IMAGES NZ

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New Zealand Institute of Mathematics & its Applications

taurangi

Cohen Holloway in *The Amazing Adventures of Doctor Faustroll and his Search for the Luminiferous Aether* in 2010. See back page. Photo: Joe Bleakley.

Following in **Klein's** footsteps

In 1984, when Bill Barton went alone as a naïve secondary teacher to the four-yearly International Congress on Mathematical Education (ICME) in Adelaide, he never dreamed that he would end up as president of its organising body, the International Commission on Mathematical Instruction (ICMI). He spoke with Jenny Rankine

"I had a lot of fun there and it put me onto mathematics education as a profession". Barton, bottom right, is now Professor of Mathematics Education at the University of Auckland and currently Associate Dean International for the Faculty of Science. His ICMI work is a voluntary addition.

He is the first president from the southern hemisphere, and looks forward to increasing the involvement of teachers in the organisation. ICMI was formed in 1908 and aims to improve the quality of mathematics teaching and learning around the world, partly by bringing together educational researchers, curriculum designers, educational policy makers, mathematics teachers, other mathematics educators and mathematicians.

"What makes ICMI different from other mathematics education organisations is its close ties with the professional mathematicians and mathematical educators and its breadth – thematic, cultural and regional," he says.

Barton says the Klein project, which he also chairs, may be one of ICMI's most interesting projects for New Zealanders. It was inspired by a 1908 book by ICMI's founding president, Felix Klein, top right, written for teachers and linking what was taught in schools to the whole of research mathematics. The project will produce a book in several languages that summarises every major field of mathematics, resource DVDs for teachers and a wiki-based website that will be continually updated.

"There'll be explanatory chapters, but it's the linking that makes the difference. We're anticipating up to 15 explanatory pages, with five to eight vignettes per chapter - examples of applications or a nice piece of mathematics, a particular proof that captures an essential idea of the topic."

Barton has two goals during his three-year presidential tenure, which started in January. Firstly, he wants to help establish a secure financial basis for the organisation. Currently it is funded by small grants from its parent body, the International Mathematical Union, but it is not sustainable as a voluntary body.

"ICMI has networks of mathematics teachers in nearly every country, so we're ideally placed to bid for and win development contracts in mathematics education," he says.

The other is to strengthen ICMI's

▶2

Welcome

March 8 was due to be New Zealand census day. In this issue you'll find out more about the census process and history, as well as other applications of statistics. Mathematics education, maths and psychology and a visual look at group theory round out our tenth issue. We hope you enjoy it.

Marston Conder and Vaughan Jones, Co-Directors

From top: Members of the ICMI executive working and relaxing; a meeting of the Klein Project design team at the University of Auckland. Photos: Jaime Carvalho e Silva, ICMI Secretary-General.

activities in developing countries. "There is still a tremendous amount of work to do in Africa, but areas like the Pacific and some parts of Asia and South America still need international support." A week-long invited workshop is being planned for teacher educators from Mali and neighbouring French-speaking African countries in September, "to build a network of educators with links to the developed world that will enable them to be self-sustaining." Similar annual events are planned in English-speaking Africa and other regions.

ICMI also publishes regular conference and research reports and newsletters. "ICMI Studies produce books that are state of the art for that area at that time." Major studies have included mathematics and cognition, mathematics popularisation, assessment, gender and mathematics education, geometry, statistics and algebra teaching, university mathematics teaching, secondary teacher development, and digital technologies. These are gradually being made available free online.

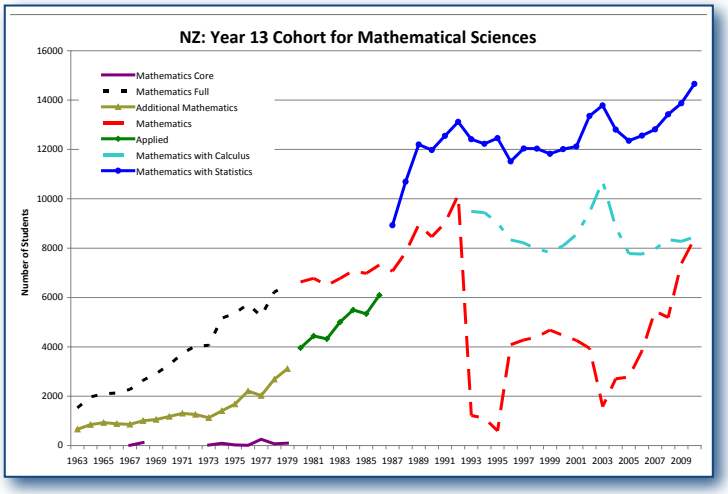
ICMI also supports regional conferences on mathematics education. "There is a very strong Australasian group in mathematics education, the Mathematics Education Research Group of Australasia (MERGA), but to link into major developments internationally, especially in Europe, Asia and North America you need the structure that ICMI supplies."

