LONDON MATHEMATICAL SOCIETY

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NEWSLETTER

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MATHS MEETS ARTS

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Sounds of Surface: an art installation by Jenny Hibberd & Andrew Johnston
Photo credit: Dean Leavers

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FROM THE EDITOR-IN-CHIEF

Well here we all are at the start of May — the sun is shining, the birds are singing and the world is so very changed. Who knew that these changes were coming? Who could have predicted that the whole world (almost) would come to a standstill — that people would stay at home, that universities would empty, that conferences would cease, that lecturing would be via a screen, and exams via the internet?

We could fill this Newsletter with what has stopped, what has been affected, and what has changed. But let's try and think of the positives — potentially, we have more time to think; more time of quiet; more time to reflect — although, perhaps, as Jonathan Fraser's article describes, this isn't the case for all of us. While many conferences have been cancelled or postponed, lots of us have finally bitten the 'online' bullet (yes, I have been quite slow to the party) and can now virtually connect as well as anyone. And what about funding? Application deadlines are ongoing — see the EPSRC *New Horizons* call — and, who could believe it, you might actually have a leisurely amount of time to put your application together.

What else? Will we join the coronavirus fight? Will we finally read that book that has been on the shelf for nearly a decade? Will we take the time to brush up on that bit of maths (or heavens, statistics!) that could be useful? Will we think about joining a Society committee — or write an article for the Newsletter? (Please do.) Will we reconnect with our hobbies (remember those?) and other interests? Have a look at Katrin Leschke's article for inspiration.

And if none of these suggestions appeal — remember — there is always the Riemann Hypothesis.

Eleanor Lingham
Editor-in-Chief

LMS NEWS

Caroline Wallace

Caroline Wallace is the Society's new Executive Secretary. She was born in New Zealand, where at the age of 8 she noticed the non-uniform gradations on a wedge-shaped rain gauge and was intrigued to know how the spacings were worked out.

A decade later Caroline became a student at Cambridge, graduating with a first in Engineering. She worked for some time as an engineer. For example, she was the radio network capacity manager for a telecoms company, where she used queueing theory to decide on the allocation of users to channels. Caroline remains a Chartered Engineer, and a member of the IET and IMechE.

Caroline's career then took her into the economic regulation of telecoms networks, and from there to public interest regulation in general. She regards it as crucially important that such regulation is informed by technical expertise.

For the last several years Caroline has been the Strategy Director at the Legal Services Board, which has made her very familiar both with managing multi-disciplinary teams and with the legal system.

Now she is very pleased to have come back into the scientific world, and started as the LMS Executive Secretary on 6 April. She says, "I am very impressed by the calibre of people at the LMS, and by its reputation and history. I am keen to make a contribution to the important work the Society does for mathematics."

Stephen Huggett
LMS General Secretary

Open Access publishing in the UK

The LMS is continuing to monitor and, where appropriate, respond to changes within the academic publishing landscape, including the recent increased drive by funders toward Open Access outputs.

In April 2020, the Society responded to a consultation on a draft Open Access policy for peer-reviewed research articles and academic books that result from research supported by UK Research and Innovation (UKRI). The Society's response reflected its role as a representative of the UK mathematics community and as a publisher. Details of the UKRI Open Access Review can be found on their website at tiny.cc/UKRI_OA.

Recently, a 'read and publish' agreement was struck between Jisc (the UK's research and education non-profit organisation that arranges licences and digital content agreements on behalf of higher education institutes), and Wiley (the Society's partner in the production, hosting and distribution of six LMS journals).

As well as being able to read all of Wiley's journals, researchers from 138 Jisc member institutions will be eligible to publish Open Access in hybrid and fully Open Access journals published by Wiley at no direct cost to the author(s) or their institutions.

Eligible corresponding authors whose papers are accepted for the *Bulletin, Journal, Proceedings, Transactions, Journal of Topology* and *Mathematika* will be automatically presented with the option of publishing the version of record of their article Open Access under a Creative Commons licence. Specific guidance can be found at tiny.cc/Wiley_Jisc.

Similar arrangements have previously been negotiated between Jisc and a number of other academic publishers. These include Cambridge University Press and Institute of Physics Publishing, with whom the Society also has publishing partnerships.

These new agreements, which are increasingly being requested by and negotiated with international library consortia, represent one way in which many publishers are proposing to gradually transition towards Open Access in a sustainable fashion.

The Society is currently preparing its response to a consultation (which closes on 29 May) on a draft Open Access policy for peer-reviewed research articles and academic books that result from research supported by UK Research and Innovation (UKRI).

John Hunton
LMS Publications Secretary

OTHER NEWS

Clay Research Fellows 2020

The Clay Mathematics Institute is pleased to announce that Amol Aggarwal and Yang Li have been awarded Clay Research Fellowships.

Amol Aggarwal will receive his PhD in 2020 from Harvard University, where he has been advised by Alexei Borodin. His research lies largely in probability theory and combinatorics, as well as their connections to mathematical physics, integrable systems, and dynamical systems.

Yang Li received his PhD in 2019 from Imperial College London, under the guidance of Simon Donaldson and Mark Haskins. He has already made significant contributions to the understanding of Calabi–Yau metrics in complex differential geometry and Riemannian manifolds with exceptional holonomy.

IMA Catherine Richards Prize

The best article in *Mathematics Today* (published by the Institute of Mathematics and Its Applications) is awarded the Catherine Richards Prize each year. Dr Mark McCartney (University of Ulster) was awarded the prize for *Fluids, Fluorescence and a Hat Full of Beetles* which was published to celebrate the bicentenary of the birth of George Gabriel Stokes.

Mark McCartney is has published widely on the history of mathematics. His most recent book is *George Gabriel Stokes: Life, Science and Faith*, which covers the many facets of Stokes's life through a collection of essays that Mark co-edited with Andrew Whitaker and Alastair Wood.

Mark is President of the British Society for the History of Mathematics, Reviews Editor of the LMS *Newsletter*, LMS Librarian and Associate Editor of the *International Journal of Mathematical Education in Science and Technology*.

2020 Abel Prize Winners Announced

Hillel Furstenberg (left) and Gregory Margulis

The Norwegian Academy of Science and Letters has awarded the 2020 Abel Prize jointly to Hillel Furstenberg (Hebrew University of Jerusalem) and Gregory Margulis (Yale University) 'for pioneering the use of methods from probability and dynamics in group theory, number theory and combinatorics'.

Furstenberg and Margulis invented random walk techniques to investigate mathematical objects such as groups and graphs, and as a result introduced probabilistic methods to solve many open problems in group theory, number theory, combinatorics and graph theory. A random walk is a path consisting of a succession of random steps, and the study of random walks is a central branch of probability theory.

Furstenberg has a deep technical knowledge of diverse areas and has made insightful and surprising connections between them. In particular, he has made fundamental contributions to the field of ergodic theory, which have had far-reaching applications in number theory, geometry, combinatorics, group theory and probability. Of his many accolades, Furstenberg won the Israel Prize in 1993, regarded as the top cultural honour in Israel, and the Wolf Prize in 2007.

During his illustrious mathematical career, Margulis has introduced many influential ideas, solved long-standing open questions, and discovered deep connections between different mathematical fields. His signature approach has been to use ergodic theory in unexpected and ingenious ways, which has led to the creation of entirely new areas of study. Throughout his career he has received several significant awards, including the Fields Medal in 1978 at the age of 32 and the Wolf Prize in 2005.

Fellow of the Royal Society of Edinburgh 2020

Beatrice Pelloni (Heriot-Watt University), a member of the LMS, the 2019 Mary Cartwright Lecturer and a former member of Council, has been elected a 2020 Fellow of the Royal Society of Edinburgh.

May 12: Celebrating Women in Mathematics

Maryam Mirzakhani, the first female Fields medallist, was born on 12 May 1977, and died prematurely on 14 July 2017. As a result of an initiative proposed by the Women's Committee of the Iranian Mathematical Society, the World Meeting for Women in Mathematics in Rio in 2018 agreed that 12 May should be chosen as the day to celebrate women in mathematics around the world.

Because of the COVID-19 crisis, 12 May 2020 will be very different from that in 2019. But despite all the restrictions, virtual events can still be organised — see may12.womeninmaths.org for ideas.

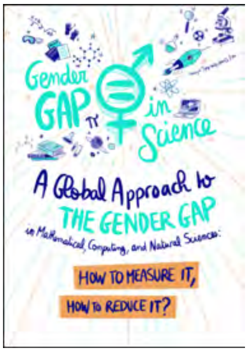
In particular, the 12 May organisers have made an agreement with zalafilms for a free screening of their beautiful film *Secrets of the Surface*, about Mirzakhani and her work. If you would like to watch the film, you are invited to register at tinyurl.com/vysafy8. You will receive a link by email for a free screening on a date of your choice the date in the period 1 April to 15 May. This link is personal to you and you are asked not to share it outside the specific use you are requesting.

Mathematics and COVID-19

An interesting side-effect of the COVID-19 pandemic has been the raising of the profile of mathematics in the public eye. Suddenly, experts on mathematical modelling of the spread of infectious diseases such as Neil Ferguson of Imperial College, London appeared as key figures on news programmes, and the general public has come to grapple with concepts of infection ratios, exponents and second derivatives.

In parallel with the calls for retired medics, other workers and volunteers to help with the physical demands of fighting the pandemic, calls also went out to mathematicians, data analysts, statistical modellers, and the wider scientific community to join the fight at the theoretical level: notably the Royal Society's RAMP initiative and the rapid response call from the Alan Turing Institute, as well as the grassroots crowdfight campaign.

The Gender Gap Project Report



This multi-author book with lively illustrations, edited by Marie-Françoise Roy and Colette Guillopé, is the final report of a three-year project (2017–19) funded by the International Science Council and involving eleven scientific partner organisations, including the International Mathematical Union (IMU). Marie-Françoise Roy, Chair of the IMU's Committee for Women in Mathematics (CWM), was one of the initiators and a main driving force throughout.

The main goal of this ambitious and extensive project was to investigate the gender gap in STEM disciplines from different angles, globally and across disciplines. The authors carried out a global survey of scientists, both male and female, with more than 32,000 responses; investigated the effect of gender in millions of scientific publications; and compiled a list of best-practice initiatives which address the gender gap in Mathematical, Computing, and Natural Sciences at various levels.

After detailed compilation of the results, the authors conclude that the gender gap is very real in science and mathematics. The book presents methodologies, insights, and tools that have been developed throughout the project, as well as a set of recommendations for different audiences: instructors and parents; educational institutions; scientific unions and other organisations responsible for science policy.

The book is freely available and can be found from the Gender Gap webpage gender-gap-in-science.org, together with a short summary booklet including the full list of recommendations. The book can also be downloaded directly from tinyurl.com/v9d8pmz. It will shortly be published with an ISBN number and a print on demand option.

Mathematics Subject Classification 2020

The latest revision of the Mathematics Subject Classification (MSC) has been published, replacing the 2010 Mathematics Subject Classification (referred to as MSC2010). Searchable versions are available from the zbMATH site: zbmath.org/classification/ and the MathSciNet site: mathscinet.ams.org/mathscinet/searchMSC.html.

Mathematical Reviews (MR) and zbMATH collaborate on maintaining the Mathematics Subject Classification, which is used by these reviewing services, publishers, funding agencies and others to categorise items in the mathematical sciences literature. It is a taxonomy created by and for mathematical researchers. Every ten years, the two editorial groups solicit input from the mathematics community. For the current revision, we received over 350 comments and suggestions from more than 100 different people. MR and zbMATH carefully considered this input from the community and used it in the preparation of our joint revision of the classification.

As anticipated, there are no changes at the two-digit level, but several at the three-digit level, and hundreds at the five-digit level. Nine new three-digit classes were added: 18M Monoidal categories and operads; 18N Higher categories and homotopical algebra; 53E Geometric evolution equations; 57K Low-dimensional topology in specific dimensions; 57Z Relations of manifolds and cell complexes with science and engineering; 60L Rough analysis; 62R Statistics on algebraic and topological structures; 68V Computer science support for mathematical research and practice, and 82M Basic methods in statistical mechanics. For five-digit classes, 113 classes were retired and 486 new classes were introduced. The new MSC contains 63 two-digit classifications, 529 three-digit classifications, and 6006 five-digit classifications.

There were some general changes. Descriptions of classes were changed to be more useful when searching online or via database interfaces. Previous descriptions assumed the user was looking at a full list of the classifications, which would provide context. An example of the limitation is a search of MSC2010 for 'optimisation', which returns 18 matches, not counting essentially every class in 49 Calculus of variations and optimal control. There were three classes named 'Flow Control and Optimization': 76B75, 76D55, and 76N25. The three different contexts were incompressible inviscid fluids, incompressible viscous fluids, and compressible fluids and gas dynamics. Now they have descriptions with more detail, as in 76B75 Flow control and optimisation for incompressible inviscid fluids. There were three classes just named 'Optimization' in the areas 74P Mechanics of deformable solids, 78M50

Optics, electromagnetic theory, and 80M50 Classical thermodynamics, heat transfer. Now they have descriptions that include the context, as in 78M50 Optimisation problems in optics and electromagnetic theory.

In previous versions of the MSC, there were some 'hyphen classes' of the form XX–00 General reference works, XX–01 Introductory expositions, XX–02 Research exposition, XX–03 History, XX–04 Software, and XX–06 Proceedings, conferences, collections, etc., along with other scattered hyphen classes. The use of hyphen classes has been made more uniform across the MSC, so that most two-digit classes now have these five subclasses. Some hyphen classes would be redundant and are omitted, such as the non-existent class 01-03, since the two-digit class for 'History of Mathematics and Mathematicians' does not need a subclass for history. The classes -08 for Computational methods for problems from the parent class, -10 for Mathematical modeling or simulation for problems from the parent class, and -11 for Research data for problems from the parent class have been added where appropriate. For example, there is now the class 20-08 Computational methods for problems from group theory and the class 20-11 Research data for problems from group theory. An example of an omission of one of these new hyphen classes for reasons of redundancy is 65 Numerical analysis, which does not need the -08 class for computational methods. Also, some classes have alternatives to -08 with more detail, such as the eight five-digit classes in the three-digit class 14Q Computational aspects in algebraic geometry. The hyphen classes -10 mostly occur for applied classes, namely MSCs 70 through 94, as in 70-10 Mathematical modeling or simulation for problems from mechanics of particles and systems.

The influences of data and computation on the mathematical sciences are reflected in the classes. In addition to the -08 classes, and not including classes from 03 (Mathematical logic and foundations) or 68 (Computer science), there are 58 classes referring to computations, computational methods, or computers. For instance, for MSC2020, two new classes, 14Q25 Computational algebraic geometry over arithmetic ground fields and 14Q30 Computational real algebraic geometry were added to the three-digit class 14Q Computational aspects in algebraic geometry, which had been added to the MSC in 1991. Similarly, two new classes were added under 37M Approximation methods and numerical treatment of dynamical systems: 37M21 Computational methods for invariant manifolds of dynamical systems, 37M22 Computational methods for attractors of dynamical systems and 37M25 Computational methods for ergodic theory. For the -11 classes, examples of the types of data envisioned include statistical data, mathematical tables, collections of mathematical objects and their properties, such as integer sequences (as found in the OEIS, for instance), or databases of modular forms or Calabi–Yau varieties. In addition to the -11 classes, there are 31 classes with specific instances of data, including the new classes 62R10 Functional data analysis, 62R40 Topological data analysis and 68P27 Privacy of data.

Mathematical Reviews and zbMATH are now using MSC2020 as their classification schemes. We welcome and encourage the community to also adopt the MSC2020. It is available from msc2020.org in PDF or TeX. A SKOS version will be available later.

The classification is jointly published by the two organisations under a Creative Commons CC-BY-NC-SA license. Corrections to possible errors in the new system can be submitted by email to feedback@msc2020.org. All information about MSC2020 is jointly shared by MR and zbMATH.

The editors and staff at Mathematical Reviews and zbMATH express their gratitude to the numerous members of the community for their assistance in this lengthy revision process.

Edward Dunne
Executive Editor, Mathematical Reviews

Mathematician Features in *The Times* Daily Quiz

On 26 March 2020 the following question appeared in *The Times* Daily Quiz:

12 Which British mathematician (1916–2020) proposed the partially tongue-in-cheek "Strong Law of Small Numbers"?

The answer is someone mentioned in this Newsletter, until very recently the oldest member of the LMS! For the curious, the 'Strong Law of Small Numbers' is described entertainingly — including 35 examples of the law — in an article by this mathematician: tinyurl.com/vn3cro6.

MATHEMATICS POLICY DIGEST

Mathematics in FE colleges report

A Nuffield funded report into mathematics education across England's further education sector has found that 'major investment in leadership training and teacher professional development is required to make more significant and sustained improvements'. The report has been published as part of the Mathematics in Further Education Colleges project (MIFEC). The report outlines how 'a range of policies, processes and people interact at different colleges and across the FE sector to either support or hinder improvement in mathematics learning'. The full report is available at tinyurl.com/wptncgl.

Parliamentary Select Committees

The House of Commons and House of Lords Select Committees have been formed for this Parliament. The Chair of the Science and Technology Select Committee is Greg Clark MP. The Chair of the Education Select Committee is Robert Halfon MP. The Chair of the Business, Energy and Industrial Strategy Committee is Rachel Reeves MP. The Chair of the House of Lords Science and Technology Committee is Lord Patel. Full details of all Committees, including membership, are available at committees.parliament.uk.

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 MATHEMATICAL SOCIETY NEWS

zbMATH is now Open Access

Zentralblatt MATH (zbMATH) is the world's most comprehensive and longest-running abstracting and reviewing service in pure and applied mathematics. It is edited by the EMS, the Heidelberg Academy of Sciences and Humanities and FIZ Karlsruhe — Leibniz Institute for Information Infrastructure. The Federal Republic of Germany has now agreed to support FIZ Karlsruhe — Leibniz Institute in transforming zbMATH into an open access platform. For more information on this important initiative see tinyurl.com/ucgvbce.

