Report of Subcommittee VII

Steering Committee for the development of

The Mathematical Sciences in Australia

A Vision for 2025

The Decadal Plan for the Mathematical Sciences 2016-25

The view of the

Australian Mathematics diaspora abroad

Report of the subcommittee for international perspectives on Australian mathematics for the Decadal Plan for the Mathematical Sciences in Australia

0. OVERVIEW

The subcommittee on international perspectives of Australian mathematics focused on quantifying the extent to which Australian mathematics and statistics was represented in the international scientific community, and on identifying areas in which Australian mathematics could learn from international best practices.

After collecting data from various sources, we found that Australian mathematics was relatively well represented in the applied, computational, and industrial areas of mathematics and statistics, for instance with the computational algebra package MAGMA, developed at the University of Sydney, being very highly regarded internationally and in widespread use. However, international representation was significantly weaker in the more basic and theoretical subdisciplines of the subject, including many areas of pure mathematics that are currently experiencing significant international activity.

We believe that this underrepresentation is due in part to an academic environment in Australia which is focused on immediate applications (particularly to industry), at the expense of more basic research. The geographic isolation of Australian universities from the international community (and to a lesser extent, from each other) is also a contributing factor. Over time, this imbalance in the Australian mathematical "ecosystem" may have adverse effects on the training of students in mathematics, as well as the potential for creating new interdisciplinary collaborations.

Our main recommendations are to attract high-quality international (and expatriate) young mathematicians to Australia with internationally competitive postdoctoral positions; to encourage international travel by Australian academics abroad, and of international academics to Australia; and to develop broad postgraduate programs that offer a wide array of graduate courses in the mathematical sciences. We also wish to emphasise the importance of basic research in the sciences, and raise the concern that this aspect of mathematics may not be receiving sufficient attention in Australia.

1. INTERNATIONAL RECOGNITION OF AUSTRALIAN MATHEMATICS

1.1. WHAT PROPORTION OF WORLD MATHEMATICAL OUTPUT ORIGINATES FROM AUSTRALIA?

This is a difficult question to answer precisely, but several statistics give the proportion as roughly equal to 2%, with some underperformance when restricted to top-tier journals:

- According to the SCI/SSCI database, 18,923 of the 788,347 (or about 2.4%) of the science and engineering papers published in 2009 originated from Australia, a proportion that has held fairly stable over recent years, and which places Australia 12th behind such countries as Canada (3.7%), the United Kingdom (5.8%), and the United States (26.5%). This is also broadly in line with population counts, as Canada has 1.5 times the population of Australia, the UK has 2.8 times the population, and the US has 14 times the population. (Source: http://www.nsf.gov/statistics/seind12/c5/c5s4.htm)
- According to the Thomson ISI National Science Indicators database, from 2001-2005, Australian scientific publications formed 2.91% of the world total, with the percentage dropping to 2.19% when restricted to mathematics (Source: http://www.amsi.org.au/images/stories/downloads/pdfs/general-outreach/NCMS_Docs/01_Disc_Profile_MathSci_Feb12.pdf)
- In the MathSciNet database, there are 74875 papers published in 2012, of which 1400 (about 1.9%) have at least one author affiliated with Australia. This fraction has also been quite stable (for instance, in 2002, the corresponding fraction was 1498 / 78045 = 1.9%). For comparison, in 2012 the proportion of papers with Canadian affiliation was 3.8% and the UK was 5.6%. (source: http://www.ams.org/mathscinet/index.html)
- The Annals of Mathematics (published by Princeton University Press) is one of the most prestigious journals in mathematics. In the 20-year period from 1993 to 2012, 1097 papers were published in this journal, of which 18 (1.6%) had an author affiliated with Australia; again for comparison, Canada was 5.5% and the UK was 8.9%. For Inventiones (published by Springer-Verlag), of the 1507 papers published in this journal, 17 (1.1%) were affiliated with Australia, with Canada at 5.2% and the UK at 7.8%. For Advances in Mathematics (published by Elsevier), of the 2812 papers, 75 (2.6%) were affiliated with Australia, compared with Canada (6.5%) and the UK (7.4%). Australian representation is stronger in statistics; for instance, in the 2123 papers published in this period by the Annals of Statistics (published by the Institute of Mathematical Statistics), 116 (5.4%) were affiliated with Australia, compared with Canada (6.4%) and the UK (6.0%), with one of the two current co-editors also being from Australia, (source: http://www.ams.org/mathscinet/index.html)

