the quantum world, in comparison with the classical, and on to what might ultimately be possible. He provided an amazing comparison of quantum and classical complexity.

Richard was followed by Dr Viv Kendon, from Durham University, who spoke on *Solving Problems by Finding Low Energy Quantum States*. Viv gave us a view of quantum computation from the perspective of computational physics. Starting from an exploration of what a "computer" is, the audience was led to continuous-time quantum computing, which provides a unified framework for quantum computing hardware, and on to adiabatic quantum computing, continuous-time quantum walks and quantum annealing. Technical aspects of Viv's talk were skillfully supported by informative images. Dr Ashley Montanaro, from the University of Bristol, then spoke on *Quantum Algorithms: From Foundations to Applications*. The focus of the talk was on quantum algorithms rather than the computers on which such algorithms are implemented. Ashley explained that although Shor's and Grover's algorithms are perhaps the best known quantum algorithms, the world of quantum algorithms is mathematically diverse and he briefly explained recent quantum algorithms for accelerating backtracking and for solving hard constraint satisfaction problems. Ashley superbly demonstrated the underpinning role of the hidden subgroup problem.

Ashley was followed by Dr Earl Campbell, from the University of Sheffield, who spoke on *Homological* and Hypergraph Product Codes for Quantum Error Correction. Starting from classical error-correcting codes, Earl took the audience through parity check codes, LPDC codes and onto quantum codes, surface codes and toric codes. The focus of the talk was on how we cope with errors in quantum computing and on an examination of the "real" number of qubits required in order to implement our quantum algorithms on our quantum computing that does not feature so heavily in the classical domain.

After tea, Dr Mark Howard, from the University of Sheffield, spoke on *Topics in Stabilizer Quantum Computation.* Mark explained how stabilizer circuits form a restricted class of circuits that are provably weaker than a "universal" quantum computer and for which there is a classical simulation algorithm that is polynomial in the number of qubits. The power of stabilizer circuits can be boosted to that of a universal quantum computer though in the presence of error correction this can be very costly. Mark expertly discussed questions related to the extension of stabilizer circuits and the resources required.

In summary, the meeting provided the audience with an informative perspective of the many facets of quantum computing, covering machines, algorithms and practical implementation. There was something for everyone as the speakers traversed the spectrum of the subject from the foundations right up to cutting-edge research.

> lain Stewart (Durham University) Prudence Wong (University of Liverpool)

### Report: Centenary Meeting of R.A. Fisher's Quantitative Genetics Paper

This Joint Meeting, held on 9 October 2018 is the second Joint Meeting that the Society has held with the Fisher Trust and Royal Statistical Society in recent years; the first was held in 2016 on the topic of Data Science. This meeting celebrated the centenary of R.A. Fisher's paper. He was a member of the London Mathematical Society, elected in 1928.

In October 1918, statistician and geneticist Ronald A. Fisher published a paper entitled *The correlation between relatives on the supposition of Mendelian inheritance*, which reconciled a dispute between biometricians and Mendelians and set the foundations for studying the genetics of quantitative traits. The paper appeared in the Transactions of the Royal Society of Edinburgh, and 100 years later a meeting was held in Edinburgh to celebrate Fisher's contribution and reflect on subsequent advances.

Brian Charlesworth (University of Edinburgh, UK) introduced the meeting and set the stage for a collection of impressive talks, including four by early-career researchers, and posters on topics which have developed from Fisher's centenary paper.

The infinitesimal model (Fisher, 1918) describes traits as being determined by an infinite number of loci each contributing a small fraction of the phenotypic variance. Nick Barton (Institute of Science and Technology, Austria) presented an extensive analysis of the generality of this model in predicting the inheritance of quantitative traits. By reformulating the model, he generalised its applicability to the presence of selection, drift, mutation, population structure and epistasis. Himani Sachdeva (early-career speaker from the same institution) presented further extensions of this work.

Fisher's 1918 model has been applied to the study of genetic relatedness between close relatives using pedigree information or DNA sequence similarity. The task becomes more difficult, however, when individuals being compared are distantly related. Sharon Browning (University of Seattle, USA) and Heather Cordell (University of Newcastle, UK) presented sophisticated computational methods significantly advancing this research.

Lab and field presentations were inspirational. Ed Buckler (Cornell University, USA) focused on maize and spoke about how we can use machine learning to optimise selective breeding in one of the largest production crops worldwide. Josephine Pemberton (University of Edinburgh, UK), a pioneer of quantitative genetics in the wild, spoke about challenges and advances in estimating variance components and predicting the effects of selection in such populations. Using two wild animal populations from islands off the coast of Scotland, the Soay sheep on St Kilda and the red deer on the Isle of Rhum, a team effort involving many researchers has assembled detailed pedigrees and has collected a vast amount of genomic and phenotypic data.



As Fisher proposed, most quantitative traits are determined by many loci of small effect. However, large effect loci can sometimes be detected. Early-career presenters Chandana Basu Mallick (Roslin Institute, UK) and Daniel Crouch (University of Oxford, UK) spoke

R. A. Fisher

about the detection of major effect loci affecting two human traits, respectively, hair shape and facial features. Richard Mott (University College London, UK) dove into the complexities of genetic architectures and how these determine germination capacity and resistance to infection in plants. Josselin Clo (an early-career presenter from Montpellier SupAgro, France) spoke about the effects of self-fertilization on the magnitude of genetic variance. He found selfing to reduce the genetic variance of traits and consequently the adaptive potential of populations. Finally, Jarrod Hadfield (University of Edinburgh, UK) restored the theoretical mindset with a very elegant presentation of alternative models for the evolution of traits involved in social interactions.

The meeting closed with a Fisher Memorial Lecture, introduced by the President of the Fisher Memorial Trust, Sir Walter Bodmer (University of Oxford, UK), and given by Michael Goddard (University of Melbourne, Australia) on the genetic architecture of quantitative traits.

> Gabriela Gomes (Liverpool School of Tropical Medicine) Jessica King (University of Edinburgh)



Panel members

The Women in Mathematics Day, which took place on 19 October 2018 at Newcastle University, provided an opportunity for women mathematicians from a range of disciplines to meet and talk with women who are active and successful in their careers. The LMS event titled *What I have done with my maths degree, and what you can do with yours* was hosted by Newcastle University (organised by Dr Maryam Mehrnezhad) in partnership with the WISDOM group of Royal Holloway, University of London (organised by Lydia Garms), and had over 50 participants.

The meeting had an exciting set of female speakers working in academia, industry and parliament who shared brilliant stories of their career journey. Eminent speakers at this event were Chi Onwurah, Member of Parliament, Newcastle upon Tyne Central; Professor Anne Taormina, Head of the Department of Mathematical Sciences, Durham University; Sarah Rees, Professor of Pure Mathematics and Dr Shirley Coleman, Technical Director & Principal Research Associate both at the School of Mathematics, Statistics & Physics, Newcastle University; Dr Siaw-Lynn Ng, Lecturer at the Department of Mathematics, Royal Holloway, University of London; Dr Thyla van der Merwe, Senior Security and Privacy Engineer at Mozilla; Dr Jennifer Warrender, Teaching Fellow and Parisa Akaber, Knowledge Transfer Partnership Associate both at the School of Computing, Newcastle University.

The event featured a discussion group in the afternoon, centred round the challenges women face in the course of their careers, and how to overcome them. Concerns included being able to maintain a work-life balance, how to deal with bias in a workplace, applying for a job or role, among other issues, and their impact on motivation and confidence. It was interesting that most participants were keen to share their personal experiences and some success stories, and these were encouraging to women at the meeting facing similar challenges.



Poster session

A retired Senior IT Manager at Procter & Gamble and currently a voluntary mentor at The Girls Network. Dr lov Dinsdale, described how she supports and mentors a number of employees both professionally and with personal matters through different schemes. This points to the need for women to mentor themselves and be able to own their career decision-making. Dr Thyla Van Der Merwe, a Senior Security and Privacy Engineer at Mozilla and Dr Maryam Mehrnezhad, a Research Fellow in the School of Computing, Newcastle University, and one of the organisers of the event, encouraged dealing with bias at a workplace in the most appropriate way, immediately as it happens. This could be by reporting it to those in authority or by other appropriate means. Having allies who are not directly affected by sexism at work is another important source of support too. The session ended with interesting remarks on the need for women to make their choices and grab opportunities to refocus when needed.

A number of participants, mostly postgraduate students from different universities across the UK, showcased their projects in the poster session. Laura Wadkin from Newcastle University won the best poster prize. More information and images from the event are available at tinyurl.com/y7vy9w92.

Report by Maryam Garba, PhD Maths Student, Newcastle University Edited by Maryam Mehrnezhad, Research Fellow in Computing, Newcastle University

### Records of Proceedings at LMS meetings Ordinary meeting: 9 October 2018

This meeting was held at the Royal College of Surgeons, Edinburgh as a joint Meeting with the Royal Statistical Society (RSS), the Genetics Society, the Galton Institute and the Fisher Memorial Trust to celebrate the centennial anniversary of R.A. Fisher's famous 1918 paper on the theory of quantitative trait inheritance: *100 Years of Quantitative Genetics Theory and Its Applications: Celebrating the Centenary of Fisher 1918*.

Over 200 members and visitors were present for all or part of the meeting.

The meeting began at 9.00 am with The Genetics Society Representative to the Fisher Memorial Trust, Professor Brian Charlesworth FRS, in the Chair.

Professor Charlesworth welcomed guests and then introduced a lecture given by Professor Nick Barton FRS, FRSE (Institute for Science and Technology, Klosterneuburg, Austria) on The Infinitesimal Model. Professor Charlesworth introduced the second lecture given by Professor Josephine Pemberton FRS (University of Edinburgh, Edinburgh, UK) on *Quantitative Genetics of Free-Living Populations: Successes and Challenges*.

Before breaking for tea, Professor Charlesworth invited Josselin Clo (Montpellier SupAgro) to give an Early Career Research talk on *How Does Selfing Affect the Genetic Variance of Quantitative Traits? An Updated Meta-Analysis on Empirical Results in Angiosperm Species.* 

After tea, Professor Charlesworth introduced a lecture given by Professor Sharon Browning (University of Washington, Seattle, Washington, USA) on *Identity by Descent and The Correlation Between Distant Relatives*.

Professor Charlesworth introduced the fourth lecture given by Professor Heather J. Cordell (Newcastle University, Newcastle, UK) on Regional IBD Analysis (RIA): *Linkage Analysis in Extended Pedigrees Using Genome-Wide SNP Data*.

Before breaking for lunch, Professor Charlesworth invited Dr Chandana Basu Mallick (The Roslin Institute, UK) to give the second Early Career Research talk on *Making Sense of GWAS: Understanding The Genetic Basis of Human Hair Shape Using Mouse Models*.

After lunch, Professor Charlesworth invited Dr Himani Sachdeva (IST Austria, Austria) to give the third Early Career Research talk on Modeling Introgression Under the Infinitesimal Model with Linkage. Professor Charlesworth then introduced a lecture given by Dr Edward Buckler (USDA-ARS, Ithaca, New York, USA) on *How to get to Plant Breeding 4.0, given that Fisher was right?* 

Before breaking for tea, Professor Charlesworth introduced the sixth lecture given by Professor Richard Mott (University College London, London, UK) on *Genomic Rearrangements in Arabidopsis Considered as Quantitative Traits*.

After tea, Professor Charlesworth invited Daniel Crouch (University of Oxford, UK) to give the fourth Early Career Research talk on *Genetics of the Human Face*.

Professor Charlesworth then introduced a lecture given by Dr Jarrod Hadfield (University of Edinburgh, Edinburgh, UK) on *Hamilton's Rule in Multiple Dimensions*.

The Chairman of the Fisher Memorial Trust, Professor Sir Walter Bodmer FRS, then thanked the organisers and speakers at the Meeting before he handed over to The President of the London Mathematical Society, Professor Caroline Series FRS, for the vote of thanks from the LMS and gave notice that the Members' Book was available for signing by LMS Members. No members signed the book and were admitted to the Society.

Professor Series then handed back to Professor Sir Walter Bodmer who introduced the 37th Fisher Memorial Trust Lecture by Professor Michael E. Goddard (University of Melbourne and Agriculture Victoria, Melbourne, Australia) on *The Genetic Architecture of Complex Traits*.

After the lecture, Sir Walter presented Professor Goddard with a silver bowl to commemorate his Fisher Memorial Lecture.

A reception was held at the Royal College of Surgeons, Edinburgh. A dinner was hosted by the Fisher Memorial Trust at the hotel, Ten Hill Place.

### Records of Proceedings at LMS meetings Annual General Meeting and Society Meeting, Friday 9 November 2018

The meeting was held at the British Medical Association House, London. About 95 members and visitors were present for all or part of the meeting. The meeting began at 3:00 pm, with the President, Professor Caroline Series, FRS, in the Chair. Members who had not yet voted were invited to hand their ballot papers to the Scrutineers, Professors Chris Lance and Charles Goldie.

The Minutes of the General Meeting held on 29 June 2018 had been circulated 21 days before the Annual General Meeting and members were invited to ratify the Minutes by a show of hands. The Minutes were ratified.

The Vice-President, Professor John Greenlees, presented a report on the Society's activities and the President invited questions.

The Treasurer, Professor Robert Curtis, presented his report on the Society's finances during the 2017-18 financial year and the President invited questions. Copies of the Trustees Report for 2017-18 were made available and the President invited members to adopt the Trustees Report for 2017-18 by a show of hands. The Trustees Report for 2017-18 was adopted.

The President proposed Messrs Kingston Smith be re-appointed as auditors for 2018-19 and invited members to approve the re-appointment by a show of hands. Messrs Kingston Smith were re-appointed as auditors for 2018–19.

35 people were elected to Ordinary Membership: Emmanuel Afolabi Bakare, Karin Baur, Shohreh Blank, Ana Bleahu, Andrea Brini, Kenya Brooks-Jones, Hung Bui, Thibault Congy, Tahani Coolen-Maturi, William Cullerne Bown, Chanchal Dass, Adam Duffie, Eleonore Faber, Damian Farnell, Molly Fitches, Marta Fulop, Janet Godolphin, Asma Hassannezhad, David Hume, Abdul Hadi Khan, Vincent Knibbeler, Eoin Long, Sofya Lyakhova, Pankaj Manjhi, Vincenzo Mantova, Margit Messmer, Ngoka Orby, Alexey Pokrovskiy, Philipp Schlicht, Petr Siegl, Kuldeep Singh, Marios Smailis, Durvudkhan Suragan, Hendrik Süß and Jan Hendrik Witte.