St Petersburg Thematic Programs 2021

The Leonhard Euler International Mathematical Institute (EIMI) in St Petersburg has opened a call for programmes in 2021. It is expected that two such programs will be hosted during the calendar year 2021. Proposals should be sent to programs@eimi.imi.ras.ru by 15 May 2020, and decisions will be made before the end of that month. For further details visit eimi.ru.

PI Day 2020

Most events for March 14 = PI Day = The International Day of Mathematics had to be cancelled because of the coronavirus crisis. However, at the Wolfgang Pauli Institute in Vienna, at very short notice, an online event took place in the form of a 24-minute video in which the WPI director Norbert J. Mauser introduced the Thumb times PI: PI-Day, where seven mathematicians in quarantine in seven different cities presented short messages for 'PI day in the year of corona'. A programme of this unusual event can be seen at tinyurl.com/vs2lvrz and the video is at tinyurl.com/yx63karr.

IMU Abacus Medal

The IMU has decided to accept the joint bid from the University of Helsinki and the Simons Foundation for the funding of the IMU Abacus Medal, which will be awarded once every four years at the International Congress of Mathematicians for outstanding contributions in mathematical aspects of Information Sciences. The IMU Abacus Medal is a continuation of the Rolf Nevanlinna Prize that was awarded from 1982 to 2018. For further details visit tinyurl.com/yx3bovxo.

EMS News prepared by David Chillingworth
LMS/EMS Correspondent

Note: items included in the European Mathematical Society News represent news from the EMS and are not necessarily endorsed by the Editorial Board or the LMS.

OPPORTUNITIES

LMS Research Grants: Call for Applications

The application deadline for LMS Research Grants is 15 May. The LMS offers a number of grant schemes to support conferences (up to £7,000 — Scheme 1), visits to the UK (up to £1,500 — Scheme 2), Research in Pairs (up to £1,200 — Scheme 4) and collaboration with developing countries (up to £3,000 — Scheme 5). For more details visit tinyurl.com/ujj7ev6.

New Horizons Call

EPSRC invites proposals for adventurous research projects across the breadth of pure and applied mathematics, statistics and operational research. Grants may last for up to 2 years and have an upper limit of £200,000. Full details of the call, including the streamlined application procedure, can be found at tinyurl.com/r8n96yk. The deadline for applications is 4 June.

VISITS

Visit of Sascha Troscheit

Dr Sascha Troscheit (University of Vienna) will be visiting the UK from 27 July to 14 August 2020. He will give lectures at the Universities of Bristol, Birmingham, and Glasgow. His work combines aspects of Dynamical Systems, Fractal Geometry, and Probability Theory. His recent research activity is concerned with determining the Assouad dimension of fractal sets that are defined via some random process. For further details contact Simon Baker (s.baker.2@bham.ac.uk). The visit is supported by an LMS Scheme 2 grant.

Membership of the London Mathematical Society

The standing and usefulness of the Society depends upon the support of a strong membership, to provide the resources, expertise and participation in the running of the Society to support its many activities in publishing, grant-giving, conferences, public policy, influencing government, and mathematics education in schools. The Society's Council therefore hopes that all mathematicians on the staff of UK universities and other similar institutions will support mathematical research by joining the Society. It also very much encourages applications from mathematicians of comparable standing who are working or have worked in other occupations.

Benefits of LMS membership include access to the Verblunsky Members' Room, free online subscription to the Society's three main journals and complimentary use of the Society's Library at UCL, among other LMS member benefits (lms.ac.uk/membership/member-benefits).

If current members know of friends or colleagues who would like to join the Society, please do encourage them to complete the online application form (lms.ac.uk/membership/online-application).

Contact membership@lms.ac.uk for advice on becoming an LMS member.

LMS Council Diary — A Personal View

Council met at De Morgan House on Friday 31 January 2020. The meeting began with an update from the new President on various matters, including the generous donation from the Liber Stiftung that is supporting the new Emmy Noether Fellowships, with a possible research event for women in mathematics also currently under consideration by the Women in Mathematics Committee, and the exciting recent announcement by government of a major funding boost for mathematics.

The discussion then turned to the Sir Michael Atiyah Memorial Projects. The President noted that the Society is involved in both the funding and the organisation of 'The Unity of Mathematics: a conference in honour of Sir Michael Atiyah', to be held at the Isaac Newton Institute in September 2020. Following the successful launch of the Atiyah UK–Lebanon Fellowships in November last year, which was attended by the Lebanese ambassador to the UK, the Treasurer reported that the deadline for the first round of applications was imminent. Given the need to establish connections and momentum for the Fellowships, a key objective in the first instance was felt to be to send UK-based mathematicians who are effective communicators to Lebanon.

Open access issues of a number of flavours were the focus of the Publication Secretary's report on Publications Committee business. As part of a group of learned societies, the Society had contributed to a consultation on open access proposals that had been put forward by the international consortium of funding organisations cOAlition-S, intended to shake up the way that publications currently operate. The UKRI Open Access Review Consultation was expected to be launched in mid-February. Concern was noted about possible financial implications for mathematics of the increasing tendency of publishers to address open access via large-scale, country-wide agreements and the way in which income from such deals is being allocated to individual publications.

Following the recent Standing Orders Review, the General Secretary reported that it was hoped the proposed amended Standing Orders would be considered at the February meeting of the Privy Council, but this was yet to be confirmed. Under financial matters, in addition to the Treasurer giving an overview of the First Quarter Financial Results, Council heard from the Education Secretary about a proposal to run two Mathematics Communication and Outreach Training Days at De Morgan House each year, and it was agreed to increase the budget of the Education Committee to provide resources for this.

There was a discussion about the invitation of the Chair of the Women in Mathematics Committee to attend Council, which has been in place for some years. It was agreed that the Chair of the Women in Mathematics Committee would become a designated position for a Member-at-Large of Council with effect from the end of the current Chair's term of office. We also heard a report from the LMS Scrutineers on the 2019 Council and Nominating Committee Elections, noted annual reports from various committees, and discussed committee membership.

The meeting closed with the President noting that this was the last Council meeting of the retiring Executive Secretary, thanking her sincerely for her years of service to the Society, and extending the best wishes of everyone for the future.

Elaine Crooks
Member-at-Large

REPORTS OF THE LMS

Report: Probabilistic Coupling and Geometry Workshop

Speakers at the event

A workshop on Probabilistic Coupling and Geometry was held on 9–10 December 2019 at the University of Warwick to mark Professor Wilfrid Kendall's 65th birthday.

Probabilistic coupling refers to the practice of constructing two (or more) probability measures on a single measurable space in order to compare them. Some of its main applications include representing one process in terms of another, proving stochastic comparison arguments, bounding the rate of convergence of Markov processes, and simulation algorithms. Wilfrid Kendall has made significant contributions in all of these areas and beyond. In addition, he has played important roles within the probability and statistics community: he was the co-founder of the Academy for PhD Training in Statistics (APTS), which for the last 13 years has provided fundamental training courses for first year PhD students across the UK; in 2011 he helped to found the Applied Probability Section of the Royal Statistical Society; and from 2013–2015 he was President of the Bernoulli Society.

Some 45 people attended the workshop, which was funded by an LMS Conference Grant, and co-sponsored by both the Bernoulli Society and the Royal Statistical Society. The workshop's principal speakers were: Sayan Banerjee (University of North Carolina), Julia Brettschneider (University of Warwick), Professor Krzysztof Burdzy (University of Washington), Elisabetta Candellero (Università degli Studi Roma Tre), Professor Huiling Le (University of Nottingham), Professor Gareth Roberts (University of Warwick), Professor Jeffrey Rosenthal (University of Toronto) and Giacomo Zanella (Università Bocconi).

Wilfrid Kendall

Over the course of the two-day workshop, attendees were treated to 15 high-quality talks. These were either delivered by Wilfrid's collaborators and colleagues, or they concerned work inspired by his research. Topics covered included change points in dynamic networks; analysis of dead pixel patterns in x-ray detectors; Archimedes' principle; Stein's method; a number of perfect simulation and MCMC techniques; stochastic control; card shuffling; an oil and water model; phylogenetic tree analysis; random growth models; random walks with memory. The mixture of theory and applications, and the broad range of subjects, showed just how widely Wilfrid has influenced the field of probability during the last forty years. The proceedings concluded with a conference dinner sponsored by the Department of Statistics at the University of Warwick.

Further details about the workshop can be found at tinyurl.com/wsk65.

Stephen Connor
University of York

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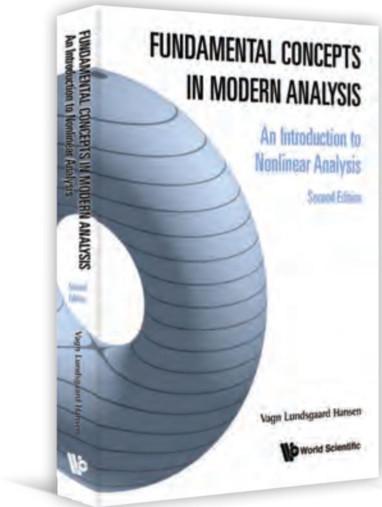

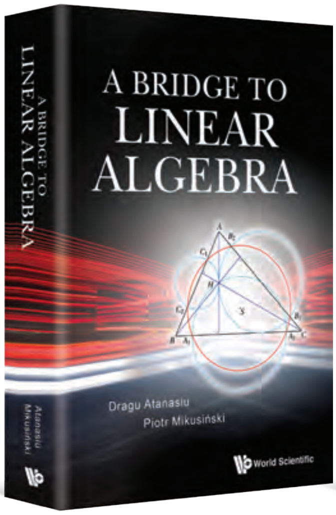

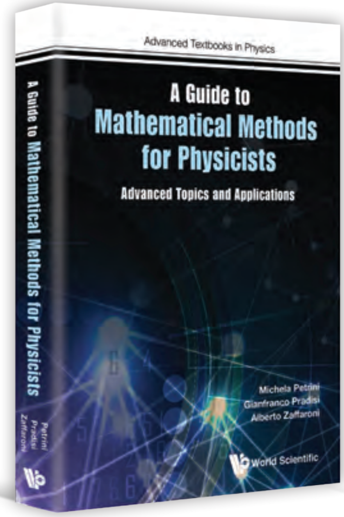

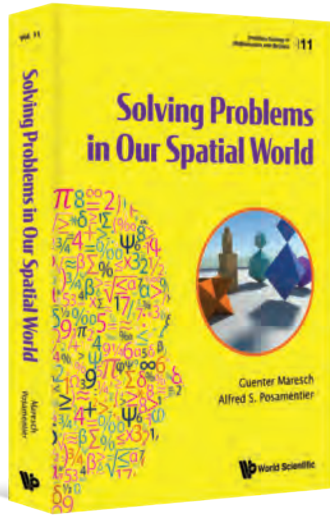

Fundamental Concepts In Modern Analysis

An Introduction To Nonlinear Analysis

(Second Edition)

by **Vagn Lundsgaard Hansen** *(Technical University of Denmark, Denmark)*

With **Poul G Hjorth**

The book provides complete proofs of the basic results from topology and differentiability of mappings in normed vector spaces. It is a useful resource for students and researchers in mathematics and the many sciences that depend on fundamental techniques from mathematical analysis.

This edition also covers a new section on partial derivatives, and new material has been incorporated to make a more complete account of higher order derivatives in Banach spaces, including full proofs for symmetry of higher order derivatives and Taylor's formula. The exercise material has been reorganized from a collection of problem sets at the end of the book to a section at the end of each chapter with further results.

Dec 2019
304pp | 978-981-1209-40-6 | £85
Ebook for individual at £35

Scan QR code for more details
https://doi.org/10.1142/11529

A Bridge to Linear Algebra

by **Dragu Atanasiu** *(University of Borås, Sweden)* &
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Hong Kong Mathematical Society

The Hong Kong Mathematical Society was established in 1979, which went along with the contemporary development of tertiary education and research in mathematics in Hong Kong. The University of Hong Kong, the first university, opened at the beginning of the 20th century and there were very few mathematicians at that time. After World War II, Professor Yung Chow Wong joined what was then the sole university as Chair of Mathematics. Professor Wong was a key promoter who established the HKMS and served as the Honorary President of the Society. In 1963 a second university, The Chinese University of Hong Kong, was established. More mathematicians were recruited for undergraduate teaching and postgraduate training as well as doing research. These two universities were the main task force in mathematical research but there were other post-secondary institutions with mathematics departments. In 1979, the HKMS was founded and its first President was Dr Irving Tang from the Hong Kong Polytechnic. In 1991 a third university, Hong Kong University of Science and Technology, was launched and some other institutes became fully accredited universities in Hong Kong. Mathematics research in Hong Kong is now well-rounded, covering various areas in pure and applied mathematics.

Prof Y.C. Wong (1970s)

The HKMS has six Institutional Members (currently local universities) and is supported by a great number of mathematicians working in these and other local institutions. Since 1982 the Society has been a member of the International Mathematical Union. The Society aims to foster academic research and information exchanges amongst colleagues and to provide favourable conditions for mathematics education, both in theory and applications. One of the regular society activities is the Annual General Meeting; the six institutional members take turn to co-organise this event in their campus. The AGM is a one-day event, consisting of a distinguished lecture, plenary lectures, parallel sessions of invited talks and award presentation. The HKMS presents a Best Thesis Award and a Young Scholar Award annually at the AGM. The HKMS Best Thesis Award recognises outstanding PhD theses (dissertations) in the fields of pure and applied mathematics, and statistics. The HKMS Young Scholar Award recognises outstanding achievements of young scholars who are working in the institutions in Hong Kong and not exceeding the age of 45.

In order to foster exchanges of ideas, the HKMS has organised several important conferences. These include the Southeast Asian Mathematical Society Conference in 1980, The First Asian Mathematical Conference in 1990 and the AMS-HKMS Joint Conference in 2000. The plenary speakers of the AMS-HKMS Joint Conference in 2000 consisted of Jianshu Li, Thomas Liggett, Fang Hua Lin, Ngai Ming Mok, Gilles Pisier, Mike Shub, Gang Tian and Zhouping Xin. Moreover, the Society supports conferences and workshops organised in local institutions, and every year it holds a HKMS Distinguished Lecture Series which is another signature event of the society.

In November 2019, the Hong Kong Mathematical Society hosted a visit of a delegation from the London Mathematical Society to build on existing links between UK and Hong Kong mathematics. There was a short meeting of people from both societies. The LMS delegation included the President Designate, Professor Jon Keating, and the Publications Secretary, Professor John Hunton, together with two LMS Members, Professor Jens Marklof (University of Bristol) and Professor Gui-Qiang Chen (University of Oxford). The participants from HKMS were the President, Professor Tong Yang, Professor Member at Large, Professor Ngai-Ming Mok, Treasurer, Professor Wei Xiang, Public Relations Secretary, Dr Yuk Kam Lau, General Secretary, Professor Tao Luo, Programme Secretary, Professor Zhian Wang. The meeting was pleasant and relaxed, and members took this valuable opportunity to build mutual understanding and to explore possible collaborations between the two societies. More fruitful and long term cooperation is anticipated in future.

More information about the HKMS can be found on its website at www.hkms.org.hk.

Tong Yang
President of the Hong Kong Mathematical Society

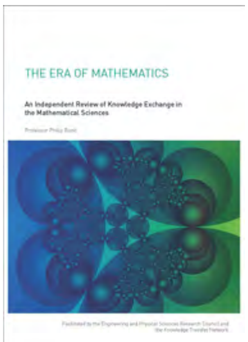
On being LMS President

CAROLINE SERIES

Professor Caroline Series FRS was LMS President November 2017–November 2019. Below she shares some of her experiences during her time in office.

My time as LMS President brought with it opportunities and challenges, responsibilities and a fair sprinkling of headaches, along with many privileges and not a few rewards. The LMS is a well-oiled machine which largely runs like clockwork, so in addition to admiring the output of our many committees, what does the President actually do? Besides representing the Society to all sorts of people at all sorts of functions, chairing numberless meetings and being present at as many of our regional meetings as possible, the job of the President as I understood it, is to fill in the gaps and take the lead on anything that doesn't sit conveniently in any of the well established categories.

April 2018 saw the launch of the Bond Review. Shortly before the launch, Philip Bond suggested that we meet at De Morgan House. Having discussed the review and his ideas at some length, he quite unexpectedly asked whether I could supply some fractal images similar to those in my book Indra's Pearls. Swallowing my astonishment that he had come across the book at all, I was pleased to help and delighted to see our pictures designed into his glossy Review booklet.



The Bond Review cover

The main question of course was, how should the LMS respond? It was clear to me both that we must in some way consider the Review's many proposals, and also that whatever finally emerged as a community response should grow out of and be endorsed by the CMS (Committee for Mathematical Sciences). Numerous phone calls and discussions behind the scenes over the summer of 2018 led to setting up the LMS Bond working group under past President Terry Lyons and the eventual emergence of the CMS proposal for a two committee structure, which took shape as the Strategic and Implementation Committees under Claire Craig and Bernard Silverman respectively. We await their conclusions later this year.

Early on, I became involved in the ongoing revision of the fifty-year-old LMS Charter, Statutes and By-Laws which set out how the LMS is governed. The revision had been started in 2014, but had been put on hold during the planning for our 150th anniversary celebrations. By the time I joined in, the major lifting was largely done, however there remained a lot of details and some knotty points to consider. A timetable had been drawn up which indicated that if we worked hard, I might hope that my last act as President would be to oversee the vote on the final revision. And indeed this is what happened, although not without a great deal of work on the part of our General Secretary, Stephen Huggett, and general prodding from me to keep things rolling along. At first sight even reading the document seemed a daunting task. I don't think anyone had ever paid much attention to the first page – I noticed that we had had a change of address since 1965 and at a later stage our Editorial Manager Ola Törnkvist realised that we had also changed parish! Such were the details – I very much hope that the general thrust of the revisions will prove as enduring a document as the previous one. It was a good moment when our homework came back from the preliminary scrutiny by the Privy Council with essentially nothing further to do.