Teachers and mathematics educators can keep up with what ICMI is doing by getting on to the New Zealand representative's email list, or subscribing to the ICMI newsletter on the website.

See also

Experiencing Mathematics! An interactive virtual exhibition: www.experiencingmaths.org/
ICMI: http://mathunion.org/icmi/home
Klein Project: www.kleinproject.org/
NZ representative: Robin Averill, robin.averill@vuw.ac.nz

International Commission on Mathematical Instruction



Flows of mathematics students

The numbers of mathematical science graduates at all levels are generally increasing, except for a few countries, according to the ICMI Pipeline project co-ordinated by ICMI president Bill Barton. This contradicts an international perception that the number of mathematics graduates is falling.

But the *percentage* of mathematical science graduates is declining slightly. This may be because more courses with mathematical content are attracting school leavers who would otherwise enrol in undergraduate mathematics.

Many senior secondary mathematics teachers in New Zealand, Australia, and the UK are also approaching retirement, and shortages of mathematics teachers are likely as fewer students enter teacher training.

The project was initiated at the request of ICMI's parent body, the International Mathematical Union, and has collected data from ten countries: New Zealand, Australia, Finland, France, Hong Kong, Portugal, Scotland, Taiwan, the UK and the USA. It found that the situation differed markedly in different countries, so has focused on national case studies of four transition points rather than a comprehensive comparison.

The transitions were from school to undergraduate courses; undergraduate to postgraduate courses, university into teaching, and university into other employment.

Results indicate that in New Zealand the number of school leavers qualifying in the mathematical sciences is increasing (see graph), as are the numbers of Bachelor, Masters and PhD graduates. However, mathematics graduates are a declining percentage of total graduates, and the median age for secondary mathematics teachers has grown to 45 - 49.

The project aims to provide data for educational decision making in different countries. Barton has presented results at conferences in Poland, Spain and New Zealand and the report is being finalised. The project will continue to update data from project countries and add other countries to the database.

See
www.mathunion.org/icmi/other-activities/pipeline-project/

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Official statistics up with the best

Former New Zealand Government Statistician, UK Chief Statistician and Chair of the NZIMA Board, Len Cook, above, spoke with Jenny Rankine.

The cancellation of the 2011 Census, which was to have taken place on March 8, is only the third time a major event has stopped the Census. In 1931 it was abandoned because of the depression, and in 1941 it was cancelled due to a world war. This time it was deferred because of disruption caused by the Christchurch earthquake.

The Census was to have been processed in Christchurch, but Statistics New Zealand buildings in Christchurch have suffered extensive damage. A replacement date has yet to be determined but it is unlikely to be in 2011.

Cook says that for New Zealand, more than larger countries such as the United Kingdom, "the cancellation of a population census creates a hole in knowledge we have about ourselves that we cannot fill adequately by other means. The Census is fundamental to public trust in government and the quality of much public policy."

He ranks New Zealand's official statistics "right up there with the best with the use of statistics methods and information technology. We've been very innovative in releasing Census data with Spacetime mapping products, in the use of tax records for economic statistics, in automated scanning of forms and organising internet access for 2011."

Professor Stephen Haslett of Massey University is one of many who have worked on linking official statistics with administrative data records "to get better detail and accuracy for less money". For example, a linkage of the unemployment register and the Household Labour Force Survey obtained "much better estimates of the International Labour Organisation's definition of unemployment" than either data set alone. He had to take into account the changing relationship between the two data sets over time with different political decisions about benefit criteria.

Says Cook: New Zealand "put a lot of effort into high quality, regularly-updated design for the Household Labour Force Survey and the Household Income and Expenditure Survey, and business surveys such as monthly retail trade."