64 people were elected to Associate Membership: Daniel Altman, Christopher Blaxland-Kay, Kieran Calvert, Jonathan Chapman, Ching Lok Chong, Argyrios Christodoulou, Mehmet Sefa Cihan, Krzysztof Ciosmak, Tim Davis, Benedek Dombos, Mateo Galdeano Solans, Søren Gammelgaard, Nikoleta E. Glynatsi, Esteban Gomezllata Marmolejo, Exequiel Gono, Ido Grayevsky, Nadav Gropper, Hannah Guggiari, Zachary Hall, Michael Hallam, Matt Hare, Amit Hazi, Oscar Armando Hidalgo Arevalo, Christopher Irving, Adam Jones, Deepak Kamlesh, Alice Kerr, Patrick Kidger, Alexei Latyntsev, Jacob Leygonie, Zhuolin Li, Barbara Mahler, William Martinson, Peter Maxwell, Oliver McGrath, Romy Minko, Joseph O'Brien, Emile Okada, Matteo Parisi, Victoria Patel, Santanu Kumar Patro, Rafael Prieto Curiel, Yikun Qiao, Marzia Romano, Cristopher Salvi, Leandro Sanchez Betancourt, Alexander Schell, Joe Scull, Octavian-Mircea Sebe, Tommaso Seneci, Rehan Shah, Atul Sharma, Francis Simkievich, David Snee, Florian Song, Daniel Straulino, Oliver Street, Jay Swar, Panagiotis Tselekidis, Brian Tyrrell, Christoph Weis, Johannes Wiesel, Naya Yerolemou and Phoebe Young.

20 people were elected to Reciprocity Membership: Adenike Adeniji, Abolape Deborah Akwu, Vasudeva Rao Allu, Samuel Asiedu-Addo, Edy Tri Baskoro, Mary Durojaye, Mohamed Abdelsabour Fahmy, Susan Friedlander, Karen Habermann, Mahouton Norbert Hounkonnou, Benedikt Löwe, Fadipe-Joseph Olubunmi, Evans Osaisai, Ogunrinde Roseline, Ramaswamy Sivaraman, Joshua Sunday, David Sward, Saliou Toure, Rajkumar Verma and Wanli Wang.

163 people were elected to Associate Membership for Teacher Training Scholars: Zainab Adam, Jubril Adebowale, Laleh Akbarzadeh, Laura Albery, Abdulraham Allaghbani, Catherine Allen, David Anderson, Lauren Archer, Tubotamuno Asembo, Aaron Barker, Molly-Rose Baxter, Sandra Beckford-Henry, Halima Begum, Alice Bennett, Ellen Berry, Cindy Berry, Simon Bevan, Gemma Birch, Ryan Bromwell, Russell Brooks, Adam Broome, Joanna Brown, Matthew Brown, Laura Burton, Ryan Butterworth, Thea Cartmell, Caroline Cheetham, Minesh Chhatralia, Alexander Cimino, Emily Clapham, James Coghlan, Bethany Cotton, Katherine Curle, Mustafa Daud, Benjamin Davies, Bruno De Martino, John Delahunty, Jacob Dempsey, Samuel Denby, Georgia Dickinson, Jessica Donnelly, Oliver Douch, Robert Drew, Lucy du Cros, Catherine Edwards, Gokhan Er, Maria Etheredge, Hal Euphrates, Samuel Everall, Mahshid Farjadpour, Shaun Flynn, Paola Fossanova, Beth Freeman, William Gaffney, Clare Gollop, Victor Gonzalez, Bethany Graham, Daniel Hague, Megan Harris, Kashif Hayat, Shona Hill, Samuel Hollis, Kaye Hudson, Tom Hughes,

Ryan Hughes, Sebastian Hunter, Jade Hutchinson, Joanna John-Baptiste, Alisha Johnson, Hannah Jones, Matthew Jones, Elizabeth Jones, Kathryn Helen Jones, Abdul Haseeb Kassam, Zara Khan, Naima Khan, Jonathan Kingsley-Mills, Styliani Kontogeorgaki, Andrea Lawson, Xiaofei Lei, Stephanie Light, Yuyan Lin, Harry Lloyd, Francisco Lobo, Natalia López Pérez, Emma Lunney, Jamie Luo, Joseph Machin, Matthew Male, Zafirah Malik, Benjamin Philip Mansbridge, Marvin Masaeli, Stephen McEvoy, Robert McPherson, Lauren Meakin, Mathew Mufiri, Rabiya Nagvi, Daniel Nerozi, Simon O'Neill, Leanne Osborne, Ian Paduraru, Patrick James Pereira Vieira, William Perriam, Michael Phillips, Keiran Poole, James Pope, Rachel Priestley, Samira Quraishy, Ross Rakauskas, Zainab Ranglia, Andrew Ranson, Zoe Redmill, Coral Reeves, Jamie Rimmington, Michel Rubini, Celia Russell, Mohammed Saghir, Nigel Sedgley, Hannah Sheath, Samantha Shimwell, Eva Sindelarova, Shatakshi Singh, Richard Singleton, Charis Smith, Jamie Smith, Molly Smith, William Smith, Robert Stothard, Jodie Street, Jessica Street, Joseph Sugrue, Jonathan Suissa, Sophia Thompson, Cameron Tran, Joanne Travell, Rebecca Triggs, Jordan Twinn, Lucy Tyreman, Rachel Uff, Geert Van Mook, Vicky Vipond, Kira Wade, Grace Wallace, Ashley Warnes, Mairianne Watson, Steven Watts, Catherine Whittock, Harley Wilkes, Benjamin Willerton, Margareta Beatrice Wills, Samuel Wilson, Charlotte Withell, Edward Withers, Adam Wooldridge, Nicole Tamzyn Wright, Patrick Wright, Iga Wroblewska, Azlina Yeo, Tanya Young, Natalie Young, Lan Yu and Rugayya Zaman.

Four members signed the Members' Book and were admitted to the Society.

The President, on Council's behalf, presented certificates to the 2018 Society Prize-winners:

Pólya Prize: Professor Karen Vogtmann (Warwick)

Fröhlich Prize: Professor Francesco Mezzadri (Bristol)

Senior Berwick Prize: Professor Marc Levine (Duisburg-Essen)

Hirst Prize: Professor Jeremy Gray (Open University and Warwick)

Whitehead Prizes: Dr Ana Caraiani (Imperial College London), Professor Valerio Lucarini (Reading), Dr Filip Rindler (Warwick), Professor Péter Varjú (Cambridge).

A Whitehead Prize was awarded to Dr Heather Harrington (Oxford). Her certificate will be presented at the Annual General Meeting in 2019. A Whitehead Prize was awarded to Professor Caucher Birkar (Cambridge) and an Anne Bennett Prize was awarded to Dr Lotte Hollands (Heriot-Watt). However, they were unable to collect their certificates and so their certificates have been sent to them.

Dr Manuel del Pino (Bath) gave a lecture on *Singularity Formation and Bubbling in Nonlinear Diffusions*. After tea, Professor Lance announced the results of the ballot. The following Officers and Members of the Council were elected.

President: Caroline Series; Vice-Presidents: Catherine Hobbs, John Greenlees; Treasurer: Robert Curtis; General Secretary: Stephen Huggett; Publications Secretary: John Hunton; Programme Secretary: Chris Parker; Education Secretary: Kevin Houston.

Members-at-Large of Council for two year terms: Alexandre Borovik, Tara Brendle, David E. Evans, Mariya Ptashnyk and Anne Taormina; Member-at-Large (Librarian): Mark McCartney.

Six Members-at-Large, who were elected for two years in 2017, have a year left to serve: Mark A. J. Chaplain, Andrew Dancer, Tony Gardiner, Brita Nucinkis, Gwyneth Stallard and Alina Vdovina.

The following were elected to the Nominating Committee for three year terms: I. David Abrahams and Elizabeth Winstanley. The continuing members of the Nominating Committee are: Kenneth Falconer (Chair), Roger Heath-Brown, Martin Mathieu, H. Dugald Macpherson and Ulrike Tillmann. Mark Chaplain will be the Council Representative on Nominating Committee.

Professor John R. King, University of Nottingham, gave the Naylor Lecture 2018 on Blow-Up Phenomena in Reaction Diffusion. Before closing the meeting, Professor Series thanked the retiring members of Council and welcomed the President Designate, Professor Jon Keating, FRS.

Professor Series also thanked the speaker at the Graduate Student Meeting in the morning, David Smith (Birmingham), and congratulated the winner of the Graduate Student Talk Prize, Fatumah Atuhaire (Southampton).

After the meeting, a reception was held at BMA House in the Paget Room, followed by the Annual Dinner, which was held in the Great Russell Suite at Montague on the Gardens Hotel and attended by 88 people.

DIMITRI ZVONKINE

Translation surfaces are surfaces glued from polygons by identifying only parallel sides of equal lengths. Many questions about them can be asked in elementary terms. Sometimes these questions can be answered using elementary methods such as polygonal billiards, monodromies and permutations, cutting and pasting. Other times they require advanced methods of dynamics or intersection theory on moduli spaces.

#### Translation surfaces

Figure 1 represents two polygons whose sides are divided into pairs of same length and direction. By gluing the polygons along these pairs of sides we obtain a *translation surface*. This is a closed surface with a flat metric (a Riemannian metric with zero curvature, locally isometric to the Euclidean plane) and a finite number of conic singularities whose angles are multiples of  $2\pi$ . In this example, the surface is of genus 3, and it has 2 conical singularities with angles  $4\pi$  (white dots) and  $8\pi$  (black dots).



Figure 1. These two polygons can be glued into a translation surface

In general, given a translation surface of genus g with n conical singularities that have angles  $2\pi(k_i + 1)$ ,  $1 \le i \le n$ , the Gauss-Bonnet formula implies  $\sum k_i = 2g - 2$ .



Figure 2. This is the same translation surface as in Figure 1

Any translation surface can be cut into polygons in many ways. We will consider all such cuttings as

equivalent; in other words, we are interested in the surface itself and in its metric, not in a particular cutting. For instance, the polygon in Figure 2 is obtained from those in Figure 1 by cutting the rightmost polygon in two and gluing the pieces along distinguished pairs of sides (the gluings are shown as dotted lines). Both figures represent the same translation surface.

Let C be a translation surface and  $S^1$  the circle of directions on the plane. Then  $C \times S^1$  carries a natural time flow: just imagine a ball rolling on the surface Calong the geodesic in the given direction. If the ball meets a side of a polygon it reappears from the other side of the distinguished pair. If it hits a vertex, then the flow is not well-defined. Thus to each translation surface corresponds a dynamical system, and we can ask whether the time flow is ergodic, whether there are periodic trajectories, and so on. See, for instance, the study of periodic orbits in the regular pentagonal billiard [2] and the corresponding jewelry at tinyurl.com/yboob8dw. Here, however, we will be more interested in the space  $\mathcal{H}_{g}(k_{1}, \ldots, k_{n})$  of all translation surfaces of genus g with conical angles  $2\pi(k_i+1), 1 \le i \le n.$ 

The complex numbers represented by the sides of the polygons form local coordinates on this space. Moreover, they endow it with an *integer affine structure*. This means that choosing a different cutting of the surface induces an affine change of local coordinates with integer coefficients. In particular, this allows us to define a canonical volume form on the space  $\mathscr{H}_g(k_1, \ldots, k_n)$ . While the total volume of this space is infinite, the volume of  $\mathscr{H}_g^{\leq 1}(k_1, \ldots, k_n)$ , the space of translation surfaces with area at most 1, was shown to be finite by Masur [7] and Veech [12].

**Question 1.** What is the volume of  $\mathcal{H}_g^{\leq 1}(k_1, \ldots, k_n)$ ?

One of the ways to answer this question is to count the translation surfaces whose coordinates are Gaussian integers a + bi,  $a, b \in \mathbb{Z}$ . Eskin and Okounkov [6] showed that the number of such surfaces with area up to N grows as  $V \cdot N^{2g-1+n}$ , where V is the volume of the space  $\mathscr{H}_g^{\leq 1}(k_1, \ldots, k_n)$  and 2g - 1 + n its complex dimension. Using representation theory and the theory of quasi-modular forms they were able to produce a method to compute the volumes of all spaces  $\mathscr{H}_g^{\leq 1}(k_1, \ldots, k_n)$ . This was later refined to deal with the volumes of connected components of these spaces, classified by Kontsevich and Zorich [9].

Let us illustrate the method with the simplest example of genus 1 translation surfaces. Because such a surface has an infinite automorphism group acting by global translations, it is convenient to mark one point on the surface and consider the space of translation surfaces with one marked point. The marked point could be viewed as a conical point with angle  $2\pi$ .

Every genus 1 translation surface of area N with one marked point can be cut into a parallelogram, as in Figure 3, in a unique way, d being an integral divisor of N, and  $0 \le a \le d$  an integer. The marked point is the image of the vertices of the parallelogram under the gluing.



Figure 3. All translation surfaces of g = 1 with 1 marked point look like this

Thus the number of such translation surfaces is the sum of divisors of N, and the corresponding generating function is the quasi-modular form

$$G_2(q) = -\frac{1}{24} + \sum_N \sum_{d|N} dq^N$$

The well-known transformation law for this quasimodular form reads

$$G_2\left(e^{-2\pi i/\tau}\right) = \tau^2 G_2\left(e^{2\pi i\tau}\right) + \frac{i\pi}{4}$$

where the first term is the standard transformation law for modular forms and the second term is the quasi-modular correction. Plugging  $h = 2\pi i/\tau$  and recalling that  $G_2(0) = -1/24$ , we obtain the asymptotic expansion

$$G_2(e^{-h}) \sim rac{\pi^2}{6h^2} - rac{1}{2h}$$

as  $h \rightarrow 0^+$ . Note that this is the *whole* asymptotic expansion: the difference between the left-hand side and the right-hand side decreases exponentially.