The President is always invited to the Abel Prize celebrations in Oslo, but I certainly had not expected to receive an invitation to give 'the speech' at one of the highlights of the proceedings: the grand banquet attended by many Norwegian politicians and dignitaries including the King. At that point the winner had not even been decided, but, after some thought and with considerable trepidation, I accepted. In the event the winner was Robert Langlands and I had to scratch my head and think back to my graduate student days when many of my colleagues were working on the mysterious 'Jacquet-Langlands'. My speech (which I am proud to say managed to weave in Pythagoras, Abel, Fermat, Selberg, Wiles and Langlands) went down well. The ceremonies were magnificent and it was an unforgettable week.

(l-r) Robert Langlands and King Harald V of Norway at the Abel Prize 2018 celebrations

The President also attends the ICM, thus in summer 2018 it fell to me to travel to Rio for the first ever Congress in the southern hemisphere. Most evenings merged into blur of receptions put on by all the larger mathematical societies, mainly held in the same room and with similar refreshments, largely alcoholic. Thus I was able to do a lot of networking which I trust was good for the Society. We had agreed that the LMS would partially sponsor Marianne Freiberger and Rachel Thomas of the online Plus magazine to assist with our publicity, and I spent quite a bit of time initiating contacts with various people, including our newly elected honorary members, Peter Scholze and Maria Esteban, for them to interview. But my abiding memory has to be of Michael Atiyah who had made the journey all the way from Edinburgh to deliver the Abel lecture. I organised a mini-reception for Caucher Birkar to meet the LMS delegation and most importantly Michael, who promptly launched into a lengthy discourse suggesting to Caucher further directions for his work. Michael also came to a lunch for 'supporters of the IMU', in which he held the floor telling the IMU that it should focus on its main objectives and not try to spread itself too widely – advice which I have often thought about, if not exactly followed, since.

I heard the sad news that Atiyah had died early in January 2019. To hit the Newsletter deadline only a few days hence, I spent the weekend writing a short obituary. The biennial Council retreat was coming up which presented the ideal opportunity for a brainstorming session on what the LMS might do to commemorate him. Discarding the idea of a statue in Russell Square and other unlikely proposals, we eventually settled on two ventures: the LMS would spearhead a major conference on the Unity of Mathematics (see www.newton.ac.uk/event/ooew02), and, as a more lasting memorial, set up the Atiyah Fellowships (see www.lms.ac.uk/grants/atiyah-uk-lebanon-fellowships) for collaboration between the UK and Lebanon. Approaches made by myself and our President Designate, Jon Keating, rapidly secured core funding for the conference, while working hard with our Treasurer, Rob Curtis, and Jihad Touma, Director of the Center for Advanced Mathematical Sciences at the American University of Beirut, we were able to announce the Fellowships by video-link to Beirut to coincide with the 20th anniversary of CAMS, the day after our AGM.

(l-r) Caucher Birkar, Caroline Series, Michael Atiyah and June Barrow-Green at an ICM 2018 reception

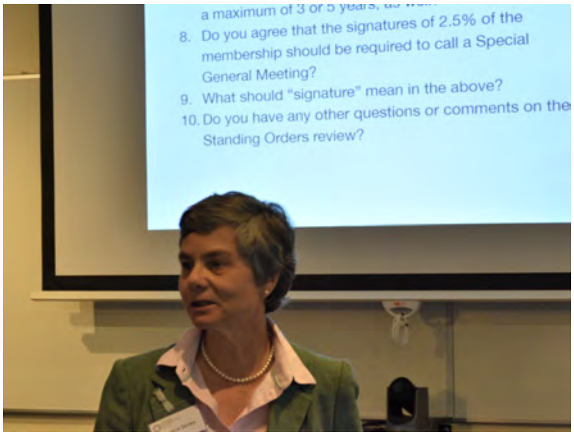
Shortly before I took up office, Council was having discussions around our IT provision, which was at that time mainly handled by our IT Consultant, Donald Eastwood, working on a part-time basis, although always on call in case of emergency. There were many conflicting demands on Donald's time, and it seemed to me that in the long term this situation was not sustainable. About the first major first thing I did as President was to propose setting up an committee to look into the matter. Fiona Nixon and Donald prepared a very thorough review of our entire IT operation, and with advice from John Cremona (Warwick) and Keith Gillow (Oxford), after only three meetings the new committee had proposed moving a large part of our operation (email and files) to the Cloud and had identified a company Fitzrovia IT to manage this. Fortuitously, our new

Head of Conferences and Buildings Andrew Dorward had overseen a similar operation in his previous post; moreover by mid-2019 Donald had decided that it was time to be moving on to other things. So my foresight had paid off. The move took place over summer and autumn 2019 and I rather doubt that many of our members were even aware that it was happening. The icing on the cake was that – quite contrary to my expectations – after the initial move the entire cost of the operation will be less than before.

The President is able to suggest minor changes and improvements with remarkable ease. The supply of hangers on the coat rack just inside the door past Reception had dwindled to three very scruffy specimens which bothered me every time I entered the building. With some hesitation, I mentioned this to Fiona – and lo and behold, next time I arrived we had a full new set! Another quick win were the wrappers on our Newsletter. In January 2018 my National Trust magazine arrived in a wrapper boasting that it was made of compostable potato starch. I asked the Newsletter editor Iain Moffatt whether we might look into doing the same, and was truly delighted when the change was implemented in time for the very next issue.

It is the President's job to do a fair amount of 'networking' on behalf of the Society. One example is a conversation I had with a member of the Abel Prize committee which we entertained in London, asking him how the AMS managed to have its Council meetings with members scattered across the continent. 'A good video-conference system' was the answer, 'couldn't do without it'. The UK is not the USA, but still, this seemed to me such an obvious idea that I pressed for it early on. Once again, the LMS machine (this time in the person of the then buildings manager Dominic Clark) swung into action, and before I knew it the equipment was installed, first in the Cartwright room and then in the Hardy room. It has been invaluable, its worth being first proved on the day of a critical Prizes committee meeting in March 2018 when, one by one, the extremities of the country got cut off by heavy snow.

The DeMorgan House anniversary event DeMorgan@21 was my idea. I was rather taken aback when some of the younger and non-British born Council members queried 'Why 21?'. However that hurdle successfully surmounted, Council approved the idea and I went ahead with a small planning committee of which the central and indispensable member was of course Susan Oakes. Our meetings and the event as it gradually evolved were among the most enjoyable of all the things I did, and I got considerable satisfaction when I saw how much people appreciated this unique event.



Caroline Series presenting the changes to the Statutes at the LMS Representatives Day 2019

I didn't get around to doing as much environmentally as I might have hoped, with so many other things going on it always got pushed back. But I did initiate a discussion at Council, the upshot of which is that we have commissioned a full energy audit of De Morgan House to look into what energy saving and other improvements we might make, and I think everyone was pleased when staff made the suggestion that hard copies of papers for meetings will henceforth only be produced on request. We are about to switch to a fully renewable electricity supply and I am looking forward to what the audit may suggest.

Of course the President's job is not completely finished until he or she has delivered the Presidential address, which happens immediately after handing over the chain of office. It is not easy to do research at the same time as fulfilling all the Presidential duties, but working on the lecture pushed me to investigate some ideas which I am looking forward to continuing in my 'retirement'. Perhaps those who set up this tradition were wiser than we knew.

Throughout these two crowded and eventful years among the greatest rewards have been the pleasure of working with so many dedicated and remarkable people, the satisfaction of setting balls rolling, and of seeing initiatives come to fruition. I was very honoured to have been asked to take on this role and I could not have done it without the support of many people, not least the wonderful staff at De Morgan House and most of all our Executive Secretary, Fiona Nixon. Without doubt, it has been one of the high points of my career.

“The Accident of Being the First Woman Senior Wrangler”

JUNE BARROW-GREEN

In 1890 Philippa Fawcett caused a sensation by scoring more marks in the Cambridge Mathematical Tripos than any of the male students. The recent discovery of letters dating from 1887–1890, including a letter from Fawcett herself, throws some new light on this famous incident.

Introduction

On the morning of 7 June 1890, the Cambridge Senate House was abuzz with excitement. The results of the Mathematical Tripos examination were due to be read out and it was anticipated that for the first time a woman, Philippa Fawcett of Newnham College, was going to outshine the men. Fawcett’s cousin, Marion Cowell, described the scene:

> “The gallery was crowded with girls and a few men, and the floor of the building was thronged by undergraduates as tightly packed as they could be. The lists were read from the gallery and we heard splendidly. The men’s names were read first, the Senior Wrangler[1] was much cheered. There was a good deal of shouting and cheering throughout; at last the man who had been reading shouted “Women.” The undergraduates yelled “Ladies,” and for some minutes there was a great uproar. A fearfully agitating moment for Philippa, it must have been; the examiner of course, could not attempt to read the names until there was lull. Again he raised his cap, but would not say “ladies” instead of “women,” and quite right, I think. He signalled with his hand for the men to keep quiet, but he had to wait some time. At last he read Philippa’s name, and announced that she was “above the Senior Wrangler.” There was a great deal of prolonged cheering; many of the men turned towards Philippa, who was sitting in the gallery with Miss Clough [principal of Newnham], and waved their hats.”[2]

The facts surrounding Fawcett’s triumph are well-known [2] and Fawcett is justly commemorated, including by the LMS who own a collection of books by and about women mathematicians which is named for her. In this article, I focus on Fawcett’s journey to Cambridge, what the triumph meant for her and how it was perceived by the popular press of the day. The motivation for the article is the discovery of some letters from Fawcett’s mother, together with one from Fawcett herself, to Karl Pearson.[3]

Fawcett’s route to Tripos success

Born in 1868, Fawcett was the only child of Henry and Millicent Garrett Fawcett, both staunch supporters of women’s rights. Henry Fawcett was 7th wrangler in 1856, apparently missing the senior wranglership through becoming over-excited in the examination! Although blinded in a shooting accident at the age of 25, he became Professor of Political Economy at Cambridge and was a successful campaigner for university reform. Millicent Garrett Fawcett, a suffragist from an early age and a strong supporter of higher education for women, was one of the founders of Newnham College.[4]

Fawcett was schooled at Clapham High School, and from the age of fifteen also received coaching in mathematics from George Atkinson, a wrangler and good friend of her father’s.[5] As preparation for Cambridge, she then spent five terms at University College London (UCL) studying both pure and applied mathematics, with time spent at Bedford College — the first higher education college for women in Britain — in the study of chemistry. In undertaking such rigorous preparation, Fawcett was following the path of many successful male students before her. At the time it was not uncommon to obtain a degree from one of the London or Scottish universities before embarking on the rigours of the Tripos.

Among Fawcett’s teachers at UCL, was Karl Pearson, then the Professor of Applied Mathematics, who taught the advanced mathematics class. Judging by an account in *The New York Times*, Fawcett made a singular impression on him:

> "Mr Pierson [sic] tells the story how when he first saw Miss Fawcett attending his advanced class he said to himself: 'Dear me, there's a poor little girl turned ambitious; of course she won't understand a word,' when presently, what was his astonishment to hear a question from the 'poor little girl' which showed that she understood to some purpose."[6]

Since this story appeared after Fawcett's success at Cambridge, precisely how much truth there is in it is hard to tell but certainly of the five students in the class Fawcett was the only woman, even though at the time UCL had a relatively high proportion of female students. Rather remarkably, one of the other five was none other than George Bennett, the man who would become the official senior wrangler in 1890.

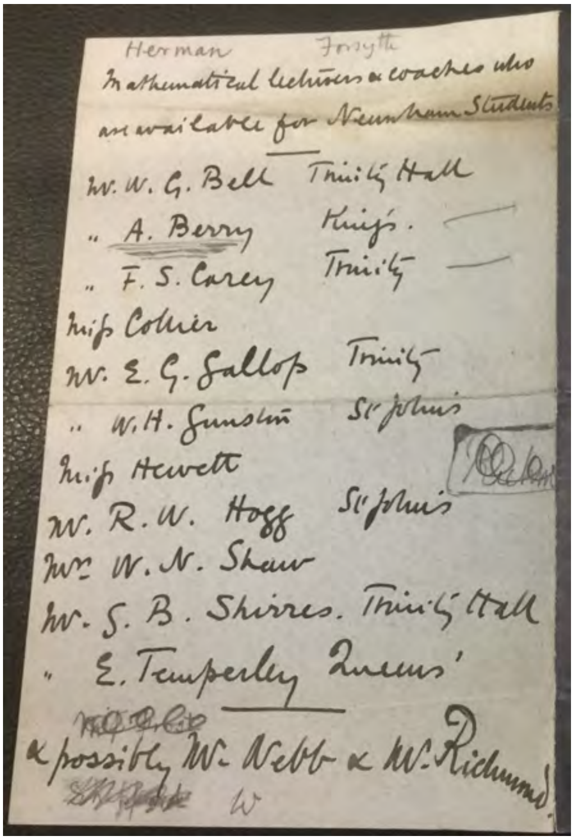

Herman Forsyth
Mathematical lecturers & coaches who
are available for Newnham Students
Mr. W. G. Bell Trinity Hall
" A. Berry King's.
" F. S. Carey Trinity
Miss Collier
Mr. E. G. Gallop Trinity
" W. H. Gunston St John's
Miss Hewett
Mr. R. W. Hogg St John's
Mr W. N. Shaw
Mr. S. B. Shirres. Trinity Hall
" E. Temperley Queens'
& possibly Mr Webb & Mr Richmond
W

Figure 1. "Mathematical lecturers or coaches who are available for Newnham Students", compiled by Millicent Garrett Fawcett, 15 May 1887.

In May 1887, in preparation for Fawcett's entry to Newnham, her mother wrote to Pearson seeking a recommendation for a mathematical coach.[7] Since success in the Tripos was dependent on such coaching, she wanted to secure the best available. Her letter included a list of the Cambridge men who had previously coached women, and she asked Pearson which of them she should choose (Figure 1). Pearson replied recommending someone not on her list, Andrew Russell Forsyth, and offering to contact him on her behalf. Forsyth, senior wrangler in 1881, had been elected a Fellow of the Royal Society the previous year for work in function theory, and he would go on to succeed Arthur Cayley as the Sadleirian Professor in 1895. He was an ambitious choice, particularly since there is no evidence that he had previously done any coaching. When it became apparent that Forsyth was going to take some persuasion, Fawcett's mother asked her friends the Sidgwicks to intervene.[8] They suggested instead she should try Robert Webb, senior wrangler of 1872 and one of the foremost coaches at the time. Webb was a 'possible' on her list and Pearson had recommended him too. But Webb was reluctant to coach women, not, he claimed, because he was prejudiced against them but rather because he "apprehended some embarrassment from the presence of a lady in the atmosphere of freely expressed criticism," which he considered an essential part of his coaching method.[9] Since he preferred to coach in groups of two or three, it seems he believed, although without verification, that women would be unable to stand up to public scrutiny of their work.

In the event, when Fawcett arrived at Newnham with a scholarship in October 1887, she was coached by neither Forsyth nor Webb. Such was her reputation that the leading coach of the previous generation, Edward Routh — he had 28 senior wranglers to his name, including Forsyth — had been enticed out of retirement for a term especially for her. Afterwards she was coached by William Hobson, senior wrangler of 1878 and another of Routh's men. (Hobson would later succeed Forsyth in the Sadleirian chair after Forsyth's resignation in 1910 due to the scandal arising from his love affair with Marion Amelia Boys, the wife of the physicist Charles Boys.)

Regardless of her performance at Cambridge, Fawcett knew that as a woman she could not be awarded a degree (with its privileges and voting rights), nor could her result be listed with those of the men. At least she did have the right to sit the Tripos examination, a right which had been only recently granted to women as a consequence of the success of Charlotte Scott who in 1880 had been ranked equal to the 8th wrangler, having previously gained special permission to sit the examination. As for women being awarded a degree at Cambridge, that would come only in 1948 when women were officially admitted to the university, a month before Fawcett's death at the age of 80.

Figure 2. Philippa Fawcett at Newnham.

Immediately after Fawcett's result was announced, there was of course great jubilation at Newnham. Bunting was hung out, bells were rung, and in the evening a celebratory dinner was held. Miss Clough proposed a toast to Fawcett to which Fawcett responded with a "pretty little speech" praising Miss Clough and modestly remarking: "in these matters the person 'coaching' was everything, the person 'coached' nothing", before proposing a toast to Hobson.[10] The celebrations continued long into the evening with a dance and fireworks. Later Hobson told Fawcett's mother that he had it on authority from the examiners that it had been a strong year, and that her daughter "was 400 marks (or 13%) ahead of the senior".[11]

The following year, Fawcett, the only woman to sit Part 2 of the Tripos — in contrast to Part I where she was one of seventeen women — was placed in Division 1 of the First Class. Only two men achieved a similar distinction, one of whom was Bennett and the other was Lawrence Crawford, the 5th wrangler. She could hardly have cemented her reputation more emphatically.