Census numbers

35 days to scan all returned forms, using 3 scanners doing 120,000 forms a day

150Gb image and back up servers to store the data and scanned forms

250 people work 2 shifts for 22 weeks to scan forms and check the information

7,000 collectors to deliver and pick up forms

7.8 million census questionnaires printed for 2011

It can be difficult to get accurate information about attitudes, he says. "Surveys of wealth have been quite difficult; people don't always know what they're worth. Areas that are stigmatised, for example, alcohol consumption in household expenditure, are often quite significantly under-reported. Developing methods to adjust for that under-coverage is always a challenge."

"On questions of identity, official statistics are always going to follow how society responds. For example, if it's not common to ask people about their sexual identity for other reasons, it's very difficult to do so in a statistical enquiry. Initially when we started measuring same-sex partnerships, we did it indirectly."

"Being a small country is a great asset. For balance of payments data, we collect information from the invoices of the largest firms. Informal ways like newspapers are more reliable to identify what new firms we should look at, which is an advantage over larger countries."

"Official and research surveys have extraordinarily good response rates; neighbourhood tracking is very strong here. The Dunedin and Christchurch studies that follow people for a lifetime have been able to get world-leading response rates."

Cook says that in almost every field "there has been a huge increase in the information available from the public – such as state administrative records and welfare information. It has created tremendous opportunities to understand a lot more about our society without collecting information directly. We're able to produce a lot of geographic information about what's going on in small areas."

See
www.census.govt.nz/
www.gapminder.org for animations from official statistics around the world.

Statistics are working

The World Food Programme in Nepal

IMAges continues with illustrations of some of the many statistical developments and applications in Aotearoa.

Modelling earthquakes

An automated statistical model of the stresses in the earth's crust may eventually be incorporated into Geonet, the national array of seismometers monitoring earthquake activity in Aotearoa.

With his colleagues in Earth Sciences at Victoria University, Dr Richard Arnold has developed new and more robust methods of estimating the properties of the ruptures that cause earthquakes.

"An earthquake occurs when two blocks slide against each other in a particular plane, sometimes with an area of only a few square metres. We need to understand the three-dimensional orientation of the fault plane and the movement in that plane to characterise the tectonic stresses that drive the earthquake.

These stresses are anisotropic – the crust is compressed more strongly in one direction than another.

"A single earthquake gives only a very limited view of what's going on in the crust, but multiple earthquakes accumulate statistical evidence to characterise the stresses: Smaller earthquakes on lesser faults help us understand the stresses the large faults are experiencing. Changes in stress can indicate impending seismic events, including volcanic eruptions." He is automating the model so that it can monitor stress changes routinely across the country.

Survey design

The reliability of population estimates in ecology is always a concern for statisticians. Standard techniques using randomly-placed transect lines in forests or oceans to measure population numbers were known to produce estimates with a high degree of uncertainty, says Associate Professor Rachel Fewster, of the University of Auckland.

Systematic survey designs, where transects start from a certain point and evenly cover the area, were known to be more reliable, how much more was unknown so they were assigned the same poor reliability as random lines. "With systematic designs, the first line determines everything, so we can't use standard statistical theory," she said. Fewster's variance estimation for systematic surveys enabled the improvement to be estimated, and showed from repeated simulations that the systematic estimates can be much more reliable than random estimates.

The result "made a big difference to a Canadian survey of threatened dolphins in fiords", and to surveys of hyenas in the Serengeti. When correctly estimated, the surveys were up to twice as reliable as previously thought. The method was included in the software package Programme Distance, distributed by the University of St Andrews in Scotland.

Targeting aid

Countries including Nepal, Cambodia, Timor-Leste, Bangladesh, the Philippines and Bhutan have benefited from New Zealand statistical expertise in estimating poverty for efficient aid allocation, in work funded by the UN World Food Programme.

Professor Stephen Haslett of Massey University in Palmerston North has worked with teams using generalised linear models combined with the country's own census data to produce detailed small-area maps of poverty levels. "If you just look at national sample surveys, they're not accurate enough. What we're doing is affecting the allocation of $100m of aid a year in Nepal alone; the money may not be spent anywhere near as well without it. A lot of sample survey results get used to form policy."

He has also designed new water and sanitation surveys of small and medium enterprises in countries such as Azerbaijan and Vietnam for the World Bank, and national surveys monitoring entrepreneurship in Tonga and Uganda.