1.2. INTERNATIONAL CONGRESSES

In pure mathematics, the International Congress of Mathematicians (ICM) is the largest and highest-profile meeting of mathematicians in the world. Meeting quadrennially since 1897 (except during World War II) and hosted by the International Mathematical Union, each ICM draws thousands of mathematicians for a large array of events, the most well-known of which are the awarding of the IMU medals, including the Fields Medal (widely considered the highest honour given to a mathematician under the age of forty). To be invited as one of the twenty or so plenary lecturers, or nearly two hundred sectional speakers, is also considered a major recognition of a substantial contribution to mathematical research. None of the 27 meetings of the ICM have been held in Australia, although it has met once in Canada and twice in the United Kingdom.

Similar congresses exist in applied mathematics, most notably the International Congress of Theoretical and Applied Mathematics (ICTAM), which has also met quadrennially since 1948, and the International Congress of Industrial and Applied Mathematics (ICIAM), which has met quadrennially since 1987. ICTAM was hosted in Adelaide in 2008, and ICIAM was hosted in Sydney in 2003. The format of these congresses are slightly different from the ICM; for instance ICTAM has fewer plenary and sectional speakers, but a large number of speakers at minisymposia, and ICIAM has a large number of contributed papers and minisymposia in lieu of sectional speakers.

Australian representation in the last few congresses have been fairly modest, again underperforming the 2% ratio mentioned previously:

Meeting	Total speakers (Plenary, Sectional)	Speakers based in Australia	Expatriate Australian speakers
ICM 2002	20, 168	0, 3	0, 0
ICM 2006	20, 169	0, 1	2, 1
ICM 2010	20, 171	0, 2	0, 3
ICM 2014	21, 205	0, 1	0, 0
ICTAM 2008	19	2	0
ICTAM 2012	17	0	0
ICIAM 2003	27	2	0
ICIAM 2007	31	0	0
ICIAM 2011	27	1	0

Sources:

- http://www.mathunion.org/imu-net/archive/2009/imu-net-036c/ (ICM 2010)
- http://www.mathunion.org/db/ICM/Speakers/SortedByCongress.php (other ICMs)
- http://ictam2008.adelaide.edu.au/invited.php (ICTAM 2008)
- http://www.ictam2012.org/?page_id=197 (ICTAM 2012)
- http://www.mafy.lut.fi/EcmiNL/older/ecmi30/conferences/node5.html (ICIAM 2003)
- http://www.iciam.org/iciam2007/scientific_program/invited_speakers.html (ICIAM 2007)
- http://www.iciam2011.com/index.php (ICIAM 2011)

For instance, for ICM 2010, two sectional speakers (Dancer and McKay) were based in Australia, with three additional expatriate sectional speakers (Evans, Kisin and Venkatesh). For comparison, in the same year, two were based in New Zealand, 12 were based in the UK, and 57 were based in the US.

1.3. MATHEMATICAL REPRESENTATION BY FIELD

It is difficult to obtain reliable statistics on how Australian mathematics is distributed by subfield, but the following table lists the number of papers tracked by MathSciNet in 2010-2012 in the 40 most popular 2010 Mathematics Subject Classification (MSC2010) numbers, sorted by the percentage of papers with at least one Australian-based author. It appears to indicate that Australian mathematics is well represented in most applied fields and in number theory, group theory, and combinatorics, but is under-represented in many core areas of algebra and analysis. These statistics are however quite crude and should be interpreted with caution; for instance, within number theory, Australia has particular strength in the computational side of the subject (see in particular the section on MAGMA below), but is generally perceived as under-represented in such areas as arithmetic geometry and automorphic forms.