The response to Fawcett's success

The news of Fawcett's success spread rapidly. Congratulations came into Newnham from across the university, including from Cayley,[12] Newnham's first president and chair of the college council. Fawcett's mother received many letters and "literally hundreds of telegrams" which showered in on her "like snowflakes in a storm".[13] Among the many letters that Fawcett herself must have received was one from Pearson as her reply to him attests. Written only four days after the results were announced, her letter gives an interesting insight into her feelings at the time:

> "Thank you very much for your kind letter and for the hope which you express that I may be able in the future to do some scientific work. But I am sure you will agree with me that the attainment of a high place in the Tripos is no evidence of power to do original work.
>
> I can only regret that the accident of being the first woman senior wrangler did not happen to someone who was capable of such work.
>
> May I take this opportunity of thanking you for the great help and stimulus that your teaching was to me."[14]

Fawcett's remark about the relationship between a high place in the Tripos and the ability to do original work, does of course have truth to it, but it is nevertheless the case that many high-ranking wranglers did go on to do original work, including Bennett who spent his career in Cambridge and in 1914 became an FRS [4]. So how should one read Fawcett's remark? Did she really believe it of herself or was it another example of her characteristic modesty alongside her crediting her success entirely to Hobson? Suffice it to say, comparable remarks from high-ranking wranglers of the period are conspicuously absent. In the event, Fawcett was largely correct in her self-analysis. Her only contribution to research was a single paper on the motion of a helicoid in a fluid [5]. This was the result of the year she spent on a research scholarship at Newnham immediately after completing Part 2 of the Tripos. Following this, she taught for some years at Newnham and in South Africa, before making a successful career in educational administration in London. Given it is not suited to everyone to do research and that at the time, apart from teaching, the opportunities for women mathematicians were few and far between, her career choice might not seem so unexpected. And yet Fawcett had won the respect of many male colleagues at Cambridge and elsewhere, some of whom would surely have supported her in research — as Cayley had done with Charlotte Scott — had she wished to continue.[15] Perhaps her first taste of research had put her off; perhaps she found that she preferred teaching. But perhaps also she was disheartened by the public clamour surrounding her, peppered as it was with conflicting attitudes towards women mathematicians.

It is no surprise that there was enormous popular interest in Fawcett's achievement. During the 19th century the Tripos results commanded attention far beyond the bounds of Cambridge, with the senior wrangler reaching close to celebrity status. Fawcett had not only surpassed the senior wrangler, achieving what many had believed impossible, but she came from a well-known family with female emancipation in their veins. From London to Glasgow and from New York to Melbourne, "The Lady Senior Wrangler" was news. Newspapers concentrated mostly on facts, giving details of her family background, schooling and so on, sometimes embellishing their reports with remarks about her steadfastness and composure. Popular periodicals were different. As well as reporting facts — and those not always accurately — they were vehicles for social comment, and the physical appearance of women mathematicians was not a subject to pass them by. Ten years earlier, when Charlotte Scott had been the focus of their attention, they were concerned that women with mathematical ability might develop "a character for deficiency in feminine gentleness", that is if they were not already "women of the masculine type".[16] In Fawcett's case, it was the fact that this didn't apply to her, that she had nothing of the bluestocking about her, that was considered newsworthy.[17]

Aside from stereotyping appearances, periodicals continued to propagate the myth that women engaging in mathematics or science had little room or strength to do, let alone be good at, anything usually expected of a woman.[18] Fawcett again bucked the trend, as the *Ladies Pictorial* pointed out:

> "Exceptional interest will naturally be felt in the portrait of Miss Fawcett which we give upon this page (Figure 2). As an interesting fact it may be mentioned that the gown seen in the photograph was made entirely by Miss Fawcett, proving conclusively that it is quite possible to unite in one woman practical domestic virtues and the highest intellectual attainments. Every stitch in the pretty tucked bodice was worked by the clever fingers of the lady who is now virtually the Senior Wrangler for 1890."[19]

Thus, it was alright for women to be good at mathematics so long as they were also good at sewing!

The *Penny Illustrated* took a different tack, they used their column on Fawcett to offer advice to "clever women" on how to procure a husband:

> "Men admire clever women, but they do not like women who are priggish, who dogmatise, who lay down the law. She will be the cleverest woman of all who, with her brilliant and cultivated intellect, retains all her pretty and coaxing ways. Depend upon it that, even if she were able to "square the circle" or to add another dimension to space, she would find that a pretty pout or a big tear on her long eyelashes would have far more power over the tyrant man than her mathematical genius, and that, no matter how cordially he may admire and praise the clever woman, soft and gracious creatures and graceful kittenish ways will subdue him far more quickly than the most brilliant exercise of brain power."[20]

The idea that mathematics and marriage were incompatible in a woman was discouragingly popular. Only the year before Fawcett's success, the science writer and novelist Grant Allen had remarked:

> "Out of every hundred women, roughly speaking, ninety-six have husbands provided for them by nature, and only four need to go into a nunnery or take to teaching the higher mathematics [6]."

Allen made no secret of his reactionary views on the higher education of women. That these views were widely known and supported is all too evident from a report on Fawcett in the *Bristol Mercury*:

> "In the regularity and self-control which have governed her work throughout, Miss Fawcett has offered a complete contrast to the conventional picture of the lady student,

> whom Grant Allen and others have loved to depict as a hysterical, overwrought, and nervous being who after a few years of morbid application prepares to sink into an early grave."[21]

Predictably, Fawcett's success was fodder for the satirical periodicals. The weekly magazine *Fun* published a cartoon showing the victorious Fawcett standing tall with a vanquished man crouching in the shadows (Figure 3).[22] In the top right corner, blowing a trumpet and holding a suffragist wreath, is a curious amalgam of a man and a woman. The figure appears to be allegorical but maybe it would have been obvious to the magazine's audience who exactly is being lampooned.[23] At any rate, it is hard to imagine it being an image likely to appeal to women. Furthermore, in the caption Fawcett is defined by her father, an all too common trope.

Figure 3. Ladies First – The Senior Wrangleress "A Worthy Daughter of a Worthy Sire" Miss Fawcett demonstrates the superiority of her sex, and defeated man takes a back seat.

Fun's older rival, *Punch*, had plenty to offer by way of comment and cartoons on both Fawcett and women students in general. Although it treated Fawcett with respect — their cartoon of her shows "Seniora Fawcett" walking victoriously between two lines of bowing men – it adopted an unmistakably demeaning tone in 1894 when there was only one woman ranked equivalent to a wrangler (Figure 4).[24]

Final Remarks

Philippa Fawcett is rightly celebrated for her remarkable performance at Cambridge. Her achievement unequivocally demonstrated the equality of mathematical potential in women and men, adding impetus to the movement for women to be awarded degrees in Cambridge, even if it was not enough for the movement to succeed at the time.[25] It was a hard battle to win, and the press response towards Fawcett's success shows the deep entrenchment of culturally adverse attitudes towards women in mathematics. From the point of view of Fawcett herself, although her mother had wanted her to make a career as an astronomer, physicist, lighthouse designer or engineer, or at the very least do something no woman had done before, such as her aunt, Elizabeth Garrett Anderson, had done, the experience left her with no such aspiration.[26]

Figure 4. *Punch* cartoon.

Since the formal admission of women to Cambridge in 1948, there have been women who have done well in the Tripos and gone on to have distinguished careers in mathematics, although they are far fewer in number than might have been hoped. And in 72 years, there has been only one female senior wrangler, Ruth Hendry in 1992. Like Fawcett, Hendry chose not to remain in mathematics [8].

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June Barrow-Green

June Barrow-Green is Professor of History of Mathematics at the Open University. Her current research interests are in the history of dynamical systems, 19th century geometric surface models, and the history of women in mathematics. When not buried in an archive or in an art gallery she can be found on a bicycle or running wherever her feet take her.

Notes

[1]Students in the first class were called wranglers, with the top student being known as the senior wrangler, an appellation which persists even today.

[2][1, p. 143].

[3]Pearson is known today for his work in mathematical statistics and in eugenics.

[4]Newnham was founded in 1871 and moved to its current site in 1875.

[5]Atkinson, 12th wrangler in 1856, was at Trinity Hall together with Henry Fawcett.

[6]*New York Times*, 24 June 1890.

[7]Millicent Garrett Fawcett to Karl Pearson, 15 May 1887. Karl Pearson Papers, General Correspondence 11/1/6/8. University College London Special Collections.

[8]Henry Sidgwick was Professor of Moral Philosophy and one of the cofounders of Newnham.

[9]*Bristol Mercury*, 'The Lady Senior Wrangler' 10 June 1890, p. 2. For a description of Webb's coaching methods, see [3, pp. 247–249].

[10]*The Ipswich Journal*, Above the Senior Wrangler, 14 June 1890, p. 5.

[11][1, p. 141].

[12]*The Australasian*, Miss Fawcett's triumph at Cambridge, 19 July 1890, p. 135.

[13]Extracts from some of these letters are given in [1, p. 140–2].

[14]Philippa Fawcett to Karl Pearson, 11 June 1890. Karl Pearson Papers, General Correspondence 11/1/6/9. University College London Special Collections. Pearson's letter to Fawcett no longer exists.

[15]Charlotte Scott was a successful research mathematician, but she spent her career in the United States where she was the founding professor of mathematics at Bryn Mawr. Grace Chisholm Young, who was only three years behind Fawcett at Cambridge, began her research career in Göttingen under Felix Klein.

[16]*The Spectator*, 7 February 1880.

[17]*The Graphic*, The Cambridge Mathematical Tripos, 21 June 1890, Issue 1073, p. 692.

[18]At the most extreme, it was believed that engaging in such study would compromise a woman's ability to have children.

[19]*Ladies Pictorial*, 14 June 1890, pp. 920–921.

[20]*Penny Illustrated*, The World of Women: Miss Fawcett, 21 June 1890, p. 394.

[21]*Bristol Mercury*, 'The Lady Senior Wrangler' 10 June 1890, p. 2.

[22]*Fun*, Ladies First – The Senior Wrangleress, 18 June 1890, p. 261.

[23]Despite the reference to him, it can't involve Henry Fawcett, who had died in 1884, since he didn't have a long beard. Could it represent Millicent Garrett Fawcett and Henry Sidgwick, the joint founders of Newnham?

[24]*Punch*, 'The Girton Girl, B.A.', CVI, 23 June 1894, p. 297.

[25]In 1897 a proposal to recognise women's degrees but with no share of university government was defeated by 1713 votes to 662.

[26]Elizabeth Garrett Anderson was the first female doctor to qualify in England [6, p. 205].

2520 Ants for Dylan

JONATHAN M. FRASER

I discuss an entertaining problem which arose in the context of singing my son to sleep.

Ants go marching…

I'm writing this from my in-laws home in Harrison, New York, during the coronavirus pandemic. My son, Dylan, is asleep at the moment (afternoon nap) and my wife, Rayna, is working in the next room. Dylan is 15 months old and, although he is far from the worst sleeper, his sleeping habits and patterns are challenging. Since our very early days with him I have sung him to sleep (benefiting from the fact that he is too young to tell me not to). It used to be nursery rhymes (Baby Beluga, Ants Go Marching, Twinkle Twinkle etc), but more recently I have drifted back towards Leonard Cohen. I digress. One such song I'm very fond of is *Ants Go Marching*. It's a sweet song about ants marching in various formations. The first verse is as follows:

> *The ants go marching one by one, hurrah, hurrah!*
> *The ants go marching one by one, hurrah, hurrah!*
> *The ants go marching one by one,*
> *the little one stops to suck his thumb,*
> *and they all go marching down,*
> *to the ground,*
> *to get out of the rain.*

The song then repeats with "two by two" and a different activity for the little one. This continues all the way until ten and *the little one stops to say the end!* One evening as I was singing this song to Dylan in the dark of his room, in a state of pseudo delirium, it occurred to me that there must be a lot of ants if they are able to walk in so many different formations. Assuming, for example, that "three by three" really means **rows of three with *no* ants left out**, the smallest number of ants required to sing this song is 2520. At first sight, this might seem surprisingly large. However, when I teased my family with this riddle the following day I tended to get an even larger number as an answer. The most common answer I received was 3628800 — oddly specific? Certainly this number is *a* solution, but it is far from the smallest. The number of ants must be divisible by one, two, three, all the way up to ten, and the most obvious way to construct such a number is to multiply them all together (10 factorial, written $10!$):

$$10! = 10 \times 9 \times \cdots \times 3 \times 2 \times 1 = 3628800.$$

OK, I admit that nobody (myself included) was able to give me the number 3628800 off the top of their heads, but the idea of multiplying the numbers one to ten together was the most common answer given. So, why is this solution such an enormous overshoot? The reason is that there is a dramatic duplication of effort in multiplying the numbers one to ten together: you don't need six, because you already have two and three (and $6 = 2 \times 3$) and you don't need ten because you already have two and five, and so on. So perhaps we only need the *prime* numbers less than ten? But $2\times3\times5\times7 = 210$ is not nearly enough. The problem this time is that we sometimes need a particular prime more than once. For example, to get four we need two twice ($4 = 2^2$), and the less said about eight the better! This line of thinking leads us to the answer: take the product of all the primes less than ten raised to the largest power we will need. This yields the optimal solution:

$$2^3 \times 3^2 \times 5 \times 7 = 2520.$$

One way to think of "the largest power we will need" is the largest number we can raise a given prime to whilst keeping it less than ten. For example, $2^3 = 8$, $3^2 = 9$, but $5^2 = 25$, which is too big.

Finding a formula

Just as any sleep deprived mathematician would do, rather than rest with the solution to the 'ants go marching problem', I instead began to think of a more general problem. What is the smallest number of ants required to sing n verses of the song, for any given positive integer n? (In order to sing n verses, the ants must be able to march in rows of one, two, three, all the way up to n.) In the previous section, $n = 10$. This is much more typical of the sort of problem mathematicians actually consider. The solution for a fixed n is just a calculation after all, but if we can understand how the solution behaves as n changes then we gain a deeper understanding. Moreover, when n is small the problem is especially subject to "edge effects" to do with primes and prime powers near n (for example, when $n = 10$, 3^2 is a relatively large prime power which 'makes the cut', whereas 11 just misses out). Therefore, the most elegant question to ask is what happens to the solution as n becomes very large? Of course it will grow, but *how* does it grow? What surprised me about this problem was that the answer is remarkably simple: the function grows like e^n.

Before I go on, I should point out that all I am really asking for here is the lowest common multiple of the numbers 1 through n, that is, $\text{lcm}(1, \ldots, n)$. This is well-understood and the mathematics which I am about to discuss goes back a long time. That said, I had fun thinking about it for myself in the dark of Dylan's bedroom. Therefore, perhaps the reader would also prefer to think about it for themselves?

Challenge

Without reading ahead, can you justify

$$\text{lcm}(1, \ldots, n) \approx e^n?$$

You can decide what sort of approximation is possible here but, for concreteness, can you deduce that

$$\frac{\log \text{lcm}(1, \ldots, n)}{n} \to 1$$

as $n \to \infty$? That is, $\log \text{lcm}(1, \ldots, n)$ is *asymptotic* to $\log(e^n) = n$.

The reasoning presented in the opening section generalises and it is 'obvious' that the solution is

$$\text{lcm}(1, \ldots, n) = p_1^{m_1} p_2^{m_2} \ldots p_k^{m_k}$$

where $p_1, p_2, \ldots$ denote the primes written in ascending order, p_k is the largest prime no larger than n, and m_i is the largest integer such that $p_i^{m_i} \leq n$. This is not a particularly aesthetic solution and the challenge lies in trying to express it in a more digestible form. In what follows, take yourself back to Dylan and the ants and permit me to be a little imprecise. More precision will follow in the next section.

Each term $p_i^{m_i}$ in the above product is no larger than n (by definition), but it seems reasonable to think that, when n is very large, it will be *roughly equal* to n: if p_i is small, then m_i will be correspondingly large. (Certainly, $p_i^{m_i} > n/p_i$.) This means

$$p_1^{m_1} p_2^{m_2} \ldots p_k^{m_k}$$

should be *roughly equal* to n^k, where k is the number of primes no larger than n. We understand from our first interactions with the primes that there are infinitely many of them in total, but that they become more sparse as we look further up the real line. The number of positive integers no larger than n is clearly n, whereas the number of perfect squares no larger than n is only around $\sqrt{n}$, which is much smaller than n. The *prime number theorem*, a cornerstone of number theory, tells us that the number of primes no larger than n is actually much closer to the number of positive integers than the number of perfect squares. In fact, the number of primes no larger than n is *roughly*

$$\frac{n}{\log n}.$$

Therefore the solution of the n by n ants marching problem should be *roughly*

$$n^{\frac{n}{\log n}} = e^n.$$

So that's that! Let's check the original problem, which considered only 10 ants. Unfortunately,

$$e^{10} = 22026.4\ldots$$

which is a rather disappointing overshoot, although much better than 10! (Recall the correct answer is only 2520.) So what is the problem? The final approximation we used came from the prime number theorem, so let's start there. We had already established that the solution should be roughly n^k, where k is the number of primes no larger than n. The primes less than 10 are 2,3,5, and 7, and so this formula would predict an answer of

$$10^4 = 10000$$

which is also a large overshoot, but not quite as bad as before. Does this mean that the prime number theorem is wrong? Certainly not. The prime number theorem does not claim that

$$\frac{n}{\log n}$$

is *precisely* correct, but only that this is a good estimate for very large values of n. Small values are subject to "edge effects" of the type I discussed at the start of this section and 10 is certainly far too small a number. A bigger problem with my rough calculations in this section is the approximation $p_i^{m_i} = n$, which is often much too large. For example, if $n = 10$ and $p_i = 5$, then $m_i = 1$ and $p_i^{m_i} = 5$ is much smaller than 10.