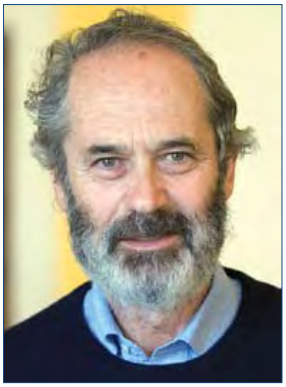
Finding gene copies

Dr Mik Black at the University of Otago is involved in next generation gene sequencing, "which is driving the Thousand Genome Project, an international effort to sequence fully the genomes of 2,500 individuals throughout the world. The amount of data is phenomenal – we're all upskilling ourselves on how to handle it."

One aspect of the project is looking at particular gene copy numbers. "We have two copies of each gene, one from mum and one from dad, but we can also have more copies of any gene from ancient variations. Sometimes this has become an increased risk for particular diseases. The analysis is not particularly hard but the volume of data is huge, so finding the multiple copies is difficult."

Abstract beauty

Professor Jan Saxl of the University of Cambridge was fascinated by the abstraction of group theory when he first studied it at university, and has been working in the field ever since.



Groups are algebraic structures made of a set and an operation that combines any two of its elements to form a third element. The presence of groups in many areas of mathematics and other disciplines makes them a central organising principle.

"By solving an abstract problem you can solve different questions in different subjects all at once. Abstraction allows you to do things you can't do otherwise."

"Octagonal coins have symmetry group D_8. Theoretical chemists can explore what shapes molecules may have, using groups of symmetries. The graphs in which I am interested have a large group of symmetries, and are best studied using this group."

With others, Saxl has worked to classify the maximal subgroups of almost simple groups. "Simple groups are the building blocks of finite groups. They're similar to primes in that all the finite groups decompose into chains of simple groups."

He is studying maximal subgroups: "my groups invariably act on some set, whether the vertices of the coin or atoms of molecules. Subgroups are substructures; maximal are the largest possible substructures."

He is also working on a big project about distance transitive graphs. "These are highly symmetric graphs, which have a very large symmetry group acting on them." During his visit he was working with Professor Eamonn O'Brien at the University of Auckland "on an enormous group acting nicely on a very large graph. A graph for me is really a group acting on that graph. This graph has about 2^{28} vertices, so it is impossible to draw. Eamonn can work with a group of size 4^{30} on a computer."

"The group is much larger, but more manageable. The Hoffman-Singleton graph (right) is complicated, but some aspects are much clearer within its group of symmetries, which is manageable despite its size."

"Abstraction excites me; it is beautiful. Lots of people can enjoy the beauty of music, but not so many people can understand the beauty of abstract mathematics. It is a great pleasure seeing clever students learning to see its beauty."

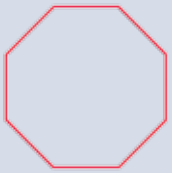
Saxl was in New Zealand in 2011 as a visiting Maclaurin Fellow. ***JR***

"The mathematician's patterns, like the painter's or poet's, must be beautiful. The ideas, like the colours or the words, must fit together in a harmonious way. Beauty is the first test: There is no permanent place in the world for ugly mathematics."

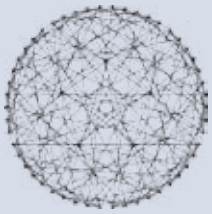
G. H. Hardy, 1877 – 1947

Levels of abstraction

1 Shapes



Octagon



Hoffman-Singleton graph

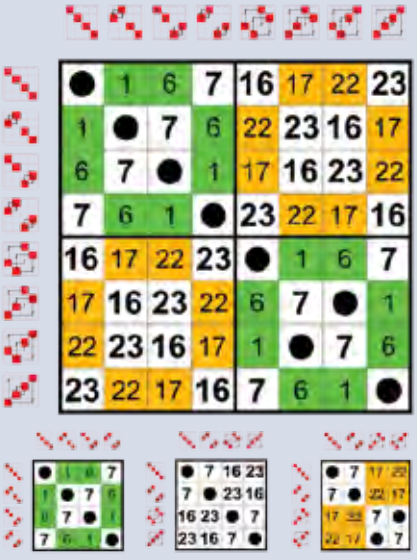
2 Symmetries

Octagons have 16 different symmetries - eight rotational (first row) and eight reflectional symmetries (second row).

