IMPRINTS
MAY 2003
INSTITUTE FOR MATHEMATICAL SCIENCES
National University of Singapore

Perspective and Direction>>>

Director
Louis CHEN

It took ten years and three attempts to finally realize the setting up of the Institute. It was the collective effort of a group of dedicated people in the National University of Singapore (NUS) which brought about this realization. A proposal for the setting up of a mathematical research institute was first submitted to NUS in 1991, revised and re-submitted in 1996, and then re-drafted and submitted again in 1998. In 2000 the Ministry of Education gave its approval and the Institute for Mathematical Sciences (IMS) was formally established on 1 July 2000, with funding from the Ministry and the University.

It is a bold undertaking for a small country like Singapore. IMS will have no permanent in-house researchers other than the Director and Deputy Director. Nor will it support or organize any long-term research projects other than short-term thematic programs. Thus it is legitimate to ask whether the small mathematical community here could sustain the activities at the Institute over a long period of time.

However, there are compelling reasons for there to be a mathematical research institute. Singapore has entered into a new phase of economic development where the creation of knowledge, particularly in science and technology, is paramount for continued economic success. Information technology and the life sciences are two key areas of national importance in Singapore's road map for economic development.

As a foundation for rational inquiry and an indispensable tool for industry, technology and scientific research, mathematics will have an important role to play in Singapore's economic development. The country will need state-of-the-art mathematical ideas and techniques to support its research in various disciplines.

An institute like IMS can help fulfill this need. Through its thematic programs, it will bring together mathematicians and scientists, both local and foreign, for research interaction and collaboration and for cross-fertilization and dissemination of ideas. Over time this will help strengthen the mathematical expertise of the local research community and enlarge the group of local scientists involved in the applications of mathematics. The local mathematicians and scientists, together with their visiting foreign counterparts at IMS, will form a microcosm of an

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extended research community from which many opportunities for creativity will blossom. Hopefully, this extended research community will, in turn, help sustain the activities at the Institute.

Therefore the mission of IMS is to provide an international center of excellence in mathematical research, focusing on fundamental areas in the mathematical sciences and their applications, as well as to promote interest in those fields and in multi-disciplinary research within Singapore and the region. The themes of the Institute's programs, each of which will normally last from one to six months, will be of international interest as well as of local relevance, with the ultimate aim of helping build strengths in niche areas in science and technology in Singapore.

Since its inception, four programs have taken place, each of duration of about six months. These are Coding Theory and Data Integrity (July - December 2001), Post-genome Knowledge Discovery (January - June 2002), Representation Theory of Lie Groups (July 2002 - January 2003) and Advances and Mathematical Issues in Large Scale Simulation (December 2002 - May 2003).

During its first year, the Institute was housed in the NUS Department of Mathematics and was subsequently relocated in June 2001 to the present two renovated colonial houses nos. 3 and 4 at Prince George's Park. It was officially opened by the Minister for Education, Rear Admiral Teo Chee Hean, on 17 July 2001 during a workshop of the inaugural program Coding Theory and Data Integrity.

The Institute also had a change of deputy director. Kan Chen, who served as its first Deputy Director from 1 July 2000 to 22 July 2001, relinquished his position to concentrate on his duties as acting head of the Department of Computational Science. He was succeeded by Yeneng Sun of the Department of Mathematics.

The Institute has also joined the International Mathematical Sciences Institutes (IMSI), an international consortium of mathematical research institutes. As a member of IMSI, the Institute hopes to play an active role in contributing to mathematical activities in the international arena.

IMS is now going through another phase of its physical development. A third building consisting of a lecture theater with a seating capacity of more than 80 and four offices for 10 more visitors is under construction. It will be adjacent to house no. 3. With the expected completion of the new building by the end of July 2003, the Institute will have offices for 22 visitors, one lecture theater, one seminar room, one lounge and one reading room. These facilities are much needed for expanded activities planned for the future.

As part of IMS's continuing development, it is perhaps time to start a newsletter. The newsletter will not only keep the local and international scientific community informed of the activities at the Institute, but also serve to maintain its links with other mathematical sciences institutes. This will add another dimension to the Institute's endeavor to achieve its objectives and fulfill its mission.

(Acknowledgment: I would like to thank my Deputy Director Yeneng Sun for his helpful and penetrating comments on the article.)

A Word from the Editor

LEONG Yu Kiang

It is almost certain, if not axiomatic, that any institute worth its salt has its own newsletter whose main purpose used to be to remind the outside world that the institute is alive and ticking. Newsletters used to be distributed only as they appear in print on all sorts of paper ranging from the very basic to the sophisticated and glossy. This has changed dramatically with the development of information technology and of one of its most potent offshoots (aka the Internet). Newsletters can now be read even before they appear in print. Old issues are kept in archives and brought back to life at any time and at the flick of

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Scientific Advisory Board

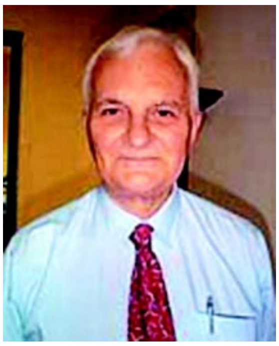
The Institute has an international Scientific Advisory Board (SAB) whose members meet annually to guide and advise on the development of the Institute.