MSC 2010 Primary	2010-2012	Aust. author	Percentage
Systems theory; control (93)	10632	325	3.06
Statistical mechanics, structure of matter (82)	3081	94	3.05
Real functions (26)	2160	64	2.96
Game theory, economics, social and behavioral sciences (91)	12148	339	2.79
Information and communication; circuits (94)	9438	252	2.67
Statistics (62)	15355	402	2.62
Number theory (11)	8098	203	2.51
Biology and other natural sciences (92)	7974	196	2.46
Group theory and generalizations (20)	5314	126	2.37
Combinatorics (05)	13380	308	2.30
Mathematical logic and foundations (03)	5716	121	2.12
Probability theory and stochastic processes (60)	10200	209	2.05
Functional analysis (46)	4240	86	2.03
Fluid mechanics (76)	7784	156	2.00
Computer science (68)	12365	246	1.99
Manifolds and cell complexes (57)	2080	41	1.97

Calculus of variations and optimal control; optimization (49)	3845	69	1.79
Global analysis, analysis on manifolds (58)	2182	39	1.78
Nonassociative rings and algebras (17)	1836	32	1.74
Mechanics of deformable solids (74)	5844	100	1.71
Operations research, mathematical programming (90)	10745	182	1.69
Linear and multilinear algebra; matrix theory (15)	2562	43	1.68
Quantum theory (81)	10085	160	1.59
Numerical analysis (65)	14891	204	1.37
History and biography (01)	2628	36	1.37
Operator theory (47)	7503	90	1.20
Several complex variables and analytic spaces (32)	1807	20	1.11
Differential geometry (53)	6504	68	1.05
Dynamical systems and ergodic theory (37)	5885	61	1.04
Mechanics of particles and systems (70)	1871	18	0.96
Relativity and gravitational theory (83)	3959	36	0.91
Partial differential equations (35)	16819	151	0.90
Ordinary differential equations (34)	10522	92	0.87
Harmonic analysis on Euclidean spaces (42)	3150	23	0.73
Difference and functional equations (39)	2244	14	0.62
Algebraic geometry (14)	4076	22	0.54
Associative rings and algebras (16)	3726	18	0.48
Commutative algebra (13)	1908	6	0.31
Functions of a complex variable (7)	4092	7	0.17
General topology (5)	3751	5	0.13

1.4 MAGMA

The MAGMA computer algebra software package (http://magma.maths.usyd.edu.au/magma/), which was created by the Computational Algebra group at the University of Sydney in 1993 and continuously developed by that group ever since, is a uniquely important contribution to mathematics, being widely acknowledged as one of the best computational algebra packages available to the international mathematics community, and the “gold standard” against which other such software are measured.

In many areas of modern mathematics, including cryptography, computational number theory, and computational algebra, the need for a powerful and easy to use software package to perform any number of complex algebraic computations (including several specialised computations, such as evaluating values of L-functions, character tables, or Grobner bases) has never been greater. For specialized subfields of pure mathematics, there are several excellent software packages for these purposes, like Pari-GP (Bordeaux, France) and Sage (Seattle, US) for number theory, Mathematica (Wolfram Research, US) and Maple (Waterloo, Canada) for basic analytic and algebraic manipulations, GAP for group theory (St Andrews, UK) and Singular for algebraic geometry (Kaiserslautern, Germany). However, the MAGMA package developed by the University of Sydney is far broader in capability; according to Tim Dokchitser (a Royal Society University Research Fellow at the University of Bristol), “there are currently no alternative computer algebra systems that come close to what Magma has to offer. Magma is by far the largest, the most thorough, most modern, and the best maintained one of them.”. Hendrik Lenstra (a renowned number theorist, and currently Emeritus Professor at both the University of California, Berkeley and the University of Leiden), “it is obvious that Magma is the classical standard against which all computer algebra systems are measured, and that it has proved immensely useful to a huge community of researchers in pure mathematics world-wide. It has, all by itself, defined Sydney as the world’s leading centre for research and development of algorithms in number theory and algebra.”