The **Hoffman-Singleton graph** on 50 nodes and 175 edges is the only regular graph of vertex degree 7, diameter 2, and girth 5.

3 Groups of symmetries

The set of the **octagon** movements, with composition as operation, forms the algebraic structure of a finite dihedral group D_8. Below is a group table for D_8, and other tables for some of its subgroups.



The symmetry group of the **Hoffman-Singleton graph** is of order 252,000.

Maths in psychology

When Sue Street moved from engineering to psychology at Massey University, she brought with her an unusual approach for this people-focused social science – mathematical simulation of the interactions of autonomous individuals that calculates their effects on a system.

In her Masters, she used this agent-based modelling to explore the impact of income inequalities on people's relationships; in her PhD, she modelled development of trust in people's behaviour on the internet auction site Trade Me.

"As an engineer coming into psychology, I was struck by the relative absence of a dimension that is always present in electrical engineering: time. And when you think about time, you're thinking about dynamics. Apart from certain fields like developmental psychology, time is curiously absent in psychology."

For her masters, Street wanted to explore the impact of differences in income, which research has shown has much more impact on the health and mortality of populations than absolute levels of poverty or wealth.

"If two people grow up in Taita and one becomes a millionaire, do they stay friends? I wondered whether the increasing income differences strain existing relationships, and cause a cascading breakdown in relationships within a population. People tend to be friends with those who are similar, so increasing the difference in income is likely to reduce that similarity."

She modelled friendships rather than marriages or sexual relationships, in a finite element structural simulation. She randomly allocated difference in wealth at two relating nodes, and how much time and effort (loading) each node put on the relationship.

"Reducing the similarity in some relationships caused some to break, and shifted the loading on other relationships, some of which also broke, so there were fewer relationships in the population. Reversing the differences didn't recover the overall level of activity in relationships, which implies that closing the gaps in the real world might not work by itself – we'd have to do something to rebuild the effects of prolonged inequality."

For her PhD, Street used Repast, which is free open-source agent-based modelling software, to create a group of traders with a randomly-assigned strategy for dealing with the limited information that Trade Me supplies. This includes the person's number of trades, their trade rating, whether or not individual trades were successful and the reasons why some were not. This could be because someone didn't respond, didn't pay or didn't send the goods. Some agents were randomly more likely to be dishonest and all could learn by getting random strategy information from traders who were doing better.

Street found that agents "got better at identifying and avoiding unreliable traders, but that learning the signs of dishonest traders and avoiding them was patchy at best. Overall, agents improved their trading success, and restricted unreliable traders, but left dishonest traders in circulation." Dishonest traders tend to re-enter Trade Me with a new ID once their original rating deteriorates, but she did not build that into her model.

Street believes that mathematical simulations are a valuable approach that is underused in psychology for analysing very complex patterns of social behaviour. ***JR***

Notable maths problems

BIRCH AND SWINNERTON-DYER CONJECTURE

Simply: Describing solutions to algebraic equations like $x^2 + y^2 = z^2$ in whole numbers becomes extremely difficult for more complicated equations. This conjecture says that for an elliptic curve (a three-dimensional curve confined to a region known as a torus), the number of solutions depends on the behaviour of an associated function (the zeta function).

Originators: British mathematicians Peter Swinnerton-Dyer and Bryan Birch in the early 1960s.

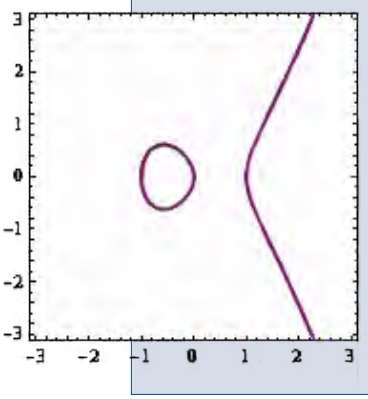
Discipline: Number theory.

Incentive: $US1million for the first proof of the whole conjecture; one of the seven Millennium Prize Problems of the USA-based Clay Mathematics Institute.

Interesting aspects: The conjecture "relates the behavior of a function *L* at a point where it is not at present known to be defined to the order of a group which is not known to be finite", according to mathematician John Tate. Elliptic curves from algebraic geometry are important to number theory – proving statements about these curves was crucial in solving Fermat's famous last theorem in 1995.