Returning to our original question, we now have

$$G_2(e^{-h}) \sim rac{\pi^2}{6} rac{1}{(1-q)^2}, \quad ext{ as } \quad h o 0^+,$$

so the coefficients of  $G_2(q)$  grow as  $\pi^2 N/6$ , the partial sums up to degree N as  $\pi^2 N^2/12$ , hence  $\pi^2/12$  is the volume of the space  $\mathcal{H}_{1:0}^{\leq 1}$ .

The group  $GL(2, \mathbb{R})$  acts on plane polygons and thus on the space of translation surfaces in the natural way. This leads to new important questions.

**Question 2.** Describe the orbit closures of the  $GL(2, \mathbb{R})$  action in the space of translation surfaces.

We will come back to this later.

**Question 3.** Restrict the action to  $SL(2, \mathbb{R})$ . What are the possible stabilizers of translation surfaces? For what surfaces is the stabilizer a lattice in  $SL(2, \mathbb{R})$ ?

If the stabilizer of a translation surface is a lattice, it is called a *Veech surface*. Veech surfaces have not been classified so far, but many unexpected examples have been constructed.

**Example**. Consider the translation surface obtained by gluing together the opposite sides of a regular 2n-gon. One can show that the matrix

$$\left( \begin{array}{cc} 1 & \operatorname{cotan} rac{\pi}{2n} \\ 0 & 1 \end{array} 
ight)$$

lies in its stabilizer and deduce that the stabilizer is a lattice.



Figure 4. An element of  $\mathrm{SL}(2,\mathbb{R})$  that stabilizes the regular 2n-gon translation surface

Further restricting the  $\mathrm{SL}(2,\mathbb{R})$  action to diagonal matrices

$$\left(\begin{array}{cc} e^t & 0\\ 0 & e^{-t} \end{array}\right),$$

we obtain a flow on the space  $\mathscr{H}_g(k_1, \ldots, k_n)$ , called the *Teichmüller flow*. Masur and Veech [7, 12] showed that this flow is ergodic on every connected component of this space. An important question is: what does this flow do to the homology classes of the translation surface as  $t \to \infty$ ? More precisely, if we consider a small open set U in  $\mathscr{H}_g(k_1, \ldots, k_n)$ , we can naturally identify the groups  $H_1(C, \mathbb{R})$  for all translation surfaces C parametrized by U, since these surfaces are obtained from each other by small deformations. Now, pick a point in U and suppose that at some moment of time t the flow brings us back to U. The translation surface has undergone some transformation that acts by a linear map A(t)on the homology group  $H_1(C, \mathbb{R})$ . Denote by

$$0 < \beta_g \le \dots, \le \beta_1 \le \alpha_1 \le \dots \le \alpha_g \in \mathbb{R}$$

the eigenvalues of  $A(t)A^+(t)$ . Because A(t) preserves the intersection pairing on  $H_1(C, \mathbb{R})$  we actually have  $\alpha_i(t)\beta_i(t) = 1$ . The Lyapunov exponents of the Teichmüller flow are defined as

$$\lambda_i = \lim_{t \to \infty} \frac{1}{2t} \ln |\alpha_i(t)|$$

By the Oseledets ergodic theorem, these limits exist and are the same for almost all starting points.

**Question 4.** What are the Lyapunov exponents  $\lambda_1, \ldots, \lambda_g$  for a given connected component of  $\mathcal{H}_g(k_1, \ldots, k_n)$ ?

Main results on this topic include the proof by Avila and Viana [1] that the Lyapunov spectrum is simple, that is,  $0 < \lambda_1 < \cdots < \lambda_g$ , and the computation of the sum  $\lambda_1 + \cdots + \lambda_g$  by Eskin, Kontsevich and Zorich [4]. The complete answer, however, is still unknown.

#### Moduli spaces and Abelian differentials

The space  $\mathcal{H}_g(k_1, \ldots, k_n)$  can be viewed in a completely different way if we realize that a translation surface is the same thing as a Riemann surface with an Abelian differential (i.e., a holomorphic differential 1-form).

Indeed, since every polygon lies in the complex plane, it inherits the complex coordinate z, that can be taken as a local coordinate on the translation surface. It also induces the holomorphic 1-form dz on the polygon. These local coordinates and holomorphic 1-forms glue nicely along the edges of the polygons: the change of local coordinate from one chart to the other is just a translation. A special treatment is needed at the conical points. If  $z_i$  is a conical point with angle  $2\pi(k_i + 1)$ , we can use  $w = (z - z_i)^{1/(k_i+1)}$  as the local coordinate at this point. The Abelian

differential  $dz = d(w^{k_i+1})$  has a zero of order  $k_i$  at the conical point. Thus we obtain a Riemann surface C with n marked points  $x_1, \ldots, x_n$  and an Abelian differential  $\alpha$  that has zeros of orders  $k_1, \ldots, k_n$  at  $x_1, \ldots, x_n$ .

The sides of the polygons are now the *periods* of  $\alpha$ , either absolute or relative between two zeros. The complete set of periods on a basis of the group  $H_1(C, \{x_1, \ldots, x_n\}, \mathbb{Z})$  forms a set of local coordinates on  $\mathcal{H}_g(k_1, \ldots, k_n)$  that are called *period coordinates*.

Denote by  $\mathcal{M}_{g,n}$  the moduli space of genus g Riemann surfaces with n marked points. This space is well-defined as soon as the Euler characteristic 2 - 2g - n of the surface punctured at the marked points is negative. Its points parametrize all possible complex structures on an oriented genus g surface with n distinct marked numbered points, up to a point-preserving isomorphism. For instance,  $\mathcal{M}_{0,3}$ is a point, because all genus 0 Riemann surfaces are isomorphic to  $\mathbb{CP}^1$  and any three points can be brought to  $0, 1, \infty$  in a unique way by an isomorphism  $z \mapsto (az + b)/(cz + d)$  of  $\mathbb{CP}^1$ . Similarly, the space  $\mathcal{M}_{0,4}$  is isomorphic to  $\mathbb{CP}^1 \setminus \{0, 1, \infty\}$ . Indeed, by an isomorphism of  $\mathbb{CP}^1$  we can bring four points  $x_1, x_2, x_3, x_4$  to  $0, 1, \infty, t$ , where

$$t = \frac{x_4 - x_1}{x_2 - x_1} : \frac{x_4 - x_3}{x_2 - x_3} \in \mathbb{CP}^1 \setminus \{0, 1, \infty\} = \mathcal{M}_{0, 4}$$

is the cross-ratio of the four points. Further, the space  $\mathcal{M}_{1,1}$  is the modular figure  $\mathbb{H}/\mathrm{SL}(2,\mathbb{Z})$ , where  $\mathbb{H}$  is the upper-half plane. Indeed, any elliptic curve can be represented as  $\mathbb{C}/(\mathbb{Z} + \tau\mathbb{Z})$  for  $\tau \in \mathbb{H}$ . The  $\mathrm{SL}(2,\mathbb{Z})$  action corresponds to replacing the basis  $(1, \tau)$  of the lattice  $\mathbb{Z} + \tau\mathbb{Z}$  with the basis  $(c\tau + d, a\tau + b)$ , and then re-scaling the lattice so as to bring the first vector of the basis to 1, the second vector becoming  $\tau' = (a\tau + b)/(c\tau + d)$ . The three simplest moduli spaces described above are shown in Figure 5.



Figure 5. Three simplest moduli spaces

The moduli space  $\mathcal{M}_{g,n}$  admits a natural compactification  $\overline{\mathcal{M}}_{g,n}$  called the *Deligne-Mumford compactifica*- 26

tion. It is the moduli space of stable curves, that is, nodal curves with *n* distinct smooth marked points that have a finite number of automorphisms. For instance,  $\overline{\mathcal{M}}_{0,4}$  is  $\mathbb{C}P^1$ , where the three extra points 0, 1,  $\infty$  correspond to the three stable curves in Figure 6.



Figure 6. The three nonsmooth stable curves of g = 0 with 4 marked points

The moduli space  $\overline{\mathcal{M}}_{1,1}$  is obtained from  $\mathcal{M}_{1,1}$  by adding one extra point. The corresponding curve is  $\mathbb{C}P^1$  with points x = 0 and  $x = \infty$  identified into a node and marked point at x = 1, see Figure 7.



Figure 7. The unique nonsmooth stable curve of g = 1 with one marked point

The moduli space  $\overline{\mathcal{M}}_{g,n}$  is a smooth Deligne–Mumford stack, or orbifold, of complex dimension 3g - 3 + n. The points of  $\overline{\mathcal{M}}_{g,n} \setminus \mathcal{M}_{g,n}$ , that we add to compactify the space, parametrize nonsmooth stable curves. They form a normal crossings divisor in  $\overline{\mathcal{M}}_{g,n}$  called the *boundary*.

The Hodge bundle  $\mathbb{E}_{g,n} \to \overline{\mathcal{M}}_{g,n}$  is the rank g vector bundle over the moduli space whose fiber over a point  $p \in \mathcal{M}_{g,n}$  is the space of Abelian differentials on the corresponding curve  $C_p$ . The Hodge bundle extends naturally to  $\overline{\mathcal{M}}_{g,n}$ . Without going into details of this, let us mention that an Abelian differential on a stable curve is a meromorphic 1-form on each irreducible component of the curve with at most simple poles at the nodes of the curve, the residues at the two branches of the node being opposite to each other. With this definition it is easy to check that the Abelian differentials form a g-dimensional vector space on any stable curve of genus g. For instance, on the genus 1 nodal curve obtained by identifying x = 0 and  $x = \infty$  on  $\mathbb{C}P^1$ , all Abelian differentials are proportional to dx/x.

Once we have introduced the moduli space and the Hodge bundle, we can remark that every space  $\mathcal{H}_g(k_1, \ldots, k_n)$  of translation surfaces is naturally embedded into the Hodge bundle  $\mathbb{E}_{g,0}$ . Specifically,

it is the locus of Abelian differentials with n zeros of orders  $k_1, \ldots, k_n$ . Actually, these spaces form a stratification of the total space of the Hodge bundle over  $\mathcal{M}_{g,n}$ . We can also view  $\mathcal{H}_g(k_1, \ldots, k_n)$  as a subspace of  $\mathbb{E}_{g,n}$  if we decide to mark the zeros of the differential. Note that the projectivization  $\mathrm{PE}_{g,n}$  is a compact orbifold, and the projectivizations  $\mathrm{P}\widetilde{\mathcal{H}}_g(k_1, \ldots, k_n)$  are its closed sub-orbifolds. This new setting leads to a new series of questions.

**Question 5.** Do the spaces  $\mathcal{H}_g(k_1, \ldots, k_n) \subset \mathbb{E}_{g,n}$  have smooth closures?

The answer to this precise question is negative: the closures are not even normal. It is conjectured, however, that their normalizations are smooth. This would provide a natural smooth compactification for every space  $\mathcal{H}_g(k_1, \ldots, k_n)$ .

**Question 6**. What is the cohomology class Poincaré dual to  $P\overline{\mathcal{H}}_g(k_1, \ldots, k_n)$  in  $P\mathbb{E}_{g,n}$ ? What is the pushforward of this cohomology class to  $\overline{\mathcal{M}}_{g,n}$ ?

As the simplest example, consider the space  $\mathcal{H}_2(2)$  of Abelian differentials with a double zero on a genus 2 curve. Every genus 2 curve *C* carries two linearly independent Abelian differentials  $\alpha$  and  $\beta$ , each of which has two simple zeros or a double zero. Their ratio  $\alpha/\beta$  is a degree 2 map from *C* to  $\mathbb{CP}^1$  or, in more intrinsic terms, to the projectivization of the dual to the space of Abelian differentials on *C*. This shows that every genus 2 curve is hyperelliptic. The degree 2 map described above has six ramification points, called the *Weierstraß points*. Every Abelian differential on *C* has either two zeros whose images under the map  $\alpha/\beta$  coincide, or a double zero at a Weierstraß point. Thus the image of  $\mathcal{H}_2(2)$  in  $\overline{\mathcal{M}}_{2,1}$ is the divisor

 $\{(C, x) \in \overline{\mathcal{M}}_{2,1} \mid x \text{ is a Weierstraß point}\}.$ 

The cohomology class Poincaré dual to this divisor was first determined by Eisenbud and Harris [3]. It is equal to



So what do all these terms mean? The second and the third terms are pictures representing boundary divisors of  $\overline{\mathcal{M}}_{2,1}$ . The second term is the boundary divisor parametrizing curves with a separating node; the third term is, similarly, the boundary divisor parametrizing curves with a nonseparating node. In both cases we take the Poincaré dual cohomology classes of these divisors. The class  $\psi_1$  is the first Chern class<sup>1</sup> of a line bundle  $L_1$  over  $\overline{\mathcal{M}}_{2,1}$ . The fiber of this bundle over a point  $(C, x) \in \overline{\mathcal{M}}_{2,1}$  is the cotangent line to C at x. In general, there are n line bundles  $L_1, \ldots, L_n$  like that over  $\overline{\mathcal{M}}_{g,n}$ , corresponding to the n marked points.

A general method to compute the cohomology classes Poincaré dual to  $P\overline{\mathcal{H}}_g(k_1, \ldots, k_n)$  in  $P\mathbb{E}_{g,n}$  was developed by Sauvaget [10], though it does not lead to a closed formula.

A conjectural closed formula for the cohomology class of the image of  $\overline{\mathcal{H}}_g(k_1, \ldots, k_n)$  in  $\overline{\mathcal{M}}_{g,n}$  was proposed in the appendix of [8]. It involves the  $\psi$ -classes introduced above, the classes of boundary strata, while their coefficients are some special values of Bernoulli polynomials.

In conclusion, let us mention two developments that connect the two views on the spaces of translation surfaces.

The first one is a conjecture by Sauvaget relating the cohomology class Poincaré dual to  $P\overline{\mathcal{H}}_g(k_1, \ldots, k_n)$  to the volume of  $\mathcal{H}_g^{\leq 1}(k_1, \ldots, k_n)$ . For n = 1 the conjecture is proved in [11].

The second is a result by Eskin, Mirzakhani and Mohamadi [5] that Anton Zorich, in his review paper [13] called "the magical wand theorem". It states that any  $GL(2, \mathbb{Z})$ -invariant closed subset of  $\mathcal{H}_g(k_1, \ldots, k_n)$  is an algebraic subvariety of  $\mathbb{E}_{g,n}$  defined over  $\overline{\mathbb{Q}}$ ; locally, in period coordinates it is an affine subspace. This is the single most important step towards the classification of all  $GL(2, \mathbb{Z})$ -invariant closed sets.