Something a little more mathematical

The most succinct way to describe $\text{lcm}(1, ..., n)$ is via Chebyshev functions. These functions play an important role in number theory and describe the distribution of the primes. The *second Chebyshev function* is defined by

$$\psi(x) = \sum_{p^k \leq x} \log p$$

where the sum is taken over all prime powers $p^k \leq x$. Here x is any positive real number but you can think of it as being the integer n that we've been considering. For example,

$$\psi(10) = 3\log 2 + 2\log 3 + \log 5 + \log 7$$

where the coefficients come from the fact that there are 3 power of 2 less than 10 (2^1, 2^2, 2^3), 2 power of 3 less than 10 (3^1, 3^2) and so on. Recalling that m_i is the largest integer such that $p_i^{m_i} \leq n$,

$$\begin{aligned} e^{\psi(n)} &= \prod_{p^k \leq x} e^{\log p} = \prod_{p^k \leq x} p \\ &= p_1^{m_1} p_2^{m_2} \cdots p_k^{m_k} \\ &= \text{lcm}(1, ..., n). \end{aligned}$$

Therefore the function ψ precisely describes the problem we are considering. Moreover, precise asymptotics for $\psi(n)$ are known, which allow us to partially justify the guessed formula from the previous section. It turns out that $\psi(n) \sim n$, which formally means

$$\lim_{n\to\infty} \frac{\psi(n)}{n} = 1,$$

that is, $\psi(n)$ is *asymptotic* to n. This does not directly yield an asymptotic for $\text{lcm}(1, ..., n)$ but it does demonstrate

$$\log \text{lcm}(1, ..., n) \sim n$$

which can be interpreted as a solution to our problem. In order for a group of ants to be able to march in rows of one, two, three, all the way up to n, there must be *roughly* e^n of them.

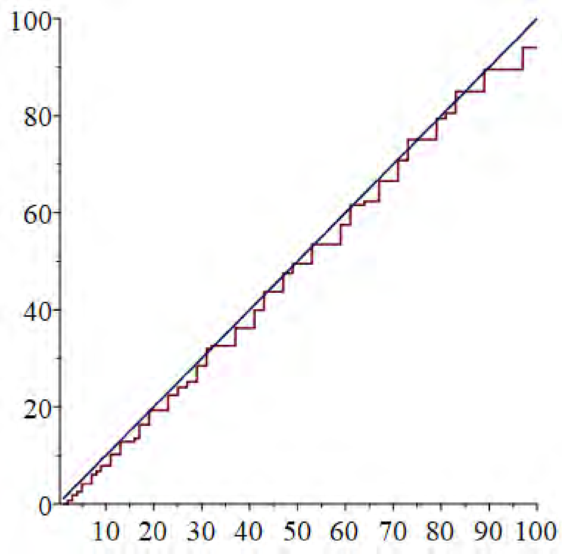

Figure 1. A plot of $\log \text{lcm}(1, ..., n)$ (in red) and n (in blue) for $n = 1, ..., 100$.

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Jonathan Fraser

Jonathan is a Reader in Mathematics at the University of St Andrews. It should be obvious from this article that he is not a number theorist. In fact, he usually spends his time studying fractal geometry. He is also an Editor of this Newsletter. He is pictured here with Rayna and Dylan (who is presumably looking at some ants).

Maths Meets Arts

KATRIN LESCHKE

When starting our project *Maths Meets Arts*, we asked whether arts can help to explain mathematics to a general audience. But soon other questions arose: Is mathematics art? Are mathematicians creative? Is creativity taught in a mathematics degree?

Motivation and first steps

When asked by non-mathematicians about my work in pure mathematics, quite often I have difficulties explaining the results. In my research area of surface theory, computer graphics enable me to show images or even 3D printed models of surfaces I work on. However, the deeper beauty of a mathematical surface often appears in the eye of a mathematician from its context in mathematics. This additional information, how results and methods fit into a broader theory, is harder to disseminate.

Figure 1. A 3D print of the Chen-Gackstatter surface, a minimal torus

Our starting question in our project *Maths Meets Arts* was to investigate whether arts can help to communicate this deeper meaning of mathematics to non-experts. Can we illustrate how mathematicians work, what problems they work on, which methods they use and what results they obtain? We used an open question in minimal surface theory, the finite topology conjecture (see text box) as a starting point for our collaboration.

Minimal surfaces occur in nature as soap films: surfaces on a wire loop dipped in soapy water minimise the area with the given boundary, and the normal curvatures of curves on the minimal surface will average to give mean curvature zero. Minimal surfaces also appear in various other settings: for example in a biological context, where triply periodic minimal surfaces describe the structure of photonic crystals of butterfly wing scales and their optical properties [1]; or in cosmology, where the apparent horizon, a quasi-local version of the event horizon, is a minimal hyper-surface (thus linking the theory of black holes to minimal surfaces and Plateau's problem [2]).

Since their introduction by Lagrange [3], minimal surfaces in Euclidean 3-space have been extensively studied in differential geometry. The classical theory flourished through contributions of leading mathematicians including, amongst others, Catalan, Weierstrass, Enneper, Schwarz, Bonnet, Serret, Riemann and Plateau. One important reason for the huge success of the theory is its connection to complex analysis: conformally parameterised minimal surfaces from a Riemann surface into Euclidean 3-space are exactly the real parts of holomorphic null curves in complex 3-space. Therefore, tools from complex analysis can be used, for example, to study the behaviour at the ends of the surface.

Minimal surfaces played an important role in introducing computer based experiments to geometry: J. Hoffman developed computer programs to visualise Costa's surface based on work of Hoffman and Meeks. This made it possible to perform mathematical experiments to obtain insights on properties of the Costa surface, see [4, 5] for details. These observations could later [6] be used to prove results rigidly, for example, the embeddedness of the Costa surface and its symmetries. Despite the numerous powerful tools of the theory, there are still many unsolved problems in this topic, such as the finite topology conjecture.

Since minimal surfaces have a physical interpretation and allow artists a visual approach, we chose a topic for our arts project from this field. We selected the finite topology conjecture as it lies at the core of my current research as leader of a Leverhulme Trust international network on *Minimal surfaces: integrable systems and visualisation* (www.le.ac.uk/miv) while at the same time being a problem which can be explained to the artists visually. Using a conjecture serves as a way to demonstrate how research questions in mathematics arise and what modern mathematical research looks like.

The finite topology conjecture

The finite topology conjecture is an open question by Hoffmann and Meeks [7] in the area of minimal surfaces. A complete and embedded minimal surface of finite total curvature is given by an embedding $f : M = \bar{M} \setminus \{p_1, \dots, p_n\} \to \mathbb{R}^3$ with vanishing mean curvature, where $\bar{M}$ is a compact Riemann surface, and $p_1, \dots, p_n$ are the ends of the minimal surface. The assumption of finite total curvature ensures that the ends are well-behaved and are of planar or catenoidal type.

An immediate question is: how many ends can occur depending on the genus of $\bar{M}$? The finite topology conjecture states that any complete, embedded minimal surface of genus $g \geq 1$ of finite total curvature has at most $g + 2$ ends.

In the case of genus $g = 0$ the finite topology conjecture is true: using a deformation on the Weierstrass data, López and Ros [8] showed that the only complete, embedded, finite total curvature minimal surfaces of genus $g = 0$ are the catenoid and the plane, thus showing that in this case the number of ends is less than or equal to 2.

During a three month residency funded by the Wellcome Trust, three artists — Chloe Aligianni, Lee Allatson and Jenny Hibberd — achieved an understanding of the contents of the conjecture, why it is believed to be true, how mathematicians approach a question and what the obstructions are to fully answering it. The first outcomes of this ongoing project were showcased by Lee Allatson and Jenny Hibberd, who were supported with music technology by Andrew Johnston, at the Artists' performance evening on 5th September 2019 at the Attenborough Arts Centre in Leicester. The event, which included a Q&A session, was part of an international workshop on minimal surfaces and was also open to the general public.

A second public artist performance evening featuring all four artists, was hosted at the Henry Wellcome Atrium and Lecture Theatre in Leicester on Thursday 3rd October 2019. The event was part of the Welcome Back activities for students returning to Leicester at the start of term but again it was also attended by the general public.

Figure 2. Maths meets Arts Tiger Team

Following on from the success of this artist residency project, the University of Leicester is now supporting an interdisciplinary research team called the *Maths meets Arts Tiger Team* (MmATT), including mathematicians, artists, computer scientists, anthropologists and teaching experts. The aim of MmATT is to create new art and expand on the previous collaboration, to investigate further how the communication between scientists, artists and the general public evolves, to explore ways to include creativity into teaching and to showcase our work in a *Maths Meets Arts Festival* in the summer.

New projects are arising from various areas of mathematics and computer science. For example, we aim to create a game which explains representation theory of algebras, and explore mathematical surfaces as a virtual reality adventure.

What did we learn?

The first open call for artists to participate in this project was a nerve-wracking moment in the project. Due to time constraints, we had to have a very short turn-around, and it was unclear to me whether we would be able to find artists who were willing to engage with a mathematician and work on a joint project, rather than responding to research only: the final output needed to communicate modern mathematics to non-experts. To my surprise, the response of the artistic community was overwhelming! In a first workshop I presented the underlying ideas of the project, and there was a lively discussion with lots of in-depth questions about geometry which demonstrated the willingness and capacity of the artists to engage with the material.

Unfortunately, we only had funding to work with three artists. The selected artists came from a variety of arts backgrounds — a drum set player, a dancer and choreographer and a performer, writer and musician. Over the duration of the arts residencies I met with each of the artists about once per week to discuss their project, each developing their own understanding of various aspects of the finite topology conjecture.

As in any interdisciplinary collaboration, there were difficult moments, for example when the artistic view clashed with my educational motivation, or when concepts were consistently misunderstood and there was a fear that this could not be resolved.

However, this challenging process was amazing and enriching for all of us: we discovered a lot of similarities between how mathematicians and artists work and that, albeit with a different background, the same curiosity drives our work. In particular, maybe to the surprise of the artists, the similarity of exploring different routes, experimenting with ideas and using intuition in our work shows that creativity is a key aspect of mathematical research.

Figure 3. Infinity core. Photo credit: G. Sian

In this collaboration I played both the role of a teacher in explaining concepts, methods and motivation, and that of a learner: I had to learn to understand the point of view of an artist but also to reshape my own ways of explaining and demonstrating mathematical concepts. Deprived of formulae and standard explanations, I needed to learn new ways to explain and explore mathematics. Through our collaboration, we created a new "language" to communicate which allowed both sides to be equal participants in the process.

The final presentations were well attended by academics, students and general public. Highlights for me included the following (tinyurl.com/yx6ajmaq):

- a non-mathematician was reluctantly entering the installation and within seconds engaged in discussions about how the sound and the shape of the surface are related,
- a colleague and her daughter could experience the shape of a surface by the sounds of the performance,
- the laughter at the clever linking of mathematical language and "normal" life observations,
- the delight of a maintenance worker at the dance rehearsals, returning for the main performance.

Figure 4. f: countless deformations

As mentioned before, the first performances were part of an international workshop on minimal surfaces and included a Q&A session with artists. The feedback from mathematicians after the event ranged from "but can the artists really understand what we are doing" to "I will steal this idea!". It was clear from the discussion though that the research community indeed feels a need to explain to a general audience what we are doing and why we think our work is important, and that art might be the appropriate tool to engage a new audience.

The second performance was also attended by students. Building on students' feedback we started to investigate further how art can be used for innovative approaches to teaching and learning of mathematics. In a first workshop, groups of three students worked with each artist to explore mathematical concepts such as continuity or random variables.

Observing the conversations between the students and artists, it became clear that both sides found it challenging to find a common language to explain topics. At the same time, all enjoyed the challenge, worked hard towards a final output and improved their understanding of mathematical concepts. In a feedback session after the event, all students agreed that this kind of exercise would have been very beneficial at the beginning of their studies. In particular, the setup helped students to lose their fear of making mistakes, and to learn to be more playful with questions.

Figure 5. Student art

The artists

Lee Boyd Allatson (tinyurl.com/t5u2n8t) is a drum set player from Leicestershire, specialising in free improvisation. He performed *Infinity Core*: At the epicentre of planes and curvatures; feeling minimal environments within a vast sense of scape. An opportunity for meditation, where tone, texture, pitch and duration become attributes of surface geometry. Communicating the "...deeper beauty of mathematical surface..." by appealing to the senses over the mind.

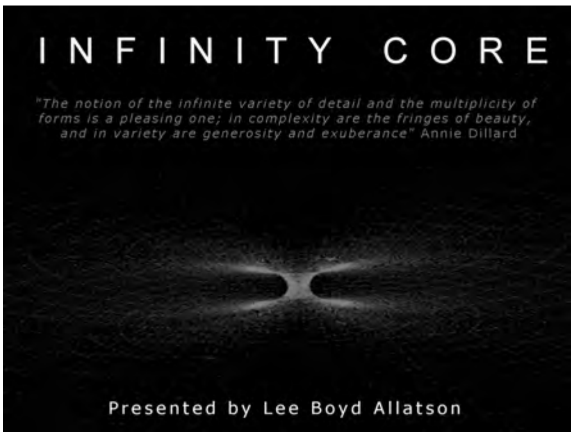

Figure 6. Infinity Core

Chloe Aligianni (www.chloealigianni.com) is a choreographer and dance artist who makes movement-based works for site specific environments and conventional theatre spaces. She performed *f: countless deformations* which proposes an open dialogue between the languages of algebra, dance, sound and motion sensing while looking for physical manifestations of mathematical processes behind minimal surface creation. One dancer, one musician and one digital artist co-exist in a space where members of the audience are able to shape the choreography by choosing mathematical propositions which performers use as improvisation formulas. The choreography, sound and light are thus put together as pieces of a puzzle with audience members experiencing the process of composition and synthesis while having the time to explore key mathematical ideas around minimal surface theory. The work seeks to re-think and re-imagine the body as brain and bring to life the workbook of a mathematician.

Figure 7. f: countless deformations

Jenny Hibberd (tinyurl.com/vh8vcn4) is an artist, performer, writer, musician and workshop facilitator. She presented an art installation with Andrew Johnston *sounds of surface* which explored the Costa surface through light, sound and shape: ever thought you could listen to a shape? 3D printed, tracked with proximity sensor technology then transformed into audio data, you can physically experience the sounds of a Costa surface.

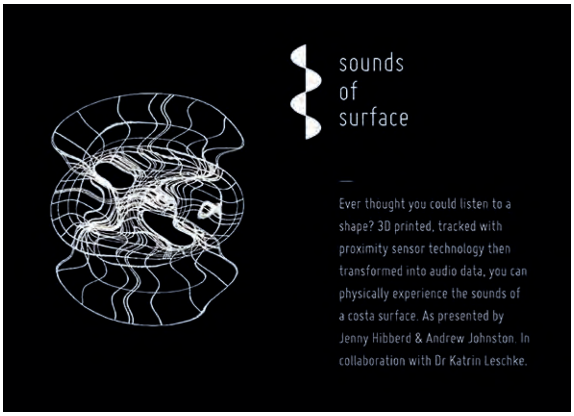

Figure 8. Sounds of surface

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Acknowledgements

We would like to thank the Leverhulme Trust, the Wellcome Trust and the University of Leicester for their support of this work.

Katrin Leschke

Katrin is a Reader in mathematics at the University of Leicester. Her main research interests are in differential geometry and visualisation. Katrin was born in Berlin and has taught in Germany, US and UK. Not being an artist, she still enjoys literature, theatre, movies and music.

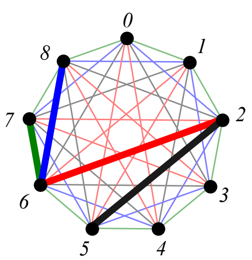
Mathematics News Flash

Aditi Kar reports on new path-breaking developments in mathematics from the past few months.

As the Covid-19 outbreak changes our lives as never before, mathematical modellers and statisticians come together to test the efficacy of social distancing. In the meantime, mathematicians grind on and we can report on several very exciting announcements.

Ringel's Conjecture: An Asymptotic Solution

AUTHORS: Richard Montgomery, Alexey Pokrovskiy and Benny Sudakov
ACCESS: https://arxiv.org/abs/2001.02665



A graph G is decomposable into copies of a graph H if the edges of G can be partitioned into edge-disjoint subgraphs isomorphic to H. For instance, the complete graph on 3 or 7 vertices can be decomposed into triangles while the one on 4 vertices cannot. Graph decomposition problems have long captivated mathematicians and inspired a formidable body of research. A favourite open question for graph theorists is Ringel's conjecture from 1963: 'the complete graph on $2n + 1$ vertices can be decomposed into copies of any tree (a graph without circuits) on n vertices.' Montgomery, Pokrovskiy and Sudakov announced an asymptotic solution to Ringel's conjecture in February this year. Their affirmative solution for large n is remarkable in that it works for trees of any valency.

A simplified version of the strategy can be described as follows: one starts with a specific colouring of the edges of the complete graph K_{2n+1}, called the near distance colouring (ND colouring) with n colours. For instance, the ND-coloured K_5 has only blue edges on the boundary pentagon with red on all the inner edges. One then finds a copy of a 'rainbow tree' with n edges in the coloured graph: all edges in a rainbow tree bear different colours. When $n = 2$, there is only one 2-tree up to isomorphism, namely, the path with two concatenated edges. Any subgraph made of one red edge and one blue edge emanating from the same vertex of the ND-coloured K_5 provides an embedding of the rainbow 2-tree. Observe now that cyclically shifting the chosen vertex to every other one step at a time, covers the entire K_5 with copies the chosen rainbow 2-tree.

Finding embeddings of every rainbow n-tree in the ND-coloured K_{2n+1} is no mean feat and therein lies the principal innovation by the authors.

Connes Embedding Conjecture is False

AUTHORS: Zhengfeng Ji, Anand Natarajan, Thomas Vidick, John Wright, and Henry Yuen
ACCESS: https://arxiv.org/abs/2001.04383

Connes Embedding Conjecture (CEC) is a long standing problem from the theory of von Neumann algebras. Formulated by Alain Connes in the 1970s, the CEC was found to be connected to a host of other open problems and questions, originating in apparently unrelated areas of mathematics. A positive solution to the CEC would imply among other things, that every countable discrete group is hyperlinear. A negative solution to the CEC was announced in January by Ji, Natarajan, Vidick, Wright, and Yuen, researchers working in quantum complexity theory.

For some, it came as a surprise! Quantum complexity theory arose in the realm of quantum computers which were inspired by principles of quantum mechanics. Computational complexity is studied using complexity classes: each class is defined as a set of (decision) problems that can be solved subject to some given constraints. For instance, the class P is the set of problems that can be solved by a Turing machine in polynomial time. Complexity theorists are interested in how different classes relate to each other.