Progress: Proofs of the conjecture have been developed from 1976 to 2010 but only in special cases, all with rank less than 2. Nothing has been proved for curves with rank greater than 1, although there are many numerical calculations supporting its possible truth. The conjecture has stimulated a lot of research and is widely recognised as one of the most challenging unsolved mathematical problems. Many details about it have become clear only after hard computation, one case at a time.

NZIMA connection: Bryan Birch was 'moral tutor' for NZIMA Co-director Marston Conder when Marston was a doctoral student in Oxford in the late 1970s.



Elliptic curve $x^3 - x = y^2$

Speeding medical images

NZIMA Scholar Rachael Tappenden is studying the algorithms behind Magnetic Resonance Imaging (MRI).

MRI scans are one of the most important diagnostic techniques that doctors can use, but it is very expensive technology, partly due to the time it takes to produce and analyse such complex images. Mathematics provides the central algorithms for analysing and reconstructing the images in real time.

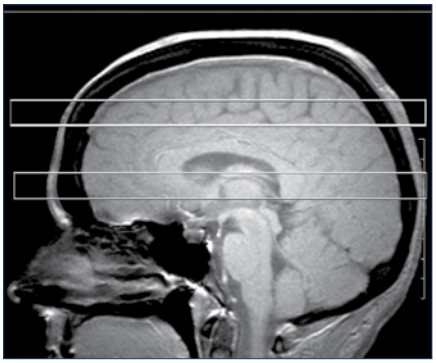
The two common algorithms, Sequential Backward Selection and Sequential Forward Selection, force a compromise between analytical speed and image quality.

Tappenden and supervisor, Associate Professor Ian Coope at the University of Canterbury, chose this issue for her PhD as "the most interesting that uses the skill base I have – linear algebra and optimisation," she says.

The algorithms rely on Least Squares approximations and the L^2 norm, but other approximation criteria, like the L^1 norm, may be useful. The images are compressed before processing using Fourier methods, but recent techniques such as compressed sensing are also being explored as an alternative.

MRI data comes in the form of a matrix but it is not feasible to look at every combination of rows. "An existing criterion uses the trace of the matrix," says Tappenden, "whereas we've created an algorithm which uses the determinant criterion to choose an optimal subset of rows to give an accurate image." Her paper was published in September in the IEEE journal Transactions on Image Processing. The algorithms will be implemented by the engineers who programme the machines.

Tappenden has also written some algorithms to reconstruct MRI scans from sparse data sets. "If you have some conditions on the image – lots of zeros and few non-zeroes – then you can do a really good reconstruction with only a tiny bit of data. These are optimisation problems with some really nice properties." ***JR***



Brain scan showing the location of two 15-minute slices of MRI data taken at different levels.

$$\frac{a^H(A^HA)^{-2}a}{1-a^H(A^HA)^{-1}a}$$

"Mathematical reasoning may be regarded as the exercise of a combination of two facilities, intuition and ingenuity."
Alan Turing, 1912-1954

MATHEMATICAL EVENTS

3-7 July 2011, Alice Springs, Australia
34th Annual Conference of MERGA (Mathematics Education Research Group Australasia)
www.aamt.edu.au/index.php/Conferences/AAMT-MERGA-conference

28-31 August 2011, University of Auckland
Annual Conference of the NZ Statistical Association
www.stat.auckland.ac.nz/nzsa2011/

27 November - 2 December 2011, Rotorua
Volcanic DELTA: The 8th Southern Hemisphere Conference on the Teaching and Learning of Undergraduate Mathematics and Statistics
www.delta2011.co.nz/delta2011

6-8 December 2011, University of Auckland
2011 New Zealand Mathematics Colloquium
www.math.auckland.ac.nz/NZMC2011

15-20 December 2011, Victoria University of Wellington
The 12th Asian Logic Conference
http://msor.victoria.ac.nz/Events/ALC2011/WebHome

AWARDS AND HONOURS

LEN COOK (NZIMA Board Chair) has been elected a Life Member of the NZ Statistical Association.

SHAUN HENDY (director of the NZIMA programme on Applications of Mathematics in the Nanosciences) has won the 2010 Research Medal of the NZ Association of Scientists.

ANDRÉ NIES (a member of the NZIMA Logic and Computation programme committee) was elected a Fellow of the Royal Society of NZ in October.

CHARLES SEMPLE (co-director of the NZIMA programme in Algorithmics) won the NZ Mathematical Society's annual Research Award for 2010.