At an SAB meeting on 10 December 2002

The current members of the SAB are (clockwise from left to right in the photograph):

- **Roger HOWE**, Yale University *(Chair)*
- **LUI Pao Chuen**, *Chief Defence Scientist, Singapore*
- **CHONG Chi Tat**, *Provost, NUS*
- **Louis CHEN**, *Director, IMS*
- **Yeneng SUN**, *Deputy Director, IMS*
- **Avner FRIEDMAN**, *Ohio State University*
- **David SIEGMUND**, *Stanford University*
- **Keith MOFFATT**, *University of Cambridge*
- **Hans FÖLLMER**, *Humboldt-University of Berlin*

The late **Jacques-Louis LIONS** (Collège de France) was also an active member of the SAB up till his untimely passing away on 17 May 2001.



The late Jacques-Louis Lions (1928 – 2001)

Management Board

The Institute has a Management Board which meets three times a year to oversee the activities of the Institute.

The current members of the Management Board are:

- **CHONG Chi Tat**
  Provost, NUS (Chair)
- **Louis CHEN**
  Director, IMS
- **LAI Choy Heng**
  Dean, Faculty of Science, NUS
- **William LAU**
  Director, Directorate of Research and Development, Defence Science and Technology Agency
- **LEE Seng Luan**
  Head, Department of Mathematics, NUS
- **LEE Tong Heng**
  Director, Office of Research, NUS
- **LIM Mong King**
  Deputy President, Nanyang Technological University
- **NG Kok Lip**
  Managing Director, Beng Kim Holdings
- **NG Wun Jern**
  Dean, Faculty of Engineering, NUS
- **K.K. PHUA**
  Chairman, World Scientific Publishing Company
- **Yeneng SUN**
  Deputy Director, IMS

The following were former members of the Management Board:

- **Shui-Nee CHOW**
  School of Mathematics, Georgia Institute of Technology
- **SU Guaning**
  President, Nanyang Technological University

Speeches at the Official Opening of IMS on Tuesday, 17 July 2001

Roger Howe, Chair of Scientific Advisory Board

Excerpts of Speech by Roger Howe, Chair of Scientific Advisory Board

Full text of speech available at http://www.ims.nus.edu.sg/opening/speech-rh.htm

I take pleasure in addressing you today. Although the number of witnesses to this opening is not large, I believe that the beginning of the Singapore Institute for Mathematical Sciences (IMS) has the potential of being a watershed in Singapore's impressive and still unrolling development. It is an undertaking both inevitable and audacious.

It is inevitable because Singapore sees itself (I believe correctly) as being a full participant in the information revolution. Few if any subjects are so deeply and broadly engaged with information technology as is mathematics, and mathematics research can be expected to be fruitful and even essential to the full realization of the capabilities of information technology. This will happen in both expected and unexpected ways.

That mathematics is relevant to the information revolution is acknowledged, at least among the technically able. It is of course the stuff of which computation is made. But that mathematical research, across a fairly broad spectrum, should be important for furthering information technology is perhaps less widely appreciated. I would like to take a few minutes to reflect on the nature and history of mathematical research.

However, even many of this more mathematically aware group seriously underrate mathematical research, and doubt its eventual usefulness. They may see current pure mathematical research as being overly refined, concerned with the modern analog of placing angels on the head of a pin. This attitude afflicts even mathematicians. Such a figure as John von Neumann, whose mathematical credentials include the definition of Hilbert space, criticized modern mathematics as being more and more 'l'art pour l'art' - art for art's sake. Yet such pronouncements have routinely been famously wrong. It is salutary to remind ourselves that much mathematics which seems fundamental today seemed strange and even fantastical when it first came into the world. Linear algebra was reviled as a useless abstraction for the first several decades of its existence, but now just one of its many applications, linear programming, saves large corporations billions of dollars annually. Linear algebra also forms the backdrop for quantum mechanics, whose most elemental formulation is in terms of a Hermitian linear operator on a Hilbert space.