Decision problems in this field are often described using formal language theory. A formal language is said to be recursively enumerable (RE) if it is a recursively enumerable subset of the set of all words in the alphabet, or equivalently, if all valid strings of the language are recognised by a Turing machine.

Ji, Natarajan, Vidick, Wright, and Yuen announced a proof that the class RE is equivalent to the more mysterious MIP* class of languages. RE=MIP* gives a negative solution to Tsirelson's problem which in turn is known to give a negative solution to the CEC.

G. Baumslag's problem on $\mathbb{Q}$-groups

AUTHORS: Andrei Jaikin-Zapirain
ACCESS: http://matematicas.uam.es/andrei.jaikin/preprints/baumslag.pdf

Around 1968, G. Baumslag was studying the structure of groups, in which extraction of n-th roots is uniquely possible for every positive integer n. The quintessential example of such a group is the additive group of the rationals and Baumslag called these groups $\mathbb{Q}$-groups. Evidently, a free $\mathbb{Q}$-group is obtained by repeatedly, freely adding n-th roots to a free group and the resulting intermediate quotients. Baumslag asked if the limiting object of this inductive process, namely, the free $\mathbb{Q}$-group is residually torsion-free nilpotent (RTFN).

This decades-old technical problem in the theory of groups has recently been resolved by Andrei Jaikin-Zapirain. A group is RTFN if every non-identity element survives in a torsion-free nilpotent quotient of the original. RTFN groups are known to possess a rich structure and hence the interest. Jaikin-Zapirain's proof uses his theory of mod-p L^2-Betti numbers for the free pro-p group.

People can handle the truth!

AUTHORS: Anne Marthe van der Bles, Sander van der Linden, Alexandra L. J. Freeman, and David J. Spiegelhalter
ACCESS: https://www.pnas.org/content/early/2020/03/17/1913678117

Who do we believe in these uncertain times? The good old Times, or lines read hastily in the Evening Standard? Our dilemma intensifies as Twitter and the rest of social media begin to expand into the news world. Experts and journalists have always presumed that hiding the uncertainty of data preserves public faith. Statistical ambiguity is presented to readers as 'absolute' data. However, recent research by mathematicians collaborating with psychologists at the University of Cambridge has shown that "people can handle the truth"! The team, supported by the Nuffield Foundation, wanted to see if they could get people much closer to the statistical truth by being honest about what we don't know, like the exact number of Covid-19 cases in the UK.

In October 2019, the research group worked with the BBC to conduct a field experiment. In a BBC News article, figures were either presented as usual or with some uncertainty like a verbal caveat or a numerical range. Readers were asked to complete a brief survey. The survey results bolstered observations from their four laboratory experiments. The findings, published in the Proceedings of the National Academy of Sciences on 23rd March, will persuade scientists and journalists to be more candid about the limits of human knowledge.

Mathematics News Flash prepared by Dr Aditi Kar

Maths and Mingle: a Monthly Gathering Organised by PhD Students, for PhD Students

LILY CLEMENTS, SAM HUGHES, MATTHEW STANIFORTH

The ever-evolving PhD environment in the mathematical sciences encourages a high level of interdisciplinary networking, skill-development, and collegiality. In this article, we introduce Maths and Mingle: a novel undertaking at the University of Southampton with the purpose of achieving exactly these aims.

What is Maths and Mingle?

Maths and Mingle is a seminar series taking place in the School of Mathematical Sciences at the University of Southampton. We are a multi-faceted, monthly get-together of graduate students, where attendees from across the school meet to address goals underpinning the postgraduate programme in the mathematical sciences. We provide a platform for the enhancement of generic key skills, whilst simultaneously encouraging presentation of students' own research, within a welcoming, friendly atmosphere. Importantly, we strive to achieve these aims within a streamlined, efficient framework, whilst appealing to students and remaining adaptable to fluctuating needs.

Students mingle before a talk

The dynamic current progression of the graduate environment in the mathematical sciences is enhanced by the continual evolution of expectations of funding bodies, universities, and students themselves. One aspect of this broadening of outlook is that increasing numbers of PhD students are moving into jobs outside academia, where there is an expectation of a keen grasp of a variety of professional skills.

Many graduate students are indeed highly skilled in a plethora of areas which fundamentally underpin postgraduate study in the mathematical sciences. Progression through a PhD carries with it an inherent, continual development of skills such as team-working, communication and presentation, and self-organisation, to an advanced level. This happens via various channels, for example through regular meetings with supervisors and colleagues, attendance of conferences, and presentation of work to peers.

Despite this, when applying for jobs, many PhD students do not sufficiently recognise their proficiency in these fields, since they were not trained in them in a formal context. One of the goals of Maths and Mingle is to provide an opportunity for students to not only develop recognition of their achievements in these skill areas, but also to fine-tune them.

Maths and Mingle also provides a platform for students to invite speakers highly experienced in areas unrelated to the mathematical sciences, such as underlying university structures and topics in wider society, to pass on their knowledge. In this way, students can be kept abreast of changes, for example, to data management regulations, health and safety requirements, and even the concrete influence of political issues on their future prospects — either in or outside of academia.

Another objective of Maths and Mingle is to have a positive impact on student welfare; to provide an open, welcoming environment in which students can socialise, encouraging inclusiveness and discouraging isolation. Consider the progression from undergraduate to graduate study: this transition is significant, accompanied by necessary changes in mindset and workflow. Maths and Mingle aims to ease the psychological load of this transition, by providing an opportunity for students to discuss matters affecting them.

Our framework

The framework of our individual meet-ups is not set in stone, but over time a regular pattern has formed which works well. For the first 15 minutes or so whilst everyone arrives, we relax, chat, and (crucially!) mingle. During this period, we bring out our monthly puzzles — often taking the form of a cryptic crossword set by the organisers. This is also a time in which we can welcome our speakers, and set up any relevant presentation software for them.

Our monthly crossword can take a bit of team work!

Business then begins in earnest with our talks. First, a 20–30 minute skills talk given on the topic for this seminar. We follow this with a very short break, and then continue with our student research talk, where a student from one of the research groups in our department gives a 20–30 minute talk on their on-going work. Each of these talks is followed by a 5–10 minute period of questions, and general open discussion on/around the subject at hand. This can often lead to quite a bit of a digression, and we actively encourage this!

After a second brief interlude, we finish with our PGR forum; the mathematical sciences postgraduate representatives host an open discussion — over pizza — about matters affecting postgraduates in the school. This not only provides an opportunity for students to raise their own concerns, but also allows our representatives to give feedback and updates on issues raised at previous meet-ups.

On the level of a more global organisational format, we have come to the conclusion that flexibility is a priority, as is coordination with leaders of other regular events. In terms of our calendar, we convene approximately monthly, aiming for ten to twelve meet-ups per year. When organising the specific dates and times of these sessions, it is important that we work closely with other school and faculty-level event organisers; not only to avoid potential clashes, but also to seize opportunities to widen our scope, joining forces and hosting cross-faculty events where possible.

Our choice of topics for skills and research talks, and respective speakers, is taken based on the factors of current relevance and utility to our audience, along with general potential interest. It is here in particular that having student organisers is of great benefit.

Where we are today

Maths and Mingle is a vibrant, busy seminar series, regularly attracting around 40 attendees. We have recently drawn interest in attendance from students outside the school, as well as from staff in running joint events at faculty level. Our generic skills training sessions host expert speakers both internal and external to the university, where topics range from the opportunities for work in international mathematical consultancy firms, to issues around equality and diversity in mathematics. One of our ongoing pursuits is to formalise this training, so that we receive formal external recognition. Running since 2018, we are now into our third year, and anticipate further evolution and improvement going forwards.

The organisers

Matthew Staniforth, Lily Clements, and Sam Hughes are second year PhD students in the School of Mathematical Sciences at the University of Southampton. They took over the organisation of Maths and Mingle at the start of 2019. Whilst their research interests differ wildly (algebraic topology, statistics, and geometric group theory, respectively), they connect on a much more fundamental level: their enjoyment of discussing Maths and Mingle meetings at the pub.

Microtheses provide space for current and recent research students to communicate their findings with the community. We welcome submissions — see newsletter.lms.ac.uk for guidance.

Microthesis: Massey Products in Moment–Angle Complexes

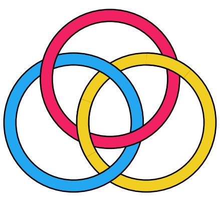
ABIGAIL LINTON

Massey products detect the "tangled" structure of topological spaces. They detect that the Borromean rings are linked, which the linking number cannot. In algebraic topology and symplectic geometry, Massey products are obstructions to formality and Kähler structure but Massey products are algebraically complicated to compute. We use combinatorics to calculate these difficult operations.

I work with moment-angle complexes Z_K, which are spaces built by gluing unions of products of discs and circles according to the relation of simplices in a simplicial complex K. These objects arise naturally in symplectic and complex geometry, topology and combinatorics. A simple example of a moment-angle complex is the 3-sphere, S^3, when K is the disjoint union of two points. If K is a triangulation of a sphere, then Z_K is a manifold. In general Z_K is complicated but the key is that the combinatorics of K encode a surprising amount of topological data about Z_K.

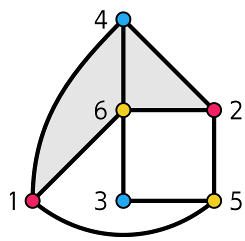
Massey products via combinatorics

Massey products are higher operations (on differential graded algebras, such as $H^*(Z_K)$), which means to define an n-Massey product $\langle \alpha_1, \ldots, \alpha_n \rangle$ we need the $(n-1)$-Massey products $\langle \alpha_1, \ldots, \alpha_{n-1} \rangle$ and $\langle \alpha_2, \ldots, \alpha_n \rangle$ to be defined and trivial. Unlike many operations, a Massey product is a set, which is called trivial if it contains 0. If it contains more than one element, we say the Massey product has indeterminacy. What makes it difficult to compute a Massey product is having to check not only that it is defined, but also that each element is non-zero.



The Borromean Rings: any two rings are not linked, but all three together are. This is detected by a 3-Massey product.

It wasn't originally clear if moment-angle complexes could have non-trivial Massey products, but the first examples were constructed by Baskakov in 2003 [1]. Let us see an example of how Massey products in Z_K are encoded in K. Suppose K is the simplicial complex below, built on 3 pairs of vertices $\{1,2\}$, $\{3,4\}$ and $\{5,6\}$. Each disjoint pair carries a class α_1, α_2, α_3 of Z_K respectively. The 2-Massey product $\langle \alpha_1, \alpha_2 \rangle$ in Z_K is carried by 1-dimensional cycles in K restricted to the vertices $1,2,3,4$. Since there is no cycle in this restriction, $\langle \alpha_1, \alpha_2 \rangle$ is trivial. Similarly there is no 1-cycle on K restricted to $3,4,5,6$, so $\langle \alpha_2, \alpha_3 \rangle$ is trivial too. This implies that the 3-Massey product $\langle \alpha_1, \alpha_2, \alpha_3 \rangle$ in Z_K is defined.

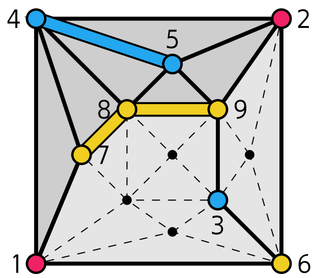


A simplicial complex K such that Z_K has non-trivial triple Massey product with indeterminacy.

Also the fact that the restriction of K on $1,2,3,4$ is disconnected implies that this Massey product has indeterminacy. In this example we can show that $\langle \alpha_1, \alpha_2, \alpha_3 \rangle$ is non-trivial by checking each element. This is one of the first examples of a non-trivial Massey product in Z_K with indeterminacy [5].

Massey products and edge contraction

If Z_K has a non-trivial Massey product and L is a simplicial complex that can be continuously deformed to K by contracting edges of L, one result from my PhD is to construct a new Massey product in Z_L [6]. Suppose L is the simplicial complex on 9 vertices below. By contracting the coloured bold edges in L, we obtain K in the example above. So by our result, Z_L has a non-trivial 3-Massey product with non-trivial indeterminacy.



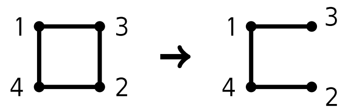
A full subcomplex $L \subset K_P$, when P is a truncated octahedron

We can use L to give an example of a non-formal manifold, that is, a manifold with a non-trivial Massey product. Consider $K_P = \partial(P^*)$, the boundary of the dual of a truncated octahedron P. The vertices of K_P are the 9 vertices of L with the 4 other vertices shown above, plus an additional vertex off the page that is connected to $1, 2, 4, 6$. A truncated octahedron P is a 3-dimensional polytope whose faces are squares and hexagons, so the vertices of K_P have valency either 4 or 6. The moment-angle complex $Z_P = Z_{K_P}$ is a (polytopal moment-angle) manifold. Since L sits inside K_P, the Massey product in Z_L lifts to a Massey product in Z_P. In general it is difficult to find examples of non-formal manifolds, but our result shows that Z_P is non-formal.

This result can construct many new and known examples of Massey products. For example we use it to give an alternative proof of Massey products in Z_P for Pogorelov polytopes P by Zhuravleva [7] from the classification of lowest degree 3-Massey products in moment-angle complexes due to Denham & Suciu [4] and Grbić & Linton [5].

Massey products and star deletion

The categorical product of two simplicial complexes is the join, $K_1 * K_2 = \{\sigma \cup \tau \,|\, \sigma \in K_1, \tau \in K_2\}$. This induces a product in moment-angle complexes $Z_{K_1 * K_2} = Z_{K_1} \times Z_{K_2}$. Another result from my PhD is to construct a non-trivial n-Massey product by starting with the join of n simplicial complexes K_i and carefully cutting simplices to trivialise lower products [6]. For example the boundary of a square K is the join of two disjoint points $\{1, 2\}$ and $\{3, 4\}$. The moment-angle complex Z_K is $S^3 \times S^3$, which has a non-trivial (2-Massey) product that is supported on the cycle in K. We break this cycle and trivialise the product by deleting the edge $\{2, 3\}$.



There is no restriction in this construction on n or K_i, so we can construct higher Massey products on torsion elements. For example by deleting simplices in $\mathbb{R}P^2 * S^0 * S^0$, we construct a 3-Massey product on a torsion element, and this Massey product has indeterminacy. Also we can detect many non-formal manifolds Z_P by finding a (full) subcomplex of K_P that edge contracts to a simplicial complex built by this construction. For example we use this to give an alternative proof that Z_P is non-formal for all permutahedra P, which was first shown by Buchstaber & Limonchenko [2].

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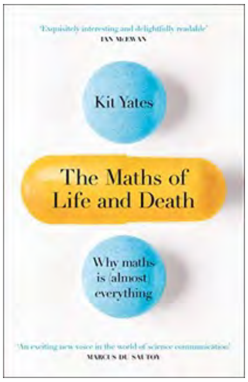
Abigail Linton

Abi is an EPSRC Doctoral Prize Senior Research Assistant at Southampton, where she finished her PhD under the supervision of Jelena Grbić in 2019. Her research interests are in algebraic topology and combinatorics. In her spare time Abi enjoys singing in a choir, running and learning to play the guitar; so far only two of these at the same time.

The Maths of Life and Death — why maths is (almost) everything

by Kit Yates, Quercus, 2019, £20, ISBN: 978-1787475427

Review by Neil Saunders



In Daniel Kahneman's book *Thinking Fast and Slow* [3], he details many examples and psychological studies revealing that many of us rely on the maxim "what you see is all there is" in our decision making. Further complicating this process are the interactions, or lack thereof, of our "two systems" of thought: "system 1" being our fast and automatic response mechanism, good for making quick and instinctive decisions; and our "system 2" being responsible for the more effortful and purposeful mental deliberations. He argues that having a well-equipped and functioning "system 2" that can intervene in the immediate, but often misguided, conclusions of "system 1" is a necessary component for making better decisions in our everyday lives. An underlying thread in the many examples of the book is that we humans are quite bad at thinking statistically (and more broadly, without proper training, mathematically) as this is the work of "system 2".

While it is clear to the LMS readership that one of the key tools in building a robust "system 2" for making better decisions in an increasingly complex world is a competent literacy in mathematics, our duty as researchers and educators to spread this message as far and wide as possible will remain pressing.

Kit Yates' wonderfully lucid new book *The Maths of Life and Death* is a fantastic contribution to this endeavour. It skilfully makes the case for the importance of mathematical literacy in our society, highlighting the indelible role it plays in every part of our lives.

The Maths of Life and Death has something for everyone in and around the world of mathematics. If you are a practising mathematician or educator needing real-world examples to illustrate a point to your students or peers, then this book provides a rich buffet of examples. On the other hand, for anyone who might have been put off by mathematics in the past, yet still appreciates its importance, the book welcomes and quickly engrosses its reader into the many different facets of mathematics and their applications.

The most striking feature of this book — a book on mathematics — is that there isn't a single equation in it. There are no overly long explanations into any deep mathematical theories and no demands on the reader to have a sophisticated mathematical background. Yates accomplishes his task of bringing mathematics to life by vividly recounting real-life stories in an engaging and vibrant way. He underscores the importance of mathematics by often recounting, in devastating detail, the tragic consequences an ignorance of mathematics can wreak on people's lives. The book offers a corrective to Kahneman's "what you see is all there is" maxim, widening the reader's vision to see that mathematics is literally everywhere.

The book comprises seven chapters canvassing a wide range of topics and the underlying mathematical principles behind them. After recounting the power of exponential growth in Chapter 1, in phenomena like an algal bloom or a nuclear reaction, Yates powerfully demonstrates the role of statistics in the medical arena. Of particular resonance are his sections on 'false positives' in diagnostic tests and how these even confuse seasoned medical practitioners from time to time: the central message being that even if a result of a diagnostic test has come back positive, the likelihood that the patient actually has the disease being tested for can still be very small.