#### FURTHER READING

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#### Dimitri Zvonkine

Dimitri Zvonkine is a CNRS researcher at the Versailles University, France. He works on moduli spaces, intersection theory, Gromov-Witten invariants, and

integrable systems. He was born in Moscow and liked math from the age of three, as documented in his father's book *Math from Three to Seven*. He likes songs by Georges Brassens, Tom Lehrer, and Yuli Kim, and those from Kabaret Starszych Panów.

<sup>&</sup>lt;sup>1</sup>One of the ways to define the first Chern class of a line bundle L is to construct a meromorphic section of L and take the divisor of its zeros minus the divisor of its poles. The Poincaré dual cohomology class of the difference between these two divisors does not depend on the section and represents the first Chern class of L.

# **Twenty Five Years of MacTutor**

IOHN O'CONNOR AND EDMUND F. ROBERTSON

MacTutor is a widely used website which covers the History of Mathematics from its very earliest development to the modern day. It provides an extensive, and ever expanding, set of articles and interactive materials on mathematics, mathematicians and mathematical societies. The year 2019 sees the site celebrate its 25<sup>th</sup> anniversary, and in this article the site's creators reflect on its development and use.

In 1988 the mathematicians at St Andrews acquired a teaching laboratory of 30 Apple Macintosh Plus computers. It was our intention to use these to show students how to experiment with mathematics without necessarily having to know how to program a computer. We found that there was no suitable software available, so we were forced to write our own.



### **MacTutor History** of Mathematics archive

Fortunately the son of one of our colleagues who was working with us over the summer was a computer scientist and he introduced us to a very innovative application called HyperCard which made it possible to produce some clever teaching material very quickly. As well as producing the usual facilities for plotting functions, sitting quizzes, etc. we were able to implement some ingenious ideas for exploring different areas of mathematics. We found that we were able to get new insights into various areas of mathematics by creating interactive computer-based models and that this was a good way of introducing students to a new manner of looking at many problems.

We called it MacTutor since it was originally developed on Macintosh computers rather than because of any particularly Scottish connection.

Our system enjoyed considerable success and we sold it to a number of other universities and other places as well as using it extensively in our own teaching. We won several prizes for our system from organisations as diverse as British Nuclear Fuels and the US Department of the Environment and demonstrated it at a number of conferences.

As a side-effect it turned out to be a great asset in giving would-be entrant students the chance to experiment on open days. In those far-off times

young people were much less blasé about computers than they are now and were much easier to impress. The parents who accompanied them on open days were even more impressed.

One of the things we added quite early on was a certain amount of material on the history of mathematics. HyperCard allowed us to attach buttons to move around inside our system and so we could arrange that if a student was experimenting with, say the Euclidean algorithm, then they could click a button and be taken to a biography of Euclid, or if they were looking at Platonic solids they could go to Plato's biography. Our early system had links to a few hundred of the most well-known mathematicians as well as a collection of essays on the history of various mathematical areas. (These eventually became the History Topics section in our history archive.)

In 1994 we entered MacTutor for the European Academic Software Award and reached the finals, which were held in Heidelberg in November of that year. As part of our preparation for our presentation there we experimented with making the historical part of our system available on the World Wide Web. This was still in its infancy (it had started in 1991) and there was essentially no material on the history of mathematics available on it.

Fortunately, the HyperCard program we had used to develop our system contained many of the features now familiar on the Web. One could highlight text in a field and arrange for the system to do something if one clicked on it. Also the text-handling capabilities of HyperCard meant that generating html code from our existing material could be done relatively easily. We won the award in Heidelberg and one of the things which most impressed the judges — as well as the other mathematicians competing for the prize — was this adaptation of the historical material to the Web. We soon found that even the small amount of material we put up in our initial attempt attracted a lot of attention from the mathematical

community all round the world. In the next few years we won a large number of awards and in those days before Wikipedia the MacTutor archive became most mathematicians' favourite source on the history of their subject.

In 1994 there were only about 20,000 websites worldwide (there are more than a billion now). Ironically, as historians (even if only amateurs) we have been rather careless about our own history. We have few records of what our original Web pages looked like but then we were only doing it for fun. We were aware of deficiencies in the material — mainly because we had not designed the system specially for the Web but rather as an adjunct to our teaching material and we steadily worked to improve its scope and coverage. The earliest copy of our site documented by the WayBackMachine (web.archive.org) shows that by 1999 we had nearly 2000 biographies and were going through the process of rewriting and expanding that we have followed ever since.

Of course, over the years we have developed and expanded the archive. We now have biographies of about 2800 different mathematicians and continue to add to this at the rate of about 100 a year. At the moment the biographies amount to more than 4 million words: the equivalent of about 10000 pages! We have pictures of about 2400 of these mathematicians and more than 6500 pictures in all. The collection of History Topics has grown to 130 and amounts to about 360,000 words.

We have added extra material on a variety of topics linked to various mathematicians and included such things as lists of publications, reviews, transcripts of lectures and other topics which are often hard to find otherwise. We have more than 1000 items of this material. We have added more than 400 obituaries culled from various sources — some quite hard to track down in other places.

We have included a considerable number of people whom one might be surprised to find in a list of mathematicians. These include artists who were interested in geometry like Leonardo da Vinci, Piero della Francesca, Albrecht Dürer or Maurits Escher; architects like Filippo Brunelleschi or Christopher Wren; authors like Lewis Carroll or Thomas Carlyle as well as people like Éamon de Valera or Florence Nightingale.

Some of the features we have added have turned out to be very popular. Our *Mathematicians of the Day* page is used as a home page by many of our colleagues world-wide and the posters which are linked to it are printed off in many schools and mathematics buildings around the world. Our section on Quotations contains about 1000 guotations by mathematicians. We have some *Timelines* which give a graphical demonstration of how the lives of various mathematicians overlapped and we have a section on Chronology which lists important discoveries in mathematics chronologically. Our section on Mathematical Societies has accounts of about 180 societies. cross-referenced to the biographies. The section on Honours and Prizes lists the winners of nearly 150 prizes or other distinctions including those receiving such unexpected honours as having a lunar crater or Parisian street named after them. Our archive now consists of more than 50000 files and so the chore of maintaining it is considerable.



The Index page of our system in 2002.

Some parts of our system remain quite similar to the original HyperCard version. The section on *Famous Curves* is taken almost directly from our original version and the Pascal routines which allowed students to interact with the material were converted to Java by one of our graduate students. The section on *Mathematicians' Birthplaces* (which now contains about 1300 places) is similar to the original (though it was much easier to program in HyperCard than in html).

Our archive has been widely referenced. It has been cited in more than 300 books with titles as diverse as The wonders of radiology; Is God a mathematician; Nonlinear gravitodynamics and Sacred mathematics: Japanese temple geometry.

We have used our experience in working with the Web to take over the documentation of several other areas.

The British Mathematical Colloquium has been running annually since 1949. Since its organisation moves around with the conference there was no natural home to store its records. We have taken over responsibility for this and have made all the details available on the Web. These include the venues, lecturers, titles and committee minutes of the 70 meetings and an index of the more than 1300 speakers who have given addresses. At the moment M. F. Atiyah and E. B. Davies share the privilege of having spoken most times (five). We have committed ourselves to keeping this archive updated — even though this means pestering successive chairs and secretaries for copies of the latest minutes.



We have amassed a considerable archive on the *Edinburgh Mathematical Society*. This includes a history from its founding in 1883, transcriptions of the first fifty years of minutes of the Society as well as details (including photographs) of the 19 Colloquia which the Society has run (mainly in St Andrews). We have compiled details of all those who spoke to the Society and the titles of the more than 1900 lectures that they gave.

In 1927 the Society published a list of all its current members. We were able to find details of many of these and include (sometimes rather short) biographies in our archive. This, together with a natural tendency to favour our home country, explains why Scotland has 34 mathematical biographies per million inhabitants, compared to England's 5.1 per million. For comparison, France has 4.3, Germany has 3.3 and the USA has 0.9. Judged by this curious metric, Hungary comes second after Scotland with a score of 6.1.

We have included the *Davis Archive* of all the women graduating in mathematics from universities in Britain and Ireland up to 1940. This consists of about 2500

records and we have arranged for the archive to be browsed alphabetically, chronologically or by universities.

We noticed that David Singmaster's admirable *Mathematical Gazetteer* of the British Isles had been consigned to the limbo of the WayBackMachine. We thought that this collection of more that 400 entries was too interesting to leave there and so we have taken it under our wing. We have linked it to our biogra-



The impressive coverage of the *Gazetteer*.

phies and extended the ways in which it can be browsed. At the moment files in the Gazetteer are being accessed more that 1000 times a day, so it is clear that our efforts have not been wasted.

Many of the people in our archive are astronomers as well as mathematicians. The *Royal Astronomical Society* has encouraged us to highlight this connection and has funded some students to work with us in the summer on this aspect of our archive.

Usage of our system expanded as the Web has become more popular. At the moment we serve about 250,000 distinct users per week who download about 2 million files. Our record is about 2 million files downloaded on a single day — though we suspect this is partly due to various search engines that constantly crawl over us! The runaway increase in our usage which we once experienced has slowed probably due to the preponderance of Wikipedia as the top reference on many of the search engines.

When we started this project browsers and computers were much less powerful than they are now. Most users had much smaller screens and narrower bandwidth than is taken for granted now. So with our original system we went to some effort to optimise the way computing power was used. This gives our pages a somewhat stark look by comparison with some of the elaborate pages available elsewhere. However, an increasing number of users are now accessing the Web on hand-held devices like mobile phones or tablets and the MacTutor archive is admirably suited to this sort of presentation on these devices. An American colleague informed us that our website was used in a course on web design at his university as an example of what a website should aim to emulate.

Most of the work we did on the original MacTutor system was done in our spare time — an alternative to watching TV in the evenings. Most of our colleagues had little enthusiasm for developing teaching software and were happy to let us get on with it. We were, however, able to write some specialised models in fractals and differential equations that some of them were able to use in their own work. Most of the work we put into developing the website was also done at home, though the department did allow us to use its servers to mount our material and its scientific officers to oversee the running of it.

The history of mathematics has had a long connection with St Andrews. The University used to be a copyright library and so has an enviable collection of ancient texts. In the 19th Century the scientist James David Forbes was Principal of the University and added some priceless mathematical works to the library. In the 20th Century Herbert Turnbull was a long-serving professor of mathematics who was very interested in the history of the subject. The collection of mathematical portraits he collected still adorn the corridors of our Mathematical Institute, and indeed was one of the inspirations for adding portraits of mathematicians to our early archive.

We and some of our colleagues taught honours courses for many years and they were a popular student option. At one time some of our colleagues were rather dismissive of our efforts in promoting the history of mathematics, but in the last few years, as the Research Assessment Exercises have begun to emphasise so-called "Impact", they have come to realise how valuable an asset a system like ours has become. Our department has begun to commit more resources to the history of mathematics and we are sure that our archive has played a great part in this.

We are happy to carry on developing our system and now that both of us are retired from our teaching jobs, working with the history of mathematics has proved to be a very satisfying hobby. We are no longer the only source on the Web for the history of mathematics, but we can still feel that we cover the subject in greater depth than any of the others. When we want to extend one of our existing biographies and we search for information on a particular mathematician we constantly find various versions of our material spread around all over the world some of it even acknowledging us as the original source!

Keeping our system abreast of the constant changes in technology has proved demanding. We had to abandon our favourite HyperCard some years ago as it was no longer supported by any of our computers, and it seems that the software we replaced it with will probably share that fate in a few years. Finding a stable method of maintaining and continuing to expand our system, particularly when we have to hand it over to others, will prove to be an interesting challenge.

Finally, we would like to say how pleased we were to win the London Mathematical Society's first Hirst Prize and lectureship and that we have had a lot of fun as well as satisfaction in constructing and maintaining what we still regard as a very worthwhile resource.





### John J. O'Connor

John J O'Connor is an ex-topologist who taught at St Andrews for his whole career. He is amusing himself in his retirement by continuing with the upkeep of the MacTutor web archive.

#### Edmund F. Robertson

Edmund F. Robertson is Emeritus Professor of Mathematics at the University of St Andrews. In addition to research in computational group

theory, he is one of the two developers of the Mac-Tutor History of Mathematics web archive. Since retiring in 2008 he is still a regular attender of the Mathematical Institute coffee room and supervises undergraduate projects on the history of mathematics.

# An Approach to Less Climate-Impactful Conferences

DAVID AYALA, LUKAS BRANTNER, THEO JOHNSON-FREYD, ANDRÉ HENRIQUES, AND AARON MAZEL-GEE

Air travelling has a large and rapidly increasing impact on our global climate; as frequent conference goers, we all share an uncomfortable responsibility. We describe a modest attempt at reducing conference-related air travel while remaining true to the core benefits of scientific conferencing.

#### The cost of air travel on our global climate

The allure of international travel will be familiar to most academics. Indeed, such travel presents a raft of benefits: the chance to deliver a talk at prestigious conferences, to meet with collaborators, and to network and develop one's professional reputation.

However, this travel comes at a considerable cost, not just to our budgets and to our lifestyles (including family life), but also to the global environment. For those who regularly travel long-distance, flights will generally be responsible for the largest proportion of their carbon footprint. For instance, a single return flight from London to New York contributes to almost a quarter of an average UK citizen's annual carbon emissions [2]. While air travel is not the only contributor to global warming, the emissions from this sector alone could exceed the constraints necessary to remain within the +2°C goal of the Paris accord [1].

For detailed information on the anthropogenic impacts on our global climate, one may consult the International Panel on Climate Change's synthesis report [3], written by some of the world's most authoritative experts on the subject. They write ([3, p.20]): "Without additional efforts to reduce greenhouse gas emissions beyond those in place today [ $\cdots$ ] global mean surface temperature increases in 2100 range from 3.7°C to 4.8°C above the 1850-1900 average. They range from 2.5°C to 7.8°C when including climate uncertainty."