As tracked by the MAGMA project, there are at least 4000 scientific publications that acknowledge the use of MAGMA (or its predecessor, Cayley, also developed at U. Sydney), and there are countless others which have directly or indirectly relied on this software without mentioning it explicitly. It is without doubt one of the great international success stories of Australian mathematics.

2 RECOMMENDATIONS

2.1. POSTDOCTORAL POSITIONS

Unlike many other countries, Australian universities do not have a large number of “postdoc” positions (fixed term positions for new Ph.D's); while ARC postdocs do exist, they are few in number, are research-only, and are not guaranteed to be granted to a given school in the long term. As such, these postdocs are not as integrated into a school of mathematics in the same way as typical postdocs are overseas.

Having a guaranteed and significant number of postdoc positions in each school (even at the cost of one or two permanent positions) would yield a number of advantages:

1. Mathematically it means that there are more people moving through the school, keeping the research activity there more energetic and less narrow.
2. A postdoc that is competitive with similar positions overseas will help attract young people to Australia at a time when they might be more willing to move there. For hiring at the tenure track level, one has to contend with persuading candidates to come a long way at a time when they are more likely to have put down roots. It is easier to attract good people earlier; this is especially relevant if you are trying to attract expatriates.
3. Furthermore, once such people are in the country on a postdoctoral position, they will often be more willing to stay. In any case, they would be an extra pool of (hopefully) high quality people available to hire to permanent positions. Australia's geographical remoteness then works in one's favour.

It would be extremely helpful for getting young mathematicians into the Australian university system if at least the leading Australian universities had a steady number of strictly temporary postdoctoral positions, similar to the American model (in which about 14% of the full time doctoral faculty are in such positions, see http://www.ams.org/profession/data/annual-survey/2010Survey-DepartmentalProfile-Report.pdf) and with a mild teaching load, which were advertised internationally and filled each year. Such postdoctoral positions should however not be created at the expense of a large number of permanent positions.

One possible model comes from the MAGMA postdocs. Much of the success of MAGMA has come from the fact that the MAGMA group have had attracted many short term visitors, who have come to Sydney for a month or two, often for several years in a row, to collaborate closely with those working long term in Sydney to develop the MAGMA programme.

Another model for how postdocs could be funded is through a distributed National Research Centre in Mathematics, similar to the Pacific Institute for the Mathematical Sciences (PIMS) Postdoctoral Fellowships in Canada. These could be funded for, say, one year research-only time by the centre, and then individual universities could combine that with 2 years of teaching/research to make a 3 year appointment.

2.2. TRAVEL

Due to geographical isolation, Australian mathematics is sometimes left out of the most exciting current developments in mathematical research. One way to ameliorate this problem is to have leading researchers (including ex-patriates) visit Australia to give short courses (via the Institutes or Universities) that are open to students and researchers Australia-wide, perhaps by video link if travel money is not available --- these researchers might also engage in collaborations, though that is not essential. There are existing programs in Australia for this purpose (e.g. the Mahler lectures), but more could be done in this area, for instance by sharing information between different departments regarding their international visitors. To contrast with other countries: China is heavily investing in bringing back ex-pat researchers to visit during the Northern hemisphere summer to collaborate and give short courses. This is having a significant effect on the preparation and breadth of their students.

Another recommendation would be to provide adequate funding resources for Australian researchers to travel to conferences or to go on research collaboration trips abroad. Anecdotally, it appears that there are fewer Australian researchers in international conferences than at previous years.

2.3. GRADUATE PROGRAM

The timetable for a PhD in Australia is accelerated when compared to countries such as the US, and the focus is narrower than with other countries, with few graduate courses available. This leads to the outcome that most strong undergraduates with an interest in continuing with mathematics are encouraged to go overseas to study, and those that stay - even if talented - tend to emerge from the PhD with a lack of perspective and depth in their education, and tend to work in fields that require less in the way of prerequisites or mathematical sophistication to get started.