RACHAEL TAPPENDEN (an NZIMA scholar) won the Aitken Prize of the NZ Mathematical Society for 2010.

GEOFF WHITTLE (an NZIMA PI and a former Maclaurin Fellow) has been selected by the London Mathematical Society and NZ Mathematical Society as its first Aitken Lecturer.

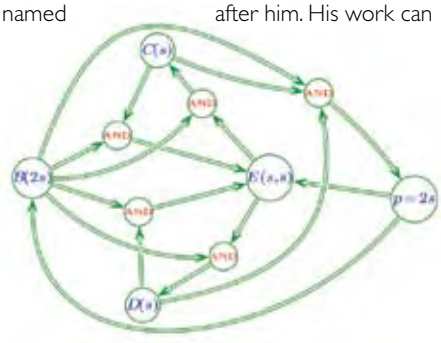
First Jones medal

John Butcher was awarded the inaugural Jones medal, named after NZIMA Co-director Vaughan Jones, by the Royal Society of New Zealand in November, and the Van Wijngaarden Award by the Centrum Wiskunde & Informatica in Amsterdam in February.

The Jones Medal is for lifetime achievement in pure or applied mathematics or statistics, and is accompanied by a $5,000 prize from the NZ Mathematics Research Institute. These awards recognise Butcher's exceptional work on numerical methods for solving differential equations, and the Jones Medal also recognises his leadership contributions in New Zealand.

Differential equations are used to study the motion of objects acted on by forces. Butcher used rooted trees, which come from a different area of mathematics, to study solutions of particular differential equations by the Runge–Kutta method. Formulae for the series of exact and approximate solutions can be written in a series of rooted trees. In the process he constructed an infinite-dimensional group that has now been named after him. His work can also be applied in the simulation of waves.

Butcher was Professor of Mathematics at the University of Auckland from 1966 to 1998, and founded its Department of Computer Science. He is now an Emeritus Professor and continues his research at a very high level.



Luminiferous aether

The application of calculus in physics may not sound like a subject of public entertainment, but the success of a pilot theatre show about it has led to the development of a full-length New Zealand play.

Professor Matt Visser and Nick Wyatt were the mathematics and physics advisors in a collaboration with Wellington's Lumina Productions, above, that led to the pilot show *The Amazing Adventures of Doctor Faustroll and his Search for the Luminiferous Aether* in 2010. Lumina included producers Mark Westerby and Howard Taylor, director Charlie Bleakley, designer Joe Bleakley, writer Jean Betts and composers John Psathas and David Downes.

The 20-minute selection of scenes aimed to bridge the gap between quantum physics and the stage. It was funded by the Ministry of Research, Science and Technology's Smash Palace Fund, which has since funded script development for a full-length play.

"It's not finalised yet," says Visser. "We're discussing calculus, waves, basic physics ideas as well as quantum physics. In the pilot we discussed Olbers' Paradox, which involves geometry and the inverse square law." It argues that if the universe is infinite, at any angle from the Earth the sight line will end at the surface of a star, so the night sky should be completely white. The darkness of the night sky is one piece of evidence for the Big Bang model of a non-static universe.

"Some people got it, and some went away puzzled," says Visser. Full-length script discussions currently include the Pauli Exclusion Principle from quantum physics, "which says thou shalt not have two electrons in the same place at the same time. It is impossible to squeeze two atoms into the same spot at all, and difficult to move them closer than normal without dynamite or a nuclear explosion."

The script will be finished by the end of the year, and Lumina aims to tour the play.

See www.htproductions.co.nz/Faustroll.htm

MATHEMATICAL JOBS TOP-RATED

Six of America's ten best jobs in 2011 require a strong background in mathematical science.

The annual Jobs Rated report ranked software engineer as the top job, followed by mathematician, actuary (employed by insurance companies to determine the probabilities of accidents, sickness, death and property loss from statistics), statistician, computer systems analyst and meteorologist. The top income was US$94,000 for mathematicians.

The report rated 200 occupations for work environment, physical demands, outlook, income and stress, and the best jobs scored high in all or most of these fields.

On average, these professions offer better than average income, comparatively low stress, a comfortable work environment, few intense physical demands and strong hiring. In short, they are much more satisfying.

See www.careercast.com/jobs-rated/10-best-jobs-2011