In short, in order to avoid *catastrophic* effects (cf. p.65 of [3]) of climate change on humanity, the global  $CO_2$  emissions must be reduced by roughly 50% in the next 30 years. In view of the overwhelming evidence supporting these dire predictions of the future, it seems unwise to ignore this situation or declare an inability to affect it.

#### What we did

We organised a 'double conference' with the following stated purposes:

- Lower the environmental impact (compared to other like events), by reducing the amount of flying.
- Raise awareness about climate change, and the responsibility that academics all share as frequent travellers.
- Spark the participants' imagination for the possibility of offering alternatives to the standard conference model, aided by present and forthcoming technologies.

In August 2018 we organised an international event entitled *Higher algebra and mathematical physics* (see tinyurl.com/y9dy4ef3). This event was a conference that was simultaneously held in two locations, one on each side of the Atlantic Ocean. One venue was the Perimeter Institute, in Waterloo, Canada; the other venue was the Max Planck Institute for Mathematics, in Bonn, Germany. The presentations and discussion sessions were live video streamed between the two institutes. The organisers, presenters, and other participants were adequately distributed between the two locations, and all were encouraged to attend the location that was closer to their home institution.

A typical presentation was an hour long, followed by questions from the audience. There was a 'live' audience, who shared the venue with the presenter, and a 'virtual' audience who participated via video link from the other side of the Atlantic. At the live venue, a video of the virtual audience was visible to the presenter and live audience. At the virtual venue, a video of the presenter was projected lifesize, and also a video of the live audience was visible via monitor or projector. Audience members at either venue were able to ask questions during the talk. Following the presentation, each venue would take turns soliciting questions for the presenter. With this concluded, video and audio would continue so that participants could ask the presenter further questions 'in-person'.

To our knowledge, this was the first implementation of such technologies for a mathematics conference.

Teleconferencing is typically inadequate for spontaneous informal mathematical discussion (and it would not be a stretch to suggest that such discussion is the primary utility of a mathematics conference). To facilitate such discussion, we set up two "wormholes" between the conference sites. Each wormhole consisted of a pair of 80-inch touch-screen monitors, one at each venue, set up as digital whiteboards with shared whiteboard environments and audio-video connections. Conference participants were encouraged to arrange transatlantic meetings, either using the wormholes or their private videocalling accounts.

#### What we learned

The participants of this conference were overall happy to be part of this experimental setup. They were generally forgiving of small technical glitches and provided useful feedback on how the technical setup could be refined in future.

We relied on state-of-the-art technology (notably, high-quality microphones that could pick up a presenter's voice, as well as sound from the audience) and on experienced technical teams who set up, tested, and controlled the technical equipment. It is our feeling that this double-conference format requires at least one person at each venue whose attention is entirely devoted to these technical aspects for the duration of the event as well as a couple days before for setting up the equipment. Current technology supports this double-conference format, but there is ample room for improvement, with prior set-up and testing being essential to the success of such an event in the future.

The organisers and technical support team communicated with each other through a chat forum to give constant feedback on adjusting aspects of the live stream. Having a large organising team was helpful for us to manage all the unforeseen tasks that accompanied the event. The wormholes were not as effective as we had hoped, due to technical problems.In the future, in order to spark increased use of these conference-wormholes, one could ask each speaker to hold an "office hour" after their talk at a pre-assigned wormhole.

Overall, we were very glad to have run this experiment, and two of us have already started organising a second double conference. As technology improves, we expect that such digital conferences will become an important tool in reducing the considerable carbon footprint of mathematicians' conference travels.

#### Conclusion

We encourage all academics to be thoughtfully aware and adequately informed of the environmental costs of international travel. While we do not advocate ceasing all long-distance travels (thereby risking intellectual fragmentation), we implore our academic community to experiment and seek realistic alternatives to air travel while not unduly sacrificing the present benefits of such travel.

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#### David Ayala

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#### Aaron Mazel-Gee

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# MathsWorldUK: Building a Mathematics Discovery Centre for the UK

#### KATIE CHICOT

MathsWorldUK was founded with the express aim of establishing the UK's first interactive Mathematics Discovery Centre, initially through touring exhibitions but ultimately with a full permanent site. This article introduces MathsWorldUK, its current activities, and its aims.

# Science discovery centres and mathematics in the $\ensuremath{\mathsf{UK}}$

Hands-on science discovery centres have been part of our landscape for the past fifty years, and have increased in number; today, 90% of the UK population lives within two hours of a science discovery centre.

As one might expect, it has been shown [2] that interactive science exhibitions increase visitors' knowledge and understanding of science. They provide memorable learning experiences which can have a lasting impact on attitudes and behaviour, and they promote inter-generational learning.



The four colour theorem

The positive example of the effects of science discovery centres has led to a movement to create a mathematics discovery centre.

Currently there are over 50 mathematics discovery centres around the world — the most popular have

annual visitors of up to 140,000 — but there is not a single one in the UK.

#### MathsWorldUK and its activities to date

MathsWorldUK was founded with the aim of establishing the UK's first interactive mathematics discovery centre. Since 2013 we have built a set of exhibits and activities that show the enjoyment of mathematical investigation as well as the surprising places mathematics appears in our lives. MathsWorldUK has taken these exhibits to a total of 14 fairs, including the Big Bang Fair and the Leeds Science Fair, reaching an audience of over 100,000.

Other successful projects are:

- Co-hosting (with the National Museum of Mathematics in New York) the second international MATRIX conference in September 2016. MATRIX stands for Mathematics Awareness Training, Resources, and Information eXchange and is essentially for people involved with mathematics museums and outreach from around the world.
- In 2016 we held the first schools competition to produce a short film communicating mathematics. This is now an annual competition jointly organised by the University of Leeds, MathsWorldUK, the United Kingdom Mathematics Trust and IMO2019Ltd.
- Joint hosting a teachers' continuing professional development activity at twilight sessions at the National Science and Media Museum in Bradford in 2017.

# Our vision of a national Mathematics Discovery Centre

The Mathematics Discovery Centre will be for all age groups, and all levels of understanding. It will contain



The ring of fire

12 themes or 'zones'. Each zone will consist of eight or more major hands-on exhibits, surrounded by various items covering related areas of mathematical impact or interest. The proposed zones are:

- (1) Mathematics of Health Research
- (2) Symmetry, Perception, Perspective Art in mathematics
- (3) Engineering and Materials
- (4) Logic and Problem Solving
- (5) Code Breaking
- (6) Fluid dynamics and Waves
- (7) Programming, robotics, digital
- (8) Chance, Risk and Number
- (9) The Mathematics of Planet Earth
- (10) The stars, space and time
- (11) Under 8's Mathematics Gallery
- (12) Sound and Music

The vision will evolve as we draw up plans and funding bids.

# MathsWorldUK next steps and what you can do to help

We are working towards establishing the Mathematics Discovery Centre in two stages. First we are raising funds for the creation of the contents of the exhibitions and the touring of the exhibitions around science discovery centres in the UK. Once five zones are funded and produced, we will begin to fundraise in earnest for the building of the Centre. We are creating the exhibition zones in partnership with subject experts, and identifying funding bodies for each of the zones.

The activities of MathsWorldUK are supported by volunteers, and we would like your support with this project. We welcome any ideas you may have for one of the museum zones, or your thoughts on the Centre. We are currently seeking volunteers for a fundraising committee, so if you have experience of large scale fundraising and would like to help then please get in touch. You can contact us on k.m.chicot@open.ac.uk.

Alternatively, if you are able to support the project financially then visit mathsworlduk.com. Donations made before June 2019 will be matched by our anonymous donor in the USA.

#### FURTHER READING

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The Science Centre Enrichment Activity Grant Project



### Katie Chicot

Katie Chicot, CEO of MathsWorldUK is a Senior Lecturer, Mathematics and Statistics in the Open University. Katie is on secondment from her senior manage-

ment role at the Open University to establish the UK's first Mathematics Discovery Centre with MWUK.

# Reciprocal Societies: New Zealand Mathematical Society



The New Zealand Mathematical Society (NZMS) was founded in 1974. Up until the early 1970's, coordination of mathematical activity in the

universities was managed through the National Committee for Mathematics (NCM) which consisted of the heads of the Mathematics Departments at the various NZ universities. By 1973 it was felt that it was time for a national society for mathematics, and a proposal for the formation of the NZMS was developed. There was some opposition to the formation of the NZMS from the NCM, who felt they might lose influence, and some thought that a merger with the Australian Mathematical Society would be more appropriate, but the NZMS was eventually formed.

The NZMS currently has about 260 members. The members are mostly staff and students of tertiary institutions in NZ from the disciplines of pure and applied mathematics, and mathematics education. The activities of the NZMS include sponsorship of conferences, co-publication of the New Zealand Journal of Mathematics, publication of a regular newsletter, allocation of travel funds for students, participation in the activities of the Royal Society of NZ (of which the NZMS is a Constituent Organisation), and involvement in various visiting lectureships with other societies. In recent years, the NZMS has also become more involved in promoting and supporting an equitable environment within the NZ mathematics community, particularly with regard to gender equity, and with supporting outreach to schools and the wider community. The Society's Education Subcommittee has a diverse membership including secondary teachers, professional teaching fellows and other academics. This subcommittee seeks strong links with teachers, and makes submissions to government on the mathematics curriculum in high schools.

The main meeting of the NZMS occurs at the annual NZ Mathematics Colloquium. The first Colloquium was held in 1966, before the formation of the NZMS, and responsibility for local arrangements rotates between the universities. In addition to enabling NZ mathematicians to meet and discuss research with their colleagues and visitors to NZ, the Colloquia pro-

vide a supportive venue for student talks and poster presentations, and opportunities for the mathematics community to address issues such as diversity in the community.

The NZMS values its links with the London Mathematical Society (LMS), particularly the two visiting lecturer schemes that are co-ordinated by the societies.

In 1986 the LMS, in consultation with the NZMS, instituted a Lectureship to NZ. The Lectureship is named after Professor H.G. Forder, formerly of the University of Auckland, and a benefactor of the LMS. The Forder Lectureship normally occurs in even-numbered years, when a mathematician from the UK is invited to give lectures at most uni-



Henry Forder

versities in NZ. Forder lecturers are chosen for their eminent contribution as research mathematicians and their skills in presentation at technical and popular levels. The inaugural Forder Lecturer was Christopher Zeeman and there has been a steady stream of fine lecturers since, with Valerie Isham the 2018 Forder Lecturer.

In 2009, the LMS and the NZMS agreed to set up a new Lectureship, named after Professor A. Aitken, a NZ mathematician who had a distinguished career at the University of Edinburgh in the first part of the 20<sup>th</sup> century. The Aitken Lectureship occurs in odd numbered years, when a mathematician from NZ is invited to give lectures at different universities around the UK. The next Aitken Lecturer, Bakhadyr Khoussainov, will visit the UK in mid-2019. Further information about the NZMS can be found on its website nzmathsoc.org.nz.

Vivien Kirk (President of the NZMS) Kevin Broughan (Member of Council of the NZMS)

Editor's note: the LMS and the NZMS have a reciprocity agreement meaning members of either society may benefit from discounted membership of the other.

# Applying for Jobs in Europe

Following the feature in the September 2018 issue on applying for jobs in the US, we invited three colleagues to offer some tips on applying for jobs in France, Poland and Sweden.



**Vasiliki Evdoridou** is a Postdoctoral Research Associate at the Open University, with research interests in the area of Complex Dynamics.

When looking for positions in Europe, Poland could be one of your

options. There are several strong mathematical groups in Poland. In addition to the variety of universities throughout the country, there is also the Institute of Mathematics of the Polish Academy of Sciences (IMPAN). Its base is in Warsaw, and it has smaller branches in other cities in Poland. Although there may be some calls for postdoc positions in some of the universities, this is unfortunately rather rare these days.

However, IMPAN has regular open calls for postdoc and associate professor positions. In particular, there are usually two calls for postdocs every year, one in winter (usually in January) and one in spring (usually in May). These are several  $\frac{1}{2}$ -2 year positions in the research groups at IMPAN. More specifically, the call in spring is aimed at young researchers with at most two years of postdoc experience. This call welcomes PhD students who are about to obtain their PhD degree too.

The best thing to do is to contact a member of IMPAN who has similar research interests to you, and express your interest. There are groups working on a variety of research areas including Algebra and Algebraic Geometry, Differential Equations, Dynamical Systems, Functional Analysis, Number Theory and Topology. Your application needs to include a research plan and you should indicate a member of IMPAN under whose guidance you will work should you obtain the position.

Moreover, there are frequent calls for 3–7 year assistant/associate professor positions, designed for experienced researchers, which give you the opportunity to create your own research group, or to join

one of the existing ones. You will find information about the institute at impan.pl/en.

Please note that you will usually need to send by post all the documents required for the application, so it would be a good idea to prepare your application well before the deadline.

From time to time there are also some calls for positions — both postdoc and permanent (at the level of associate professor) — associated to specific projects.

One thing to keep in mind is that the positions at IMPAN are not advertised on many well known websites. So if you are interested you should keep an eye on impan.pl/en/events/competitions.



**Olof Sisask** is a Senior Lecturer in Mathematics at Uppsala University, with interests in Fourier analysis, combinatorics, probability and number theory.

Finding and applying for jobs in mathematics in

Sweden is for the most part a fairly straightforward process, with one or two perhaps unusual aspects.

Job openings usually turn up on the website Nordic-Math-Job (tinyurl.com/ycthzpz4), which lists links to job adverts at many of the research-active institutions around Sweden. International applicants are welcome; most institutions offer their job adverts in both Swedish and English, and the working research language is usually English. One normally has 2 years to get on top of Swedish for jobs that involve teaching. The types of positions available are typically postdocs, tenure-track lectureships, tenured lectureships and professorships. Postdocs almost always have a maximum duration of 2 years.

The application process itself is usually fairly straightforward, involving the usual combinations of CVs and research and teaching statements, usually in English, but usually no letters of recommendation. Some institutions require a certain application template to be used, which can make the process more time consuming.

The most noteworthy aspect of the whole process perhaps lies in how applicants are assessed. After the deadline, the department will usually appoint a panel consisting of 3–4 external referees (often from outside Sweden) to assess all the applications. These will narrow the list of applicants down to a top group of about four people who get called to a trial lecture and interview. The external panel is present for these, and then produce a final ranking of this top group. The department is then to a large extent expected to appoint the panel's top-ranked candidate.