Chapter 3 contains some sobering accounts of how ignorance of statistics, simultaneously combined with its misuse, has resulted in some heartbreaking miscarriages of justice. The case of Sally Clark, the mother who was wrongfully convicted of murdering her two infant children largely on the statistically misguided (yet extremely convincing to a statistically ignorant jury) testimony of the expert witness, is particularly devastating.

Chapter 4 contains some humorous and infuriating examples of how statistics are often misused by unscrupulous media organisations and advertising corporations in creating false narratives. It serves as a reminder that there are *lies, damned lies and statistics* and that one must always have the sceptical dial turned up to extra-sensitive when hearing claims that sound too good to be true.

After an entertaining Chapter 5 on the history of the development of our number systems and how they have often let us down, Yates concludes the book with two chapters largely on mathematical algorithms and their use (and misuse) in decision-making, automated machines and disease modelling. It's here where we really see why the term 'almost' is put in brackets in the subtitle of the book, as Yates is as eloquent as he is convincing in arguing that while mathematics is pervasive and powerful, we shouldn't blindly allow it to control our lives. The algorithm is "as strong as its weakest assumption" and we should "be careful not to get carried away…by attempting to extend it beyond its remit". This perhaps further strengthens the argument for including an ethics component to the teaching of mathematics in our institutions.

In Daniel Dennett's book *From Bach to Bacteria and Back: The Evolution of Minds* [2], he quotes a maxim of one of his former students: "you can't do much carpentry with your bare hands and you can't do much thinking with your bare brain". Kit Yates has written an enthralling and enlightening account of how mathematics is a necessary tool for furnishing brains with better thinking capacities. Its engaging and lucid style makes it readily accessible for all readers regardless of the level of their mathematical background.

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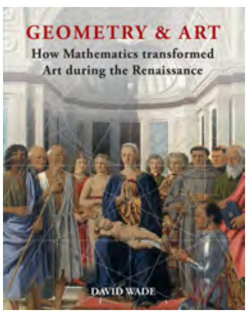
Neil Saunders

Dr Neil Saunders is a Senior Lecturer in Mathematics at the University of Greenwich. His research is in algebra and geometric representation theory. He was born in Australia and completed both his undergraduate and postgraduate studies at The University of Sydney. He's a keen cricketer and musician.

Geometry & Art: How Mathematics transformed Art during the Renaissance

by David Wade, Shelter Harbor Press, 2017, £16.99, US$24.95, ISBN: 978-1627951050

Review by Snezana Lawrence



Geometry & Art: How Mathematics Transformed Art during the Renaissance, is a beautifully produced book with many beautiful illustrations. A hardback hefty folio is reminiscent of the now disappearing coffee-table book format, and its content is an invitation for an occasional as well as more concerted effort by the reader. Certainly it is one of those books you would like to be placed next to your most comfortable reading chair so that you can remind yourself often of how some of the most beautiful images of the Renaissance art relied so heavily on geometry. This reliance, of course, has many layers. One is the actual knowledge of geometry, another, for example, the beauty of geometrical objects lent to visual arts. The book we have in front of us is important in another way too: it leads its readers to understand more of geometry themselves, and therefore enhance their own enjoyment of art which had such a close connection with geometry and the mathematical and scientific progress of the times.

The book is divided into five sections: *The divine beauty of geometry, The revival of the Latin West, Geometria and the Northern Renaissance, Polyhedra and the creative imagination*, and *The continuing influence of Geometria*. Its opening statement gives a clear aim: to begin to trace the common threads of invention and imagination which were so purposefully joined in the Renaissance art:

'The history of Art is intimately linked to the history of Ideas, and both have common ground in the human capacity for invention and imagination'.

This sets the tone for what is to come and provides a common thread from the history of geometry to modern times, with a heavy emphasis on the period leading up to the Renaissance, this period itself, and its aftermath. You will find here diverse subjects and topics: regular and semi-regular polyhedra, the theory of optics, the neo-Platonic influence on both Western and Islamic arts, invention and the uses of perspective, and the portrayals of astronomical investigations in paintings of the time, to name some.

Each part of the book has individual chapters ranging from seven to seventeen. If we assume that the number of these shows the emphasis more clearly, then *The Revival of the Latin West* (seventeen chapters) and *Polyhedra and the creative imagination* (twelve) are the sections that are most important. The chapters are short, succinct, and well-illustrated. Each chapter has an emphasis box in which the most important concepts, histories, and personalities are explained. The narrative is clear, well-written, and with many details to get the interested reader to search the sources further. But unlike Pedoe's [1] or Heilbron's [2] books Wade does not contain direct references. This is probably the weakest link in the book for a scholarly reader — but certainly makes the reading for a novice or an art enthusiast quicker. A bibliography is given at the end of the book pointing those wanting to learn more to the main sources the author consulted, and through which he based his findings.

The images are plentiful and beautiful. But unlike, for example, Martin Kemp's now classic *The Science of Art* [3], this volume does not give image references next to the images themselves. These are to be found at the back of the volume, and are quite hard to distinguish or find.

Perhaps these are comments which are not relevant for the public for which the book seems to be aimed. Its aim is to educate and entertain, not the scholar or academic, but the popular and interested public. Such public will enjoy the text and images as a starting point for meditations and thinking about the links between geometry and art. Sure, readers may need to do some more research themselves to either confirm or learn more of what they find in this volume, but enjoy they will, and feast on this book weaved from the many common threads between art, mathematics, and history.

FURTHER READING

[1] D. Pedoe, *Geometry and the Visual Arts*, Dover Books, St Martin's Press, New York, 1976.
[2] J.L. Heilbron, *Geometry Civilized, History, Culture, and Technique*, Clarendon Press, Oxford, 1998, 2000.
[3] M. Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*, Yale University Press, New Haven and London, 1990.

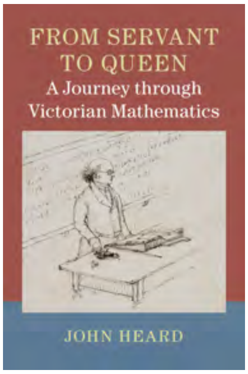
Snezana Lawrence

Snezana Lawrence is a Senior Lecturer in the Department of Mathematics at the University of Middlesex, London, England. She has published on the history of mathematics and its relationship to education, and her main focus area within this field is the history of geometry, as well as the perception of mathematics and mathematicians in mathematics education and popular culture.

From Servant to Queen: A Journey through Victorian Mathematics

by John Heard, Cambridge University Press, 2019, £34.99, US$44.99, ISBN: 978-1107124134

Review by Alex D.D. Craik[†]



This book is not intended as a comprehensive survey of Victorian mathematics, about which much has been written in recent years. Instead, it focusses mainly on the development of attitudes towards pure mathematics and its rise to become an independent subject free of association with applications to 'the real world'. In other words, Heard charts the transition from 'Servant' to the applied sciences then dominant in Britain, towards 'Queen': an independent professional group concerned with abstract ideas and their intrinsic beauty. In Heard's words, "Their success did not come easily, because they had adopted a philosophy concerning mathematics that was opposed to the prevailing utilitarianism of the Victorians, and consequently they became the target of considerable criticism concerning the value of their activities" (p.1).

After an introductory chapter *Setting the Scene*, Chapter 2 *The Legacy of Newton* addresses the state of British mathematics in the eighteenth century, highlighting the dominance of Cambridge in mathematical instruction, with its emphasis on the competitive Tripos examinations. But the preference for Newton's fluxions and fluents over Leibniz's superior differential notation for the calculus led to a too insular view in which continental achievements were disregarded. The few who espoused continental methods of analysis are identified as Woodhouse, Ivory, Babbage, Herschel and Thomas Knight. (To this list might be added William Wallace and William Spence.) The Royal Commissions of 1850 into Oxford and Cambridge castigated Oxford for its neglect of mathematics; but regarding Cambridge "On the importance of [mathematical] studies it is impossible to dwell too strongly". The chapter concludes with a few random examples of mathematics that may be regarded as abstract, including quaternions, matrices and Boole's Laws of Thought; and with some comparisons with the study of classical literature.

The long Chapter 3 is devoted to the London Mathematical Society, from its foundation with Augustus De Morgan as president until the 1920s. Suffice to say that it became the leading society for pure mathematicians, who were kept abreast of recent British work by its lectures and Proceedings. But Heard is critical of the narrow view that prevailed: "it did little to engage with the non-mathematical universe, but rather immured itself in splendid isolation, keeping the world at bay as it preserved the engrained traditions of British mathematics". A harsh view, but one supported by the Society's lack of involvement with other bodies.

Chapter 4, entitled *The Pure Mathematician as Hero* highlights the work of James W.L. Glaisher, Henry Baker, Henry J.S. Smith (of Oxford), and Percy McMahon. Less is said about Arthur Cayley and James Joseph Sylvester, rightly described as Britain's leading pure mathematicians, both being the subjects of full recent biographies: one learns only that they conducted research primarily on matrices and invariant theory, and that their work was superseded by continental advances. Also mentioned is Andrew Russell Forsyth, who broke with British insularity to write an influential work on complex analysis. It is disappointing that Heard does not engage with these

[†]We note with sadness that Alex Craik died on 17 November 2019.

various research topics: what, for example, is Cayley's invariant theory about? The absence of any mention of William Burnside's work on group theory is also surprising. And why were the pure mathematicians so insular when the applied mathematicians were not?

Chapter 5, *Mathematics in an Aethereal World*, leaves the pure mathematicians behind to outline the remarkable accomplishments of British applied mathematicians and natural philosophers at this time, including Airy, Kelvin, Stokes, Maxwell and Tait. But this is something of a digression and much has been written elsewhere. Chapter 6, *Apologias for Pure Mathematics* discusses the professionalisation of Victorian society, but concludes that "pure mathematicians could not have constituted a social profession". Conflicting views were advanced as justifications for pure mathematics. According to Henry John Rose, an editor of the Encyclopaedia Metropolitana, its value lay in providing "stores for future use" in natural philosophy; but William Thomson complained to Hermann Helmholtz that Cayley and his like should "take their part in the advancement of the world" instead of devoting their skill to "pieces of algebra which possibly interest four people in the world". Further such criticisms came from Airy and T.H. Huxley. A reply to the latter from Sylvester emphasised that pure mathematics required imagination and creativity, "constantly invoking the aid of new principles, new ideas, and new methods...". Citing Cayley as "the Darwin of the English school of mathematics", he compared the apprehension of new mathematical objects with the discovery of new species of living things, and likened the pure mathematician to an explorer of an abstract world. But, according to Heard, "by the late 1870s...pure mathematicians...needed to present their discipline in a completely new way".

This new way is outlined in Chapter 7, *Embracing Beauty*. Walter Pater's essays on aesthetics rejected the notion that the value of a work of art lay in the moral truth that it conveyed, and claimed that beauty could be found anywhere. Adopted by artists and writers, including J.M. Whistler and Oscar Wilde, this became the influential, but sometimes lampooned, Aesthetic Movement. By 1883, the Irish mathematician George Salmon, in a celebratory piece about Cayley, described him as a "great artist" who had lived "a life devoted to the contemplation of beauty and truth...the fact that it is a very limited circle which is capable of appreciating the beauty of the work done by a great mathematician should not prevent men from understanding that it is like the work done by a poet or painter...". Salmon's article closely reflects the views of Pater and the aesthetes. Later examples include Bertrand Russell's 1907 statement that "Mathematics, rightly viewed, possesses not only truth, but supreme beauty...".

The idea that the function of pure mathematics was to pursue truth and beauty raised the question of what pure and applied mathematics had in common. Sir George Darwin, an expert on ocean tides, in an address to the 1912 International Congress of Mathematicians, admitted that "when I gaze on some of the papers written by men in this room I feel myself much in the same position as if they were written in Sanskrit". Further, he believed that applied mathematicians had come to be thought inferior to pure; yet "If our methods are often wanting in elegance and do but little to satisfy that esthetic sense...yet they are honest attempts to unravel the secrets of the universe in which we live".

Chapter 7 ends with an appreciation of the achievements of Hardy and Littlewood in firmly establishing the status of pure mathematics in Britain and rescuing it from its insularity. A final brief *Epilogue* completes the book. Readers may be disappointed to find little about actual mathematics in this book; but it interestingly charts the evolution of attitudes towards pure mathematics, and the growing confidence of pure mathematicians themselves to present themselves as searchers for truth and beauty, rather than mere servants of science.

Alex Craik

Alex Craik was Emeritus Professor of Mathematics at St Andrews University. Before turning to history, his research concerned fluid mechanics. He also enjoyed playing classical guitar and travelling in Greece.

Obituaries of Members

Vernon Armitage: 1932 – 2019

Dr Vernon Armitage, who was elected a member of the London Mathematical Society on 15 December 1955, died on 12 December 2019, aged 87. Dr Armitage was Obituaries Editor of the LMS Bulletin (1973–96).

John Parker writes: Vernon Armitage was born on 21 May 1932 in Settle, Yorkshire. His father was a signalman on the Settle to Carlisle railway and Vernon retained a passion for steam trains all of his life. Another of Vernon's passions was mathematics, and especially teaching mathematics. He loved to be there when students understood any new concept, and in turn the students appreciated his care and love for the subject.

Vernon studied at University College London where he was awarded a Mathematics BSc in 1953 and a PhD, supervised by Harold Davenport, in 1956. He then spent a year at Cuddesdon College Oxford before teaching mathematics at Pontefract High School and Shrewsbury School. In 1959 Vernon became a Lecturer in Pure Mathematics at Durham University and was invited by fellow mathematician Syd Holgate, the Master of the newly founded Grey College, to become a fellow of the college. In 1967 Vernon returned to London as a Senior Lecturer at Kings College before becoming the first Shell Professor of Mathematics Education at the University of Nottingham in 1970. Vernon was back in Durham in 1975 as Principal of the College of St Hild and St Bede, which was then a Church of England college formed by the merger of two teacher training colleges. Vernon navigated the college through the process of joining Durham University in 1979. He was held in great affection by many generations of students in Hild-Bede, who gave him the nickname 'Prin'. When he retired in 1997, the students renamed the college bar 'The Vernon Arms' in his honour. Vernon continued teaching and supervising student projects in the Department of Mathematical Sciences until 2016 with the title Honorary Senior Fellow. During this time Vernon published a book in the LMS Student Texts series on Elliptic Functions, which combined a manuscript by Eberlein, which he edited, and material he had taught in Durham.

On a personal note, it was while I was taking Vernon's third year course on Elliptic Functions that I was inspired to do a PhD. I was greatly honoured that, when I returned to Durham ten years later, I was given this course to teach. Many years later, I asked Vernon for help with non-Archimedean metric spaces and the resulting research paper was Vernon's last. He will be greatly missed.

Martin Taylor writes: After his thesis, Vernon's mathematical interests widened to include curves over finite fields and especially their zeta functions. He was fascinated by the interplay of ideas between such curves and number theory, and this came into sharp focus with his study of the constants in the functional equation of L-functions known as root numbers.

His knowledge of root numbers played a pivotal role in the formulation of the Fröhlich conjecture. Fröhlich and Martinet had been studying the Galois structure of the rings of integers of tame Galois extensions with Galois group H_8; and Vernon had been thinking about the root numbers in just this situation. Serre joked that it would be wonderful if the two were connected. Vernon checked some root numbers, and his calculations matched perfectly with the Galois side. Fröhlich went on to prove the result for H_8-extensions, and then to formulate a conjecture for general Galois groups.

Vernon also worked in the field of mathematical education and during the 1960s he helped with the development of the School Mathematics Project (SMP). But, over time, he became unhappy as mathematical education moved towards academic theory.

Paul Cohen had once said to David Williams "There is only one thing sacred in this world and that is the Riemann Hypothesis". Vernon was greatly inspired by this comment, and he devoted a considerable amount of time in trying to prove the Riemann Hypothesis by utilising symmetry properties associated with the equation of heat flow. Vernon drew great encouragement from his conversations on the matter with both David Williams and Enrico Bombieri. The Riemann Hypothesis is considered to be the 'Holy Grail of Mathematics' and, at least for Vernon, like the Holy Grail, it was sought but never found.

After his retirement, Vernon collaborated with Alice Rogers on Gauss sums and Quantum theory, and he greatly enjoyed this project. Indeed, Vernon had always been inspired by using ideas from physics in number theory.

To conclude, Vernon was once asked in an interview how he would like to be remembered. He answered simply "As a good man". Well, he was certainly that — with much room to spare! But he will also be remembered as an inspiring and elegant mathematician who could communicate his ideas with wonderful charm and clarity.

S. James Taylor: 1929 – 2020

Professor S. James Taylor, who was elected a member of the London Mathematical Society on 17 June 1954, died on 22 January 2020, aged 90. Professor Taylor was General Secretary and Journal Secretary 1962–65; General Secretary and Proceedings Secretary 1967–71; and Proceedings Secretary 1980–82.

John Kingman writes: After a childhood in Nigeria, James Taylor, an Ulsterman of missionary parents, received his mathematical education in Belfast and Cambridge. His PhD, under the supervision of A.S. Besicovitch, was on Hausdorff measures, which can be used to measure the size of complicated sets such as the fractals popularised by Mandelbrot. Taylor realised that another interesting class of sets were generated by the sample paths of random processes such as those modelling Brownian motion. He was able to prove many subtle results, by combining the hard analysis of the Cambridge school with a deep probabilistic intuition.

The interest he developed in probability theory drew him in the early 1960s into the Stochastic Analysis Group, a small group of British probabilists who were trying to introduce into the UK the modern approach due to A.N. Kolmogorov which was already accepted on the Continent and in the USA. Britain had espoused a more 'applied' approach in which probabilities were manipulated, often to good effect, with little concern for the underlying mathematical basis. The Group decided that a textbook was needed, that would develop basic probability theory as a branch of measure theory, and Taylor was a natural choice for author. In the event he and I collaborated on an *Introduction to Measure and Probability,* published in 1966.