The UK has a similar system to Australia, but recently they have made efforts to have short courses to mitigate the narrow focus of the PhD training. Some of those short courses are conducted using video conferencing equipment.

3. THE IMPORTANCE OF SUPPORTING BASIC RESEARCH

As noted previously, the mathematical sciences in Australia are comparatively strong in the applied branches of the discipline, but is often underrepresented internationally in several of the more theoretical subfields of mathematics and statistics, and within pure mathematics in particular. This may in part be due to the pressure within Australian universities to secure external funding through liaison with industry; it also appears to reflect the higher mathematics education system in Australia, in which it is not uncommon for core mathematics topics to be taught by lecturers in other disciplines than mathematics or statistics.

In today's world, with an increasing need to perform large computations and to process ``big data'', mathematics and statistics is being applied to other disciplines to an extent vastly greater than ever before. However, much of the long-term value of the mathematical sciences comes from the basic research activity that is not directly tied to an immediate application, but nevertheless sets up such application in the future. An excellent example of this is the research of Professor Terry Speed FRS (recipient of the 2013 Prime Minister's Prize for Science), whose basic research in mathematics and statistics is now used extensively in the analysis of microarrays and other large data sets in genomics.

To quote from the 2012 review of the Mathematical and Statistical Sciences in Canada (available at http://longrangeplan.ca/):

> ...in terms of scientific leadership and innovation, a vibrant research program in mathematical and statistical science is essential. However, it is not possible to predict which particular fields of mathematics and statistics that will guide innovation in the next few decades. Indeed, all areas of mathematical and statistical science have the potential to be important to innovation, but the time scale may be very long, and the nature of the link is likely to be surprising. Many areas of mathematical and statistical science that strike us now as abstract and self--referential will be useful for applications that we cannot currently imagine.

Furthermore, a strong national commitment to basic mathematical research builds up a reservoir of expertise, which then trickles down to other disciplines and industrial applications in a number of different ways, such as training students and in creating interdisciplinary collaborations. To quote from 2013 review of of the Mathematical Sciences in the United States (available at http://www.nap.edu/catalog.php?record_id=15269):

> A strong core in the mathematical sciences—consisting of basic concepts, results, and continuing exploration that can be applied in diverse ways—is essential to the overall enterprise because it serves as a common basis linking the full range of mathematical scientists. Researchers in farflung specialties can find common language and link their work back to common principles. Because of this, there is a coherence and interdependence across the entire mathematical sciences enterprise, stretching from the most theoretical to the most applied.
>
> … The mathematical sciences function as a complex ecosystem. Ideas and techniques move back and forth—innovations at the core radiate out into applied areas; flowing back, new mathematical problems and concepts are drawn forth from problems arising in applications. The same is true of people—those who choose to make their careers in applied areas frequently got a significant part of their training from core mathematical scientists; seeing the uses and power of mathematics draws some people in to study the core. One never knows from which part of the mathematical sciences the next applications will come, and one never knows whether what is needed for a possible application is existing knowledge, a variation on what already exists, or something completely new. To maintain ... leadership in the mathematical sciences, the entire ecosystem must remain healthy.

This subcommittee is concerned that the vital role of basic science, as opposed to immediate industrial application, is not as strongly recognised and supported by Australian governments and universities as it is in peer countries such as Canada and the United States; we are dismayed, for instance, that there is no longer a Cabinet-level position in the Australian federal government that is explicitly responsible for science and research, with the relevant institutions now overseen by the Department of Industry. At the university level, the research contributions of staff may be given less weight than other university priorities, such as increasing student enrollment or securing external funding, leading to an academic culture in which basic research is passively or even actively discouraged, with some core areas of the mathematical ecosystem in Australia in danger of falling below critical mass. While the international subcommittee does not have specific recommendations to remedy these problems, we urge that the role of basic research in the mathematical sciences not be neglected, and that efforts be made to improve the academic environment for such research in the future.

4. SUBCOMMITTEE MEMBERS

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