The written assessments produced in this process are usually sent to all the applicants afterwards, or are available upon request.

One can also apply for research funding from various sources in Sweden, whether one is already at an institution in the country or not — but the grants are usually to be hosted at a Swedish institution. The main source is Vetenskapsrådet (see vr.se), the Swedish Research Council, who have deadlines a couple of times a year. They offer funding for up to four years for various types of positions and projects. Tenured lecturers in Sweden are expected to apply for this funding on a regular basis, in order to fund their research time, which tends not to be budgeted for in the departmental funding to the same extent as in the UK.



**Marthe Bonamy** is a CNRS researcher at LaBRI in Bordeaux, with interests in graph theory and graph algorithms.

France has a reputation for loving exceptions. It is no surprise, then, that the academic

market can be baffling at first. As an early-career researcher, you can get two types of permanent positions: Maître(sse) de conférences (universitybased position with 192 hours of teaching per year, the rest devoted to research and various duties) or Chargé(e) de recherches CNRS (national research-only position)<sup>1</sup>. In the first case, speaking French fluently is unsurprisingly a requirement in most places. While the attractiveness of such a position varies a lot depending on the university (better students, better amenities, or fewer duties to share between the faculty members), there is one unusual nationwide feature to the recruitment process. Prior to applying for any such job, one needs to obtain a "qualification", which has to be requested in October roughly a year before the desired starting date. All the information can be found here: cnu27.iut2.upmf-grenoble.fr (in French, as part of the fluency test). Please note that there are many different sections corresponding to various fields, and that you may well be eligible for more than one (for example, in my community of combinatorialists, it is not uncommon for someone to be "qualifié" for sections 25, 26 and 27). It is worth keeping an open mind about which sections to apply for. The job openings are all available through the not very user-friendly website Galaxie<sup>2</sup>.

In the second case, speaking English is sufficient. There are even examples of long-time chargés de recherche CNRS still having barely more than survival skills in French, though of course that may dampen the experience. A CNRS researcher is always part of the workforce of a university, but there is significant flexibility regarding switching universities. Very casually speaking, the CNRS hires researchers then lends them to partner labs. Thankfully, a researcher is only ever reassigned at their request. The application process usually starts in early January for possible starting date on 1<sup>st</sup> October, see the website cn6.fr for more info. Note once again that there are different sections, though they are independent from the ones previously mentioned (people I collaborate with are typically part of sections 6 or 7).

In both cases, one factor which cannot be overestimated is obtaining strong local support. For CNRS, you need to suggest three labs that you could be sent to, and actually justify how your research proposal will fit there: each of the labs sends a letter discussing the different candidates that expressed interest in being sent to them. These ties should ideally be developed more carefully than through an email shortly before the deadline — it is often good to visit and give a seminar, or at least to have extensive discussions over email or Skype. Once they are convinced that they want you as a colleague, they will most probably help you navigate the often confusing French system (I promise that you can survive it!).

 $<sup>^{1}</sup>$ Let us also mention Inria, another institute similar to CNRS, though dedicated to more applied areas of Computer Science  $^{2}$ Available through the cnu27 webpage

# Mathematics Rebooted: A Fresh Approach to Understanding

by Lara Alcock, Oxford University Press, 2017, £19.99, US\$ 25.95, ISBN: 978-0-198-80379-9

Review by Michael Grove



In its synopsis, Mathematics Rebooted: A Fresh Approach to Understanding makes the claim that if you would like to understand more mathematics, and were interested in the subject at some point in your past, then you should read this book. Attempting to write a text which intro-

duces a range of ideas that build from arithmetic and go on to encompass number theory and geometry, for a broad and diverse audience, is a bold move. Yet this book does this rather well through an almost conversational style of writing, and one that allows the personal perspectives, experiences and opinions of the author to shine through.

This isn't, however, a book for everyone, there is too much mathematics in it for that. The widespread use of equations, identities, calculations and diagrams to support the explanations is not for those who are truly terrified. But, at all times the author makes a point of beginning each chapter by presenting and discussing mathematical ideas in their fundamental form before building towards more advanced notions. Certainly, there are occasions where it overlooks some of the subtleties when a particular topic is introduced, which the author acknowledges in her introduction, but doing so allows the non-specialist, or non-familiar reader to instead focus upon the substantive, and underpinning, mathematical ideas rather than the nuances which can sometimes mask them. This book is less about the presentation of mathematical facts, and more about the development and understanding of key mathematical ideas, and their connections, through a well-structured process of mathematical reasoning which the reader is carefully guided through.

And here is where perhaps the greatest strength of this book lies. You only have to look at the comprehensive references section to see the way in which the author has drawn upon findings from mathematics education. Findings about how individuals learn and where common misconceptions, or 'blocks' in understanding lie, have been used to shape the ways in which ideas are introduced, and the way in which reasoned mathematical arguments are used. Indeed it even begins with tips for the reader on how to read the content so as to be able to appreciate, and understand, the mathematical concepts that follow. Throughout, the book seeks to ask questions of the reader, and encourages him or her to think about particular mathematical ideas before moving on. That said, this is not an introductory mathematics textbook, nor a review of current pedagogical theories, but then it doesn't pretend or claim to be. It is instead a book that introduces and explains the most fundamental ideas that underpin our discipline, but crucially it does so in a way that the author has carefully thought through with a view to making these understandable to the reader.

The book recognises that individuals will read to different points, and you can see where these are in the way chapters are structured. Indeed for such a broad intended audience, there will be those that want to know more, and understand why certain results are so. This book caters for these readers too as mathematical ideas and concepts are often revisited and reinforced later in the text. Take, for example, Chapter 4 which asks the reader to accept the fact that  $(-r)^2 = r^2$ , but revisits this in Chapter 5 to help the reader understand why this is true. Throughout, examples are very well used to make links between the fundamental mathematical ideas and introduce

the terminology that is vital to understanding our discipline.

Experienced mathematicians may not learn any new mathematical ideas, but this book will certainly help all to appreciate the different ways in which others think about them. Going beyond the content, the style of the book encourages you to not only reflect upon your own mathematical understanding of fundamental topics, but also the way in which we might communicate them. Although those currently teaching mathematics were not listed amongst its intended audience, I am sure that they too will find something of value here.



#### Michael Grove

Michael Grove is a Reader within the School of Mathematics at the University of Birmingham. He is also Honorary Secretary of the Institute of Mathematics and

its Applications with responsibility for education. Michael has a number of hobbies that seem to depend upon the time of year, most notably DIY, playing the guitar, and the latest being an attempt to finally master the game of golf.

# Equivalents of the Riemann Hypothesis, volumes one and two

by Kevin Broughan, Cambridge University Press, 2017, £195, US\$ 250, ISBN: 978-1-108-29078-4

Review by R.S. MacKay



Riemann's hypothesis is considered by many to be the most important open problem in mathematics. It has resisted 150 years of attempts by a large number of fine minds to either prove or disprove it.

In these two volumes, Kevin Broughan surveys in detail a wide range of

equivalents of Riemann's hypothesis.

I state the Riemann hypothesis in the form given by Riemann himself, namely that all zeroes of the entire function

$$\xi(t) = 4 \int_1^\infty \frac{d(x^{\frac{3}{2}}\psi'(x))}{dx} x^{-\frac{1}{4}} \cos(\frac{t}{2}\log x) \ dx$$

are real, where Jacobi's  $\psi(x) = \sum_{n=1}^{\infty} e^{-n^2 \pi x}$ . Most subsequent authors changed Riemann's notation by writing  $\xi$  as a function of s = 1/2 + it. Broughan continues the latter convention but in this review I translate to Riemann's form.

The fundamental significance of the Riemann hypothesis is for the distribution of primes, namely Riemann's hypothesis is equivalent to  $\pi(x) - li(x) = O(\sqrt{x} \log x)$ , where  $\pi(x)$  is the number of primes less than x and the logarithmic integral li(x) is the principal value of  $\int_0^x \frac{dt}{\log t}$ .

In the quest for proofs or disproofs of the Riemann hypothesis, and hence of the above statement, many people have come up with other equivalents. Such equivalents allow you to keep an open mind about whether you want to try to prove Riemann's hypothesis true or false. They will also allow you to deduce many things as soon as you prove it or disprove it. The first volume surveys the principal arithmetic equivalents of the Riemann hypothesis. They are weird and wonderful. Here are some examples:

- Schoenfeld  $|\psi(x) x| \leq \frac{\sqrt{x}\log^2 x}{8\pi} \quad \forall x \geq 74$ , where Chebyshev's  $\psi(x) = \sum_{p^m \leq x} \log p$ ;
- **Littlewood**  $\sum_{n \le x} \mu(n) \ll x^{\frac{1}{2}+\varepsilon} \quad \forall \varepsilon > 0$ , where Möbius'  $\mu(n)$  is 0 if *n* has a repeated prime factor, else  $\pm 1$  according as the number of prime factors is even or odd;
- $\begin{array}{l} \mbox{Robin } \sigma(n) < e^{\gamma}n\log\log n \; \forall n \geq 5041, \mbox{where } \sigma(n) \\ \mbox{is the sum of the divisors of } n \mbox{ and } \gamma = \\ \lim_{n \to \infty} \sum_{m=1}^n 1/m \log n; \end{array}$
- **Nicolas**  $\frac{ne^{-\gamma}}{\varphi(n)} < \log \log n + \frac{4+\gamma-\log 4\pi}{\sqrt{\log n}} \quad \forall n \ge N_{120569},$ where Euler's  $\varphi(n)$  is the number of integers in [1, n] coprime to n, and  $N_k$  is the product of the first k primes.

Perhaps the most delightful is the Caveney-Nicolas-Sondow equivalent: the only extraordinary number is 4 (where "extraordinary" is defined in terms of abundance of divisors).

The second volume surveys many analytic equivalents of the Riemann hypothesis. It begins with the Riesz and Hardy-Littlewood equivalents, about growth of certain power series with coefficients involving the zeta function at even or odd positive integers respectively. Next is the Nyman-Beurling criterion about certain subsets of a Banach space having dense span. This is followed by Lagarias' criterion that the logarithmic derivative of Riemann's  $\xi$ has positive imaginary part in the lower half plane, the Sondow-Dumitrescu criterion that  $|\xi|$  is strictly increasing along vertical lines in the upper halfplane, and Li's criterion about the positivity of certain sums over the zeroes of  $\xi$ . Many other equivalents are treated, though the volume is not encyclopaedic. The last one I'll describe is the de Bruijn-Newman criterion. This is a tautology in my opinion but interesting nonetheless. Riemann's  $\xi$  can be considered as  $\xi_0$  in a family  $\xi_{\lambda}$  of functions such that  $\partial \xi / \partial \lambda = \partial^2 \xi / \partial t^2$ . Diffusion never creates real zeroes and it removes multiple ones. There is a  $\Lambda \in \mathbb{R}$  such that for  $\lambda \leq \Lambda$ all zeroes are real and for  $\lambda > \Lambda$  there are some complex ones. So Riemann's hypothesis is equivalent to  $\Lambda \geq 0$ . Newman conjectured that  $\Lambda \leq 0$  and this has recently been proved by Rodgers and Tao [4] (NB: who use the opposite sign convention). So the

Riemann hypothesis is equivalent to  $\Lambda = 0$ , and if the Riemann hypothesis is true it is on the edge of being true, which may explain why it is so difficult to settle.

Broughan's two volumes are not an introductory text, so the uninitiated would be well advised to first read something that starts from the beginning. For example, alternative surveys of equivalents of the Riemann hypothesis, with introductory material, appear in Conrey [3], Chapter 5 of Borwein et al. [2], and Section 4 of Balazard [1], but they are nowhere near as comprehensive as Broughan's two volumes. He gives proofs for most of the stated results.

Nonetheless, Broughan does summarise basic material, making the two-volume set self-contained, and with a minimum of cross-referencing between them. He has also written Mathematica scripts to evaluate many relevant functions, available on his website, which allow one to play around and reproduce various steps.

The two volumes are a very valuable resource and a fascinating read about a most intriguing problem.

#### FURTHER READING

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#### Robert MacKay

Robert MacKay is a Professor in Mathematics at the University of Warwick and Director of Mathematical Interdisciplinary Research. His main research interests

are in dynamical systems and their applications, but he developed an obsession with Riemann's hypothesis, starting on New Year's day 2015. He used to fantasise about becoming a rock star but settled for a safer life as an academic.

# Differential and Complex Geometry: Origins, Abstractions and Embeddings

by Raymond O. Wells, Jr., Springer, 2017, hardback, pp319 + xiv, £56.99, ISBN 978-3-319-58183-5.

#### Review by Jeremy Gray



It is likely that the first mathematician to draw a clear distinction between intrinsic geometric properties of a figure and those of its embeddings was Bernhard Riemann in his famous paper of 1854 (first published in 1867) *On the hypotheses that lie at the foundations of* 

*geometry.* Prior to that one might say that all figures came naturally embedded, either in the plane or three-space.

This book gets us to this decisive point via a leisurely account of aspects of the work of most of the familiar names in geometry before Gauss, including Monge and Poncelet. Then it gives a clear summary of Gauss' proof of the Theorema Egregium, which says in our language that curvature of a surface is invariant under isometries. After this we get a survey of Riemann's higher-dimensional geometry, concentrating on some of the key results but with no more mathematical detail than is necessary.

Next comes complex geometry, which proceeds via an account of elliptic and abelian integrals and elliptic functions to a quick history of complex analysis, and on to Riemann surfaces and the Riemann-Roch Theorem. This part of the book ends with the uniformisation theorem for Riemann surfaces and Weyl's book *Die Idee der Riemannschen Fläche* (1913).

The final, and for most readers probably the most interesting, part of the book is on twentieth-century embedding theorems. In four consecutive chapters we get Whitney's, Nash's, and Kodaira's theorems for differentiable, Riemannian, and compact complex manifolds respectively, and then a survey of what can be said about non-compact complex manifolds. Given the difficulty of the material, these chapters are a remarkably effective introduction to these major results. Key concepts are explained, proofs are outlined, the crucial difficulties described along with enough hints about their resolutions to be instructive. The account of Nash's work, for example, is considerably more elementary than the recent accounts in the *Bulletin of the AMS* (vol. 54.2, 2017). Graduate students in geometry would be well advised to read this part of the book, and there are several references to other accessible accounts.