Working with James was an entirely pleasant experience. His deep knowledge, his insistence on high scholarly standards, and his ability to explain complex concepts, were salutary. He was a scholar and a gentleman. Another mathematician who enjoyed his collaboration was Paul Erdős, with whom James wrote several papers. James was one of the 'bankers' who facilitated the wanderings which for many years Erdős made across the globe.

Peter Giblin writes: In 1964 James Taylor was appointed to the Chair of Mathematics at Westfield College, University of London (he was later Dean of Science) and in 1975 he moved to a Chair of Pure Mathematics at the University of Liverpool. He succeeded Terry Wall as Head of the then Department of Pure Mathematics in 1979, retiring for the first time in 1983. Much of James's considerable energy during this period was devoted to projects to improve the quality of teaching in the university and also in schools. He served as Chair and as Treasurer of the Joint Mathematical Council, but his greatest contribution in Liverpool was his instrumental role in the founding in about 1976 of 'Mathematical Education on Merseyside' (MEM), an organisation which continues to flourish today.

James was also active in the already venerable Liverpool Mathematical Society (LivMS, founded 1899), serving as its President 1975–76. The first 'VI form Lecture' in a series started by James was given by his friend Sir Hermann Bondi. James, together with the late Ian Porteous, worked very hard to involve local school teachers and the local authorities in planning and carrying out MEM initiatives, including secondary schools' 'Challenge' competitions sponsored by local industry and commerce (these are still running) and recreational mathematics events.

Over the years, many more members of staff (including myself), from all three Liverpool Universities — including now Liverpool John Moores and Liverpool Hope — have been recruited to carry on the good work of MEM and LivMS, new ventures including a more advanced VI form 'Open Challenge' competition, the LivMS FunMaths Roadshow, MEM Masterclasses and a continuing series of schools lectures by well-known speakers. There was even for a time a 'Radio Challenge' competition hosted by a local radio station, Radio City. But it was James's initiative, persuasiveness, imagination and foresight which started and nurtured the crucial early phases of all this important outreach into local schools and the local community. From Liverpool James and his wife Maureen moved in 1984 to the University of Virginia at Charlottesville. James (predictably) became Head of Department and remained in Charlottesville until his second and final retirement to Sevenoaks in 1996. James is survived by Maureen, whom he married in 1955, their four children, 17 grandchildren and six great-grandchildren. His life's work was greatly influenced by a strong Christian faith, and he combined this with his mathematical interests in making many trips to China, including after his second retirement.

Eric W. Wallace: 1931 – 2018

Eric Wallace, who was elected a member of the London Mathematical Society on 17 December 1964, died on 23 June 2018, aged 87.

Chris Lance writes: Eric was the youngest of six children of William and Catherine Wallace in Anfield. His father was a marble polisher and his mother was a tram conductor until she married. Eric was always very proud of his Liverpool roots. From Anfield Road Elementary School he passed the 11 plus into Alsop High School, where he was grateful for an excellent education. He was the only member of his family to continue to higher education, living at home while a student at the University of Liverpool as he could not afford accommodation elsewhere.

His mathematical talent impressed his teacher A.G. Walker (a future LMS President, 1963–65), who took him on as a PhD student. He gained his doctorate in 1956 with a dissertation *On the Classification of Lie Algebras*. He then, apparently at Professor Walker's suggestion, chose to do his National Service in the Navy, where he achieved the rank of lieutenant despite a lack of nautical skills, by teaching mathematics and the art of semaphore signalling to the naval recruits. In 1956, while stationed in Portsmouth, he married Anita Fisher and they set up home in the Navy's married quarters.

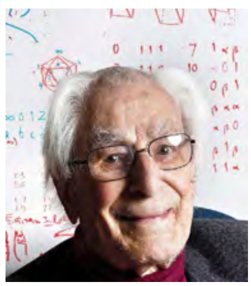
In 1958, with his National Service completed, Eric took up a post in the University of Leeds, where he spent his whole career as a Lecturer and later a Senior Lecturer in the Department of Pure Mathematics until his retirement in 1996, interspersed with sabbatical teaching visits in New York (SUNY Buffalo), Illinois and Michigan. He published several papers on Lie algebras and associative algebras, and served a three-year term as Head of Department. His three PhD students in Leeds, John Fountain, David Towers and Mike Holcombe, all went on to successful academic careers. He also acted as an Open University Tutor in Pure Maths for a number of years.

Eric and Anita were the social heart of the Department, and were largely responsible for its warm and friendly atmosphere. In the 1960s and 1970s, when universities had many young lecturers with growing families, Eric was among a small group who each year organised a grand Christmas party for the many children of the Maths and Computing departments. Professors and parents provided funds, and Santa Claus (possibly in the form of Eric himself) had presents for the children. In later years Eric and Anita continued to give many parties at their large house in Pool-in-Wharfedale.

Anita developed severe health problems, and Eric cared for her devotedly for several years until her death in 2003. But he found happiness again with Moira Wright, whom he married in 2008, and they continued the tradition of hospitality with dinner parties for Eric's colleagues, most of whom had retired by then.

In 2018, Eric had a severe stroke which left him almost completely incapacitated. His last weeks in hospital were difficult, but he was cheered by visits from his old colleagues and friends. He is much missed by Moira, his daughter Rachel and seven grandchildren. His son Jonathan died in 2017.

Richard Guy: 1916 – 2020



Richard Kenneth Guy, who was elected a member of the London Mathematical Society on 17 March 1960, died on 9 March 2020, aged 103, being the oldest member of the LMS.

Kenneth Falconer writes: Richard Guy was born in Nuneaton in 1916, his father having survived the Gallipoli campaign. From Warwick School he gained a scholarship to Gonville and Caius College, Cambridge, to read Mathematics. After graduating he worked as a school teacher, interrupted by war service as an RAF meteorologist, before becoming a lecturer at Goldsmith's College, then a teacher training college, in 1947. A desire to see more of the world took him to the University of Malaya in Singapore in 1951 and in 1962 he went on to the new Indian Institute of Technology in Delhi. In 1965 he moved to the newly founded University of Calgary where he remained for the rest of his life.

Richard did not start serious research until around 1960 when he made progress on some problems given to him by Erdős. He started working on combinatorics and graph theory, his interests broadening into number theory and combinatorial game theory — all areas where he made significant contributions.

He wrote more than 100 papers with over 50 collaborators including John Conway, Paul Erdős, Martin Gardner and Donald Knuth. A problem-solver, he thrived on 'intuitive' problems which are easily explained to the non-expert but which may require sophisticated or ingenious proofs. He authored two books in the Springer *Unsolved Problems in Intuitive Mathematics* series, on number theory and on geometry. As well as publishing in research journals he inspired mathematicians at all levels with expository accounts, clever proofs and unsolved problems in publications such as the *American Mathematical Monthly* and *Mathematics Magazine*.

Richard's best known contributions, whilst not his deepest mathematically, have an endearing appeal. He invented the 'glider', a period-4 configuration that travels across the grid in Conway's *Game of Life*. He designed a 'unistable' polyhedron with 19 faces which when made of a uniform material always rolls onto the same face. He formulated the 'Strong law of small numbers': that there are not enough small numbers to meet the demands placed on them, illustrating this law with examples drawn from across mathematics.

Richard became increasingly interested in combinatorial games and an extensive project with Elwyn Berlekamp and John Conway evolved. Their two volume (four in the second edition) classic *Winning Ways for your Mathematical Plays* is totally unique in content and style and appeals as much to enthusiastic amateurs as to research mathematicians. The first volume covers the general theory of partisan games, and the second relates this to a cornucopia of combinatorial games and puzzles. Richard's wit and clarity of exposition are readily apparent, as indeed they are throughout his work.

In 1940 Richard married Louise Thirian who shared Richard's passion of mountaineering and together they climbed many peaks in the Rockies and across the world. They had a close association with the Alpine Club of Canada who named a hut near Mont des Poilus after them. Louise was supportive of all Richard's activities and welcomed the many mathematicians who came to stay. As a 90th birthday present for Richard she set up the Richard and Louise Guy Popular Lecture Series at the University of Calgary. After she passed away in 2010 Richard raised considerable sums for charity in her memory.

Although he nominally retired in 1982, Richard was at his desk in the Calgary mathematics department almost daily until shortly before his death. He never took a doctorate but in 1991 Calgary awarded him an Honorary Doctor of Laws, 'out of embarrassment' Richard claimed. His final book *The Unity of Combinatorics*, co-authored with Ezra Brown, will be published by the Mathematical Association of America in May.

Death Notices

We regret to announce the following deaths:

- Professor John H. Conway, FRS, Princeton University, who died on 11 April 2020.
- Professor Freeman J. Dyson, FRS, of Princeton University, who died on 28 February 2020.
- Mr Ronald C. Ledgard, who died on 12 November 2019.
- Dr R. Michael F. Moss, St Andrews University, who died 5 November 2019.
- Professor Peter Vámos of Exeter University, who died on 17 March.

COVID-19: This information is provided so that Members are aware of events that were planned before the coronavirus pandemic. Many of these events have now been cancelled, postponed or moved online. Members are advised to check event details with organisers.

Beyond the Boundaries: New Directions in Financial and Actuarial Mathematics

Location: The Rose Bowl, Leeds
Date: 18–20 May 2020
Website: tinyurl.com/rpmuxxm

The conference will bring together leading experts and promising early career researchers from a variety of mathematical backgrounds interested in the interplay between theoretical and applied research in financial and actuarial mathematics. At the core of the conference: stochastic control, robust finance, pathwise stochastic analysis, credit and default risk, risk management, machine learning. Registration deadline: 10 May 2020.

Bioinformatics Awareness Day (BAD) — Single Cell RNAseq Hackathon

Location: University of Leeds
Date: 3–5 June 2020
Website: tinyurl.com/ukturrr

Bioinformatics Awareness Day (BAD) Single Cell RNAseq Hackathon will provide researchers with the opportunity to gather, discuss, and implement ideas/projects during intensive and productive coding sessions in bioinformatics. The topics will be aligned to challenges proposed by the local applied statistics and mathematics and biomedical communities, with particular focus on Single cell RNAseq data, together with training on a selection of new methodologies.

RSC Student Conference

Location: University of Nottingham
Date: 21–24 July 2020
Website: tinyurl.com/u8vy5u5

The Research Students' Conference is returning to the University of Nottingham for a fourth time since it began in 1980. This conference is for PhD students based in Probability and Statistics fields, organised by PhD students every year in the UK. If you're a student and interested in speaking at the conference, complete the validation questionnaire when booking your place. Supported by an LMS Early Career Research grant.

LMS/Gresham College Annual Lecture 2020

Location: Museum of London
Date: 28 May 2020
Website: tinyurl.com/scoxac8

The first and only female Fields Medalist, Maryam Mirzakhani, left an astonishing mathematical legacy at her untimely death in 2017. The lecture, given by Holly Krieger, will explain the lasting contributions of her work to our understanding of the world and give a glimpse into Maryam's imaginative and hands-on approach to mathematics. No reservations are required for this lecture. It will be run on a 'first come, first served' basis.

22nd Galway Topology Colloquium

Location: University of Portsmouth
Date: 6–8 July 2020
Website: tinyurl.com/tpcomxe

These colloquia provide postgraduates, early career researchers in topology, and seasoned academics with an opportunity to engage in an open exchange of ideas and results. Topology is interpreted broadly and includes set-theoretic topology, algebraic topology, continua theory, topological dynamics, and topological data analysis, as well as cross fertilisation between topology and category theory, order theory, metric space theory, and analysis. Early-bird registration: 5 June.

Integrable Probability Summer School

Location: University of Oxford
Date: 27 July–7 August 2020
Website: tinyurl.com/y6lm7wtw

The domain of integrable probability seeks to understand universal phenomena through exactly solvable probabilistic systems of algebraic and representation theoretic origin. This CMI-HIMR school will feature several mini-courses and research talks on methods to find and analyse such solvable systems, as well as on more probabilistic approaches to expand the universality classes around them. For graduate students or early career researchers who work in this area or nearby fields.

COVID-19: This information is provided so that Members are aware of events that were planned before the coronavirus pandemic. Many of these events have now been cancelled, postponed or moved online. Members are advised to check event details with organisers.

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.

May 2020

1-3 UKACM 2020 Conference, Loughborough University (486)
4-7 Partial Differential Equations and Fluid Mechanics, University of Bath (487)
5-7 Swinnerton-Dyer Memorial Workshop, Newton Institute, Cambridge (487)
7 Burnside Rings for Profinite Groups, Lancaster University (487)
6-9 Joint BMC/BAMC Meeting, University of Glasgow (485)
11-13 Heilbronn Distinguished Lecture Series 2020, University of Bristol (487)
11-15 Methods for Random Matrix Theory & Applications, LMS Research School, University of Reading (486)
18-20 Wales Mathematics Colloquium 2020, Gregynog Hall, Tregynon (487)
18-20 Beyond the Boundaries: New Directions in Financial and Actuarial Mathematics, The Rose Bowl, Leeds (488)
18-22 Counting Conjectures and Beyond, INI, Cambridge (486)
18-22 Integral Equations and Operator Theory Workshop, University of Reading (487)
28 Joint LMS/Gresham College Annual Lecture 2020, Museum of London (488)

June 2020

1-5 Mathematical Physics: Algebraic Cycles, Strings and Amplitudes, INI, Cambridge (486)
3-5 Bioinformatics Awareness Day — Single Cell RNAseq Hackathon, University of Leeds (488)
8-10 Young Researchers in Mathematics 2020, University of Bristol (487)
15-19 Tropical Geometry, Berkovich Spaces, Arithmetic D-modules and p-adic Local Systems, Imperial College, London (487)
12 Hanna Neumann Day, University of Hull (487)
24-26 7th IMA Conference on Numerical Linear Algebra and Optimization, Birmingham (487)

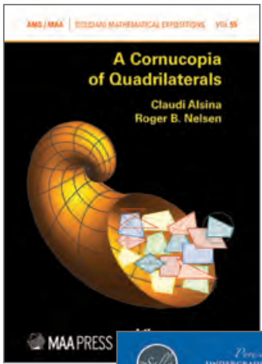
July 2020

5-11 8th European Congress of Mathematics, Portorož, Slovenia (486)
6-8 22nd Galway Topology Colloquium, University of Portsmouth (488)
12-19 14th International Congress on Mathematical Education Shanghai, China
14-16 IMA Modelling in Industrial Maintenance and Reliability Conference, Nottingham (486)
20-24 Point Configurations: Deformations and Rigidity, LMS Research School, University College London (487)
21-24 RSC Student Conference, University of Nottingham (488)
24-26 7th IMA Conference on Numerical Linear Algebra and Optimization, Birmingham (487)
27-7 Aug Integrable Probability Summer School, University of Oxford
24-30 27th International Mathematics Competition for University Students, Blagoevgrad, Bulgaria (487)
27-7 Aug Integrable Probability Summer School, University of Oxford (488)

August 2020

3-7 New Challenges in Operator Semigroup, St John's College, Oxford
17-21 IWOTA 2020, Lancaster University (481)

AMERICAN MATHEMATICAL SOCIETY



A CORNUCOPIA OF QUADRILATERALS

Claudi Alsina, Universitat Politècnica de Catalunya & Roger B. Nelsen, Lewis & Clark College

Collects and organises hundreds of beautiful and surprising results about four-sided figures. The book contains hundreds of challenging four-sided problems. Instructors of number theory, combinatorics, analysis, and geometry will find examples and problems to enrich their courses.

Dolciani Mathematical Expositions, Vol. 55

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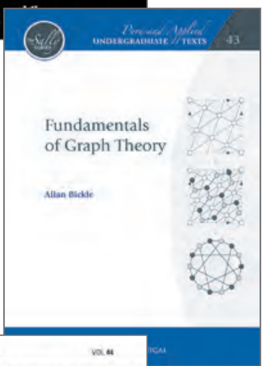


FUNDAMENTALS OF GRAPH THEORY

Allan Bickle, Pennsylvania State University Altoona

Graph theory is a fascinating and inviting branch of mathematics. The goal of this textbook is to present the fundamentals of graph theory to a wide range of readers. The has author included the shortest, most elegant, most intuitive proofs for modern and classic results while frequently presenting them in new ways.

Pure and Applied Undergraduate Texts, Vol. 43

Apr 2020 336pp 9781470453428 Hardback £81.50

MEETING UNDER THE INTEGRAL SIGN?

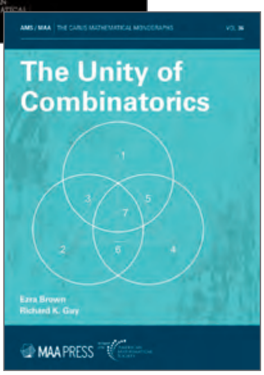
The Oslo Congress of Mathematicians on the Eve of the Second World War

Christopher D. Hollings, Mathematical Institute and Queen's College, University of Oxford & Reinhard Siegmund-Schultze, University of Agder

Examines the historically unique conditions under which the International Congress of Mathematicians took place in Oslo in 1936. Relying heavily on unpublished archival sources, the authors consider the different goals of the various participants in the Congress, most notably those of the Norwegian organizers, and the Nazi-led German delegation.

History of Mathematics, Vol. 44

Apr 2020 362pp 9781470443535 Hardback £114.00



THE UNITY OF COMBINATORICS

Ezra Brown, Virginia Polytechnic Institute and State University & Richard K. Guy, University of Calgary

Combinatorics, or the art and science of counting, is a vibrant and active area of pure mathematical research with many applications. *The Unity of Combinatorics* succeeds in showing that the many facets of combinatorics are not merely isolated instances of clever tricks but that they have numerous connections and threads weaving them together to form a beautifully patterned tapestry of ideas.

Carus Mathematical Monographs, Vol. 36

MAA Press

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