The final part of the book differs from the previous parts in various ways. Each chapter is aimed at indicating what the subject area was, why a particular theorem was desirable, and then how the discoverer of the appropriate result went about it. In each case there is no dispute about the originality, or indeed the nature, of the contribution of Whitney, Nash, Kodaira, or Grauert, Remmert, Narasimhan, and Bishop, although of course, as Wells indicates, other mathematicians were also involved. This gives the author not only a simple selection criterion but a clear focus for the chapters. In fact, this book is two different books yoked together. The twentiethcentury material is described well, and the information it conveys is not readily found in one single place. The difficulty of the mathematics has not yet drawn historians to examine it in any detail, so an account of the acknowledged highlights is still the best one can do historically.

The same cannot be said of the earlier material. These pages are adorned with a wealth of illustrations, frontispieces, and copies of opening pages (displaying them in their original languages) The profusion of reproductions of pages is charming, but the overall account is not historical — nor, indeed, does Wells say that it is. He aims, he says, to give readers "some sense of the language and understanding of the earlier mathematicians" (p. vii). To do this he modernises the expositions and imposed modern estimates of their significance. The effect is something of a projection from the tangled space of earlier concepts and methods onto a simpler space of what we would expect Gauss, Riemann, and company to say if they were graduate students now. This has many virtues: it moves things along because it is mathematically clear, introduces important ideas that will matter later, and does indeed give a sense of what was going on. But it can unfortunately repeat ideas that historians of mathematics have shown to be be at best misleading, if not indeed wrong. For example, Descartes did not define geometric objects to be solutions of algebraic equations, as Wells insists on p. 7. As Bos has shown at length in [1], curves were geometric objects to Descartes, and as such to be drawn by linkages; a considerable amount of La Géométrie was devoted to discussing how this could be done. Elsewhere, say in the chapters on complex geometry, complexity, muddle, and even aspiration are leeched out of the historical story. This is largely the consequence of decision to communicate the mathematics clearly by anachronistically granting 19<sup>th</sup> century mathematicians modern concepts, but it is regrettable that the author has not consulted the body of reliable historical literature that does exist, and does not even direct his readers to it. As a result, some of the understanding of the original mathematicians is lost.

#### FURTHER READING

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### Jeremy Gray

Jeremy Gray is an Emeritus Professor of the History of Mathematics at the Open University, and the author of a number of books on the subject. He is currently writing

short stories and revising a play about human genetics.

# **The QJMAM Fund for Applied Mathematics**

The Quarterly Journal of Mechanics and Applied Mathematics (QJMAM) fund supports UK Applied Mathematics. The fund, which aims to distribute up to £75k each year, is administered by the Institute of Mathematics and its Applications, but decisions on the award of grants are made by a panel appointed by the Trustees. The next round will open in February and close on 1 March. Further details, including the rules of the fund, closing dates and instructions on how to apply can be found at https://ima.org.uk/support/grants/qjmam-fund/

Applications will be invited under a number of headings, expected to include: Conference and workshop organisation, conference travel, collaborative research visits and academic-industrial collaborations. Priority will be given to applications that clearly enhance the fields of mechanics and applied mathematics and award recipients will be encouraged to report their research findings in QJMAM.

The Trustees also intend to award an annual prize (*the QJMAM Prize*) for the best paper in QJMAM in the previous calendar year; they will make the award on the basis of recommendations by the Executive Editors of the journal.

**The Trustees:** John King (john.king@nottingham.ac.uk), Chris Linton (C.M.Linton@lboro.ac.uk), Andrew Norris (norris@rutgers.edu) and Tim Pedley (T.J.Pedley@damtp.cam.ac.uk).





#### OBITUARIES

# **Obituaries of Members**

### Kay Magaard: 1962 – 2018



Kay Magaard, who was elected a member of the London Mathematical Society on 15 September 2008, died suddenly of undiagnosed coronary artery disease on 26 July 2018, aged 56.

#### Corneliu Hoffman and Ter-

rie Magaard write: Born in Kiel, Germany, Kay spent an idyllic childhood playing in the woods and swimming in the lake in the nearby leafy city of Preetz. At the age of 12, his parents, the mathematician and oceanographer Lorenz Magaard, and laboratory technician, Ursula Magaard, née Böehme, moved with him to Honolulu, Hawaii. Kay spent half of his personal and professional life in the United States and Canada and half in Europe.

Graduating from high school in Honolulu at age 16, Kay completed his BA in Mathematics at the University of Hawaii. His friends remember being impressed with his memory and concentration as he attended all lectures but never took notes. Kay then attended Bonn University and graduated with his Diploma in 1986. He returned to the United States and completed his PhD at Caltech under Michael Aschbacher in 1990 with a thesis on the maximal subgroups of the Chevalley groups  $F_4$ .

Before taking up a permanent position at Wayne State University in Detroit in 1991, Kay visited Yale University for a year. There he met his future wife, Terrie Romano, a native of Windsor, Canada (across the border from Detroit), a historian of science and later Canadian diplomat. Kay and Terrie were to spend the rest of his life together and had two sons Lorenz and Carlo.

He worked at the University of Birmingham between 2007 and 2017. During his last year, Kay moved with Terrie to her new posting in India, which was his base for fruitful research trips to Europe, California and South Africa. When he died, Kay was enthusiastically preparing for his new position at the University of Arizona.

Mathematics was Kay's true passion and he was always ready to discuss the subject with anyone. He was a tireless and generous researcher; his list of publications includes 66 papers and 68 coauthors from 12 different countries. Throughout his career he supervised six PhD students and mentored countless young researchers. He visited numerous universities and research centres on six continents.

Kay's research interests were broad, ranging from Algebraic Geometry and Number Theory to Representation Theory. However, he was first and foremost a group theorist. He loved the subject and worked tirelessly both in researching and promoting the field. Kay coorganised many conferences and special semesters, the last of which will be a special semester at the Isaac Newton Institute in Cambridge in the Spring of 2020.

Outside of Mathematics Kay was widely read in history and geography and could equally easily discuss Alexander the Great's campaigns or battles of the American war of 1812. The grandson of a Lutheran minister, Kay was proud of his family's history and role in the Reformation. He loved music and art and enjoyed attending punk rock concerts and art exhibitions. Our mathematics conversations were often expertly interlaced with quotes from the Dead Kennedys, a band we both loved.

He was also passionate about politics and social justice. He served as the vice-president of the Birmingham UCU.

Beginning with the lake in Preetz, water was a constant theme in Kay's life — an expert swimmer, he loved sailing, boogie boarding in Hawaii's large waves and spent many happy days on the beaches of the Pacific, the Atlantic and the Great Lakes.

Kay was also extremely hospitable — he and his family hosted many mathematicians for weeks or even months on research trips or while they looked for permanent accommodation. An excellent cook, most famous for his pizzas, he was often the centre of impromptu dinner parties for visiting colleagues, family, friends and neighbours.

Kay truly embodied Gandhi's admonishment to live as if you were to die tomorrow and learn as if you were to live forever. He will be sorely missed.

### John Meldrum: 1940 – 2018



Dr John D.P. Meldrum, who was elected a member of the London Mathematical Society on 15 March 1973, died on 9 August 2018, aged 78.

*Carl Maxson writes:* John Meldrum was born in Rabat, Morocco. His

early schooling was in Casablanca until age 16 when his family returned to England settling in Ipswich. John entered Cambridge University, Emmanuel College in 1958, receiving a B.A. with First Class Honours in 1961, an M.A. in 1965, and his PhD in 1966 under the supervision of Derek Roy Taunt. The main part of his dissertation *Central Series in Wreath Products* was published in 1967 in the Proceedings of the Cambridge Philosophical Society. John's last publication in 2016 also contained material on wreath products. John met his wife, Pat, in Cambridge at St. Barnabas Church, and they were married on 30 March 1968. Pat died on 4 May 2011.

John remained at Cambridge until 1969 serving as a Fellow and College Lecturer in Pure Mathematics at Emmanuel College. He moved to the Department of Mathematics, University of Edinburgh in 1969, where he remained until his retirement in 2005. John was a teacher and a mentor. He supervised six PhD students and served as the host and mentor of a number of young mathematicians. I quote from one of his PhD students, Sarwar Abbasi: "John will always remain alive in our hearts and minds. He was a role model for me. He was not only a great mathematician but also a very gentle, kind and honest person. I always felt myself a lucky student to have him as my research supervisor. When I joined him in 1985 at Edinburgh University, I knew nothing about research in Mathematics. He made me able to accomplish my goal and his guidance made me what I am today. May his soul rest in peace."

John Meyer, a professor from the University of the Free State in South Africa, writes: "I met John in the early 1980's when he visited Stellenbosch in South Africa. It was during this visit that he and Andries van der Walt coined some new ideas which eventually became the topic of my PhD dissertation. John was therefore instrumental in putting me on the launching pad of my mathematical career. Shortly afterwards, in 1990, I paid him a visit in Edinburgh for a period of four months — a period during which I got to know him and his wife Pat very well. During later years, several further visits followed, in both directions, and we also met at several conferences. I have very fond memories of all these visits. I was especially touched by his kindness, his gentleness, his sense of humour, and the way in which he cherished and lived his Christian values. He will be greatly missed, not only by the mathematical community with who he closely collaborated, but also by his many friends. In particular, I am filled with gratitude for the lasting positive influence he had on my life. He was a good man."

John's main research area was in the broad subject of algebra but more specifically in the subject of near-rings generated by a semigroup of distributive elements, referred to as d.g. near-rings. He had over 70 publications including two books, *Near-rings and their Links with Groups and Wreath Products of Groups and Semigroups.* Moreover he translated a French book on the history of mathematics into English and served as a co-editor of the Proceedings of the 1997 Stellenbosch near-ring conference.

John's 1985 book on near-rings was the second book written on this topic and had a focus quite different from the book by G. Pilz (1977, revised 1983) which is a thorough and almost complete survey of the subject. The first part of the Meldrum book is a gentle, detailed introduction to the general area of near-ring theory while the second part reflects John's interest in the flow of information between groups and associated near-rings. It remains a classic and continues to be the main reference to d.g. near-rings.

Most of John's research was in this area of d.g. nearrings with particular emphasis on near-rings of functions on non-abelian groups generated by group endomorphisms. John was the unquestionable leader in this arena of near-rings and was so recognized.

However, there are other areas of near-rings influenced by John. Together, with Andres van der Walt, John initiated the study of matrix near-rings. Because of the lack of one distributive law and commutativity of addition in near-rings, this topic required new definitions, insight, and constructions. Research on matrix near-rings continues to be an active research topic.

John was a deeply religious man, a committed, active church member, a man of intelligence and integrity, a man who had a profound love for his family. He will be sorely missed but has left many wonderful memories for those who knew him. The world is a better place because of him.

### John Wallington: 1924 – 2018



Dr John Wallington, who was elected a member of the London Mathematical Society on 21 November 1957, died on 4 September 2018, at the age of 94.

Catherine Wallington writes: John was born in

Chalfont St Peter, Buckinghamshire in 1924. When he was about seven the family moved to Dordrecht in the Netherlands and for several years he attended school there. As all lessons were conducted in Dutch, he, with his sister and brother, had to learn the language very quickly.

After a few years the family moved back to England and John attended Watford Grammar School. While there he became a good gymnast and with the school gymnastics team performed in the War Room in London. He obtained a state scholarship to Queens' College Cambridge, where he matriculated in 1942 to read Mathematics and Mechanical Sciences. His studies at Queens' were interrupted by World War II and he undertook his war service from 1944 to 1946 in the Royal Engineers at the Royal Aircraft Establishment, Farnborough working under Major Green. He co-authored with Major Green a paper on Aircraft Propulsion with particular reference to turbines, which was published in 1947. He was called up for national service in the Royal Engineers from 1946 to 1948 and during this time was posted to Fort George in Scotland and Harwich. His experiences at Farnborough led to him changing the focus of his studies from an engineering bias to pure mathematics. On returning to Queens', John went on to obtain an MA in 1949 and was awarded a PhD in 1957 for his thesis Some Properties of Incidence Varieties.

After leaving Queens', John became a lecturer in Pure Mathematics at Hull University in 1954 where he remained until his retirement, discovering a keen interest in and aptitude for teaching. In addition to lectures and tutorials, he also played a role in the administration of the department. He acted as external examiner at St Andrews University and for several years at Edinburgh University.

John had a great interest in the outdoors and the environment. In his younger days he was a keen walker and cyclist. On one occasion he walked home to Rickmansworth from Queens' and he regularly cycled to and from Rickmansworth during periods of leave while at Farnborough. He regularly went on walking holidays on his own, with his brother Peter and with friends from Queens', mainly in Scotland and the Lake District, and this interest continued in later life. Photography was another major interest, as was poetry and boating. As a family we spent many holidays afloat on the Norfolk Broads and in Ireland. John also enjoyed the many holidays spent in France. He had a great love of classical music and regularly went to concerts held at the concert hall of Hull University.

John married Henriette in 1954, a happy marriage that lasted until her early death in 1999. His father-in-law was himself a mathematics teacher, firstly at the Lycée in Valenciennes (Nord) where Gustave Choquet was one of his pupils. John was unfortunately badly affected by Alzheimer's in the last few years of his life. He is survived by his daughter Catherine and son Peter.

Former colleagues Roy Dennett et al write: John joined the Department of Mathematics at Hull University in 1954, the year that Hull was granted full university status having previously been an external college of The University of London. Soon, separate departments of Pure and Applied Mathematics were created. Bill Cockcroft was Professor of Pure Mathematics but he was becoming very involved with mathematics at the national level and it fell to John and his colleague Geoff Roberts to oversee the day to day running of the department. This was an onerous task which they carried out unselfishly until their retirement, probably to the detriment of their careers. John was extremely good at admin — a meticulous scrutiniser of examination questions with a comprehensive command of University Regulations. Initially of course, all this was before the advent of photocopiers (there was a Gestetner in the departmental office), word processors and spreadsheets. He also had to contend with a fire in the department which destroyed most of the contents of his office!

Throughout his career at Hull John divided his time between his administrative duties and his undergraduate teaching, delivering beautifully precise lectures mainly in courses in algebra. He was calm, courteous, approachable and provided a great source of information and support for both new members of staff and students.

### Paul Busch: 1955 — 2018



Professor Paul Busch, who was elected a member of the London Mathematical Society on 4 March 2000, died on 9 June 2018, aged 63.

Stefan Weigert writes: Born in Refrath near Cologne on 15 Febru-

ary 1955, Paul grew up as the eldest of six brothers. He studied physics, mathematics, chemistry and philosophy at the university of Cologne. In 1982, he obtained a PhD with a thesis supervised by Professor Peter Mittelstaedt, a leading figure in the foundations of physics. Paul's Habilitation (1988), at the time a necessary qualification for an academic career in Germany, was followed by his appointment to Extraordinarius in 1995. In the same year he joined the Department of Mathematics at the University of Hull as a Lecturer and was promoted to Professor of Mathematical Physics eight years later. As Head of Department he was forced to oversee the sudden closure of the department, which affected him strongly. From 2005 onward he held a professorship at the University of York and, over time, became a member of learned societies such as the Institute of Physics and the Académie Internationale de Philosophie des Sciences.

The early exposure to conceptual problems of quantum theory posed by uncertainty relations, quantum measurements and incompatible observables turned out to be formative for Paul's scientific interests. For more than three decades he sought to clarify conceptual muddles besetting the foundations of quantum theory, by providing mathematically rigorous answers. A well-developed physical intuition guided his efforts, combined with the willingness to think long and hard about difficult questions. Early on, he advocated the use of positive-operator-valued measures (POVMs), which represent the most general type of quantum measurements; they have now become an indispensable tool in quantum information theory.

Nearly 100 refereed papers vividly demonstrate Paul's

rare gift of physical insight combined with mathematical rigour. He co-authored three widely-read books (1991, 1995, 2016) on foundational aspects of quantum theory; all of them are still in print. His meticulous and critical — but impartial — attitude was sought after by journal editors and colleagues alike. Paul's large number of collaborators and friends included ten PhD students who benefited from his nearly unlimited availability, his persistent questioning, curiosity and generosity to share what he knew.



background Paul's proved to be important for his recent and widely-noted work on quantum measurement uncertainty relations (2013, jointly with long-time collaborators P. Lahti Werner). and R.F. The physics underlying Heisenberg's famous "microscopeargument", which he

used in 1927 to motivate the incompatibility of an electron's position and momentum, is reassessed and put on firm grounds. To further investigate the fundamental limits of high precision quantum measurements, the Royal Society awarded Paul a Leverhulme Trust Senior Research Fellowship (2017-18).

Paul was a sociable person, and his open mind aligned naturally with an open house inviting colleagues and students on many occasions. He played the piano well, and would have liked to play more often.

Rational and disinterested argument — in the positive sense of the enlightenment — was close to Paul's heart. He despaired at political games played with(in) universities, at dishonest political discourse and at needless human misery.

Paul was a gentle man, and a gentleman. I like to think of him as an enlightened scholar from the 18<sup>th</sup> century, transposed into today's world. In his modesty, Paul would probably intervene at this point, kindly telling me not to exaggerate.

### Det Instruction LMS Meeting

## Hirst Lecture & Society Meeting

#### 21 March 2019, De Morgan House, 57-58 Russell Square, London WC1B 4HS

#### Website: tinyurl.com/ybewfqz7

The meeting features the Hirst Lecture, given by the winner of the Hirst Prize and Lectureship 2018, Jeremy Gray (OU and Warwick), followed by a second speaker to be confirmed. It will be followed by a reception at

De Morgan House. For further details and to register for a place, see the website. A Society Dinner will be held after the meeting at a nearby venue, at a cost of £35.00, including drinks. To reserve a place at the dinner, email Imsmeetings@Ims.ac.uk.

# 2018 Christopher Zeeman Medal presentation and lecture

| Location: | Royal Society, London |
|-----------|-----------------------|
| Date:     | 5 March 2019, 5:30pm  |
| Website:  | tinyurl.com/zeeman19  |

The 2018 Christopher Zeeman Medal will be presented to Dr Hannah Fry. The presentation will be followed by a talk by Dr Fry, and a wine reception. Email prizes@Ims.ac.uk to register your attendance.

#### Integrability and Conformal Field Theory

| Location: | University of Oxford |
|-----------|----------------------|
| Date:     | 29–30 March 2019     |
| Website:  | tinyurl.com/ya96q3jz |

The 23rd in a series of UK meetings on new developments in integrability and conformal theory, with an emphasis on the interplay between mathematics and physics. Supported by the LMS, the Peierls Centre, and All Souls College.

#### Tropical Geometry meets Representation Theory II

| Location: | University of Leicester |
|-----------|-------------------------|
| Date:     | 8-12 April 2019         |
| Website:  | tinyurl.com/yabcm67n    |

The workshop will bring together early-career researchers from representation theory, cluster algebra, toric and tropical geometry to explore the interrelations between these areas.

#### Geometry and Mathematical Physics

| _ocation: | Loughborough University |
|-----------|-------------------------|
| Date:     | 27–30 March 2019        |
| Website:  | tinyurl.com/y7mq6bd6    |

This workshop will focus on recent developments in geometry and mathematical physics. Financial support is available for PhD students; see the website for details. Supported by an LMS Conference grant and the Loughborough Institute of Advanced Studies.

#### Mary Cartwright Lecture

| Location: | ICMS, Edinburgh      |
|-----------|----------------------|
| Date:     | 5 April 2019         |
| Website:  | tinyurl.com/ycv3ssfq |

The 2019 Mary Cartwright Lecture will be presented by Professor Beatrice Pelloni (Heriot-Watt University) with an accompanying presentation by Professor Vassilis Dougalis (University of Athens). To register, contact womeninmaths@lms.ac.uk.

#### British Algebraic Geometry Meeting

| Location: | University of Liverpool |
|-----------|-------------------------|
| Date:     | 24–26 April 2019        |
| Website:  | tinyurl.com/ya84g3hy    |

The aim is to bring the UK algebraic geometry community together and showcase the best research in the field happening both nationally and internationally. The meeting is designed with particular regard to the needs of younger participants.

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#### Looking Forward to 2050: Closing Workshop

| Location: | Isaac Newton Institute, Cambridge |
|-----------|-----------------------------------|
| Date:     | 29 April–3 May 2019               |
| Website:  | tinyurl.com/y9my5zaq              |

This workshop will report on progress achieved during the Mathematics of Energy Systems programme, including work on both operational timescale and investment timescale problems. There will be a knowledge transfer day and talks on research priorities.

#### **Optimal Design of Soft Matter**

| Location: | Isaac Newton Institute, Cambridge |
|-----------|-----------------------------------|
| Date:     | 13–17 May 2019                    |
| Website:  | tinyurl.com/ycunf3nh              |

The workshop will address challenges in optimal design of soft matter, identifying the most productive directions for research and applications and discussing the development of new methodological approaches. A one-day Women in Materials Science event will be part of the workshop. Application deadline: 10 February 2019.

#### Idealised Models of Numerical Weather Prediction for Data Assimilation Research

| Location: | University of Leeds  |
|-----------|----------------------|
| Date:     | 16–17 May 2019       |
| Website:  | tinyurl.com/yas8gqr8 |

This workshop is directed at current and potential users of the 'modRSW' model, developed for data assimilation research. Limited funds are available; see website to register interest. Partially supported by an LMS Research Workshop grant.

#### Interactions between Representation Theory and Homological Mirror Symmetry

| Location: | University of Leicester |
|-----------|-------------------------|
| Date:     | 7–10 May 2019           |
| Website:  | tinyurl.com/y8ao6vzq    |

This meeting will focus on the interactions between representation theory of finite dimensional algebras and homological mirror symmetry, drawing together researchers from the different communities. Email RepThHMS2019@gmail.com to register attendance.

#### Modern Applied Probability

| Location: | ICMS, Edinburgh      |
|-----------|----------------------|
| Date:     | 15-17 May 2019       |
| Website:  | tinyurl.com/y7xc7tfl |

This workshop, in celebration of Sergey Foss' 65th birthday, will focus on the modern problems of applied probability. Funding is available for PhD students and early career researchers who can further benefit from attending the LMS Lecture Series on financial mathematics in life insurance held after this workshop. Supported by an LMS Conference grant.

#### Women in Noncommutative Algebra and Representation Theory Workshop

| Location: | University of Leeds  |
|-----------|----------------------|
| Date:     | 20-24 May 2019       |
| Website:  | tinyurl.com/ybs6tyoo |

This workshop will enable some of the best experts and junior participants working on these topics to collaborate on research projects. All participants will be women and non-binary researchers. Supported by an LMS Research Workshop grant.

### Description LMS Meeting

## LMS Invited Lecture Series 2019

#### 20-24 May 2019: ICMS, The Bayes Centre, 47 Potterrow, Edinburgh EH8 9BT,

#### Website: https://tinyurl.com/yb7v47yu

Søren Asmussen (Aarhus University): Advanced topics in life insurance mathematics. Accompanying lecturers: Dr Corina Constantinescu (Liverpool University), Applications of fractional calculus in insurance/risk theory; Professor Pauline Barrieu (London School of Economics). For further details about the LMS Invited Lecture Series and to register for a place, visit the website.

Funds are available for partial support to attend the LMS Invited Lecture Series. Requests for support with an estimate of expenses, email the organiser Fraser Daly (f.daly@hw.ac.uk).

# Society Meetings and Events

### March

- 5 Christopher Zeeman Medal Presentation and Lecture, Royal Society, London (480)
- 21 Hirst Lecture and Society Meeting, De Morgan House, London (480)

### April

- 5 Mary Cartwright Lecture, ICMS, Edinburgh (480)
- 10 LMS Meeting at the BMC, Lancaster
- 29–3 May LMS-CMI Research School, PDEs in Mathematical Biology—Modelling and Analysis, ICMS, Edinburgh

### May

20-24 Invited Lecture Series, London (480)28 Northern Regional Meeting, Newcastle

### June

- 28 Graduate Student Meeting, London
- 28 General Meeting of the Society and Aitken Lecture, London

### July

- 1–5 LMS Research School: *Random Structures:* from the Discrete to the Continuous, Bath
- 8–12 LMS Research School, Mathematics of Climate, Reading

### September

11 Midlands Regional Meeting, Nottingham

### November

- 15 Graduate Student Meeting, London
- 15 Society Meeting and AGM, London

### January 2020

15 South West & South Wales Regional Meeting, Bristol

# Calendar of Events

This calendar lists Society meetings and other mathematical events. Further information may be obtained from the appropriate LMS Newsletter whose number is given in brackets. A fuller list is given on the Society's website (www.lms.ac.uk/content/calendar). Please send updates and corrections to calendar@lms.ac.uk.

### January

### February

- 15-19 Theoretical and Algorithmic Underpinnings of Big Data INI Workshop, Cambridge (472)
  - 23 Calcium Signalling in Fertilisation, Embryogenesis and Development: Modelling and Experiments, Cardiff (479)
- 7-8 Probabilistic Reasoning using Chain Event Graphs Workshop, Glasgow
- 22 Stochastic Models in Risk Analysis and Queuing Workshop, University of Leeds
- 27-1 March Postgraduate Conference in Complex Dynamics 2019, De Morgan House, London

### March

- 5 Christopher Zeeman Medal Presentation and Lecture, Royal Society, London (480)
- 18-22 Electricity Systems of the Future: Incentives, Regulation and Analysis for Efficient Investment, INI, Cambridge (479)
  - 21 Hirst Lecture and Society Meeting, de Morgan House, London (480)
- 27–30 Geometry and Mathematical Physics Workshop, Loughborough University (480)
- 29–30 Integrability and Conformal Field Theory 2019, University of Oxford (480)

### April

- 1-3 Mirrors in the Midlands, University of Birmingham
- 3-5 Young Functional Analysts' Workshop, University of Leeds
- 5 Mary Cartwright Lecture, ICMS, Edinburgh (480)
- 8-11 British Mathematical Colloquium 2019, Lancaster University (479)
- 8-12 Tropical Geometry meets Representation Theory II, University of Leicester (480)
  - 10 LMS Meeting at the BMC, Lancaster
- 24-26 British Algebraic Geometry Meeting, University of Liverpool (480)
- 25-26 Mathematics of Operational Research, Aston University, Birmingham (479)
- 29-3 May Looking Forward to 2050: Closing Workshop, INI, Cambridge (480)
- 29-3 May LMS-CMI Research School, PDEs in Mathematical Biology—Modelling and Analysis, ICMS, Edinburgh

### May

- 7-10 Interactions between Representation Theory and Homological Mirror Symmetry, University of Leicester (480)
- 13-17 Optimal Design of Soft Matter, INI, Cambridge (480)
- 15-17 Modern Applied Probability Workshop, ICMS, Edinburgh (480)
- 16-17 Idealised Models of Numerical Weather Prediction for Data Assimilation Research, University of Leeds (480)

- 20-24 LMS Invited Lecture Series 2019, Professor Soren Asmussen (Aarhus University), ICMS, Edinburgh (480)
- 20-24 Women in Noncommutative Algebra and Representation Theory Workshop, University of Leeds (480)
  - 28 Northern Regional Meeting, Newcastle

### June

July

- 10-14 New Trends and Challenges in the Mathematics of Optimal Design, INI, Cambridge
- 17-21 MAFELAP 2019, Brunel University London (479)
- 17-21 Approximation, Sampling, and Compression in High Dimensional Problems, INI, Cambridge
  - 28 LMS Graduate Student Meeting, London
  - 28 General Meeting and Aitken Lecture, London
  - 1-4 Dense Granular Flows IMA Conference, Cambridge
- 1-5 LMS Research School: *Random Structures:* from the Discrete to the Continuous, Bath
- 8-12 LMS Research School, Mathematics of Climate, Reading
- 8-12 Measurability, Ergodic Theory and Combinatorics, University of Warwick (479)
- 22-26 Postgraduate Group Theory Conference 2019, University of Birmingham
- 28-3 Aug International Mathematics Competition for University Students, Blagoevgrad, Bulgaria
- 29-2 Aug British Combinatorial Conference 2019, University of Birmingham (479)

### September

11 Midlands Regional Meeting, Nottingham

### November

- 15 Graduate Student Meeting, London
- 15 Society Meeting and AGM, London

### January 2020

15 South West & South Wales Regional Meeting, Bristol

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