Having mentioned quantum mechanics, I can easily turn to my own main research love, representation theory, or what physicists usually call "group theory". It is the mathematics of symmetry. Every physicist today knows that the story of 20th century theoretical physics is the story of group theory, with symmetry ideas being the main guide as investigations advanced into the realm of the very small and the very large. The most fundamental quantum mechanical systems - the hydrogen atom and the harmonic oscillator - are simply exquisite in the degree of symmetry they exhibit, and this symmetry can only be seen fully using representation theory. However, at the beginning of the century, group theory was regarded as a hopelessly abstract topic. Its study and uses had been confined to pure mathematics (although a codification and systematization of the principles of geometry had been one of its applications). In 1905, the eminent physicist Sir James Jeans, as part of a discussion of the necessary mathematical training for physicists at Cambridge University (which was at that time clearly a (if not the) leading center in the world for physics), said "Well, we can leave group theory out of it." Yet 1905 was the year that Einstein introduced special relativity, which was immediately interpreted by Hermann Minkowski as the simple statement that the Lorentz group is the symmetry group of space-time. A quarter- century later, Lorentz invariance was one of the desiderata that P.A.M. Dirac used to guide him to his equations for quantum electrodynamics.

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Speech by SAB Chair

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The point is, the future is a complicated place. We don't know, we cannot know, what the future holds. We cannot select which of today's many lines of investigations will prove invaluable, and which will deserve forgetting.

This point, of the unpredictability of important ideas, is key, but is hard to absorb. To give a sharp example of it, let me refer again to von Neumann. One of his last mathematical creations was what are now known as von Neumann algebras. These are a generalization, based on very abstract and theoretical principles, and in a purely infinite dimensional context, of the (now mundane) idea of a matrix algebra. After an initial wave of interest because of connections with group representation theory, research on von Neumann algebras had devolved into a domain for specialists which may well have been seen even by typical mathematicians (and I will confess here to being among them!) as being a self-preoccupied theory, out of the proverbial 'main stream'. Then, in what must count as one of the most dramatic confluences of 20th century mathematics, Vaughan Jones discovered a connection between a technical topic in von Neumann algebras which he had been investigating, and the theory of knots, the study of how strings wind around themselves in space. This led to a frenzy of research, with the outcome being not only new classes of invariants for low-dimensional topology, but new mathematical tools for molecular biologists studying the three-dimensional configurations of DNA.

This is a very hard lesson for us to learn, even for mathematicians. The impulse to second guess is overwhelming. We all want to push the subjects we know, to bet on the sure things. Yet in doing so, we close off the unexpected, the flashes of illumination that change the world and pay many times over for the whole enterprise, for the time we spend traveling up blind alleys or simply wandering in the dark. While we would be silly not to follow paths of investigation that show clear promise, and while applications are an integral part of the mathematics research institute must always include subjects chosen for their lively internal agendas, irrespective of known prospects for application.

Thus, in the U. S., there are over 30 times the number of mathematicians per mathematics institute than there are in Singapore. While a mathematics institute in the U. S. will serve and can draw on a population of 4000 - 5000 mathematical scientists, the Singapore IMS has 100 give or take a few. Furthermore, while the mathematics institutes in the U.S. can specialize, the Singapore IMS will have as portfolio the whole spectrum of mathematical activity. It is in contemplating these facts that the audacity of this enterprise sinks in.

I think that these figures hold some implications for how the Singapore IMS should operate. It cannot focus solely on responding to ideas from the mathematical research community. It must also work to enlarge, deepen, and enhance the capabilities of that community. It must serve as an advocate for mathematical research and for the mathematics research community, to government and to business. It must seek to strengthen the ties between mathematical research and other sectors in Singapore. It must educate as to the possible roles of Ph.D. mathematicians in business. Software development, both of a more standard sort and of the type represented by the recently founded Akamai internet services company, presents relatively obvious job opportunities for mathematics Ph.D.s. Modeling of various technical and business process can also make good use of a high level of mathematical expertise. In America over the past decade, large banks and other financial institutions have found that the skills developed by mathematics Ph.D. programs, notably the skills and tolerance for thinking in non-routine situations, bring substantial value-added to their activities.

The Singapore IMS will also have to give careful thought to promoting mathematical research in Singapore, to strengthening existing research groups, and to extending the range of topics in which Singapore has a research presence. In doing this, the Singapore IMS will have to reach out, to the region and to the world. It will have to identify areas which can strengthen Singapore's mathematical presence. It may have to lay the groundwork for programs by organizing 'pre-programs', in which local personnel travel to centers of expertise and return with the knowledge base needed to run a successful program in a given area. It may have to work with local groups to formulate programs that will most benefit them. It may have to develop collaborations with other mathematical institutions in the region. For example, recently in Hong Kong, several university-based mathematics institutes have started operation. It may be possible to work with them to develop mutually

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Speech by Minister

The Minister for Education delivering his opening speech

Excerpts of Speech by Rear Admiral TEO Chee Hean, Minister for Education

Full text of speech available at
http://www.ims.nus.edu.sg/opening/speech-min.htm

Throughout the centuries, the development of mathematics has been fuelled by the need to solve real-world problems and the intellectual desire to search for truth.

Mathematics provides the logical foundations for scientific inquiry and the construction of theories of physical science. It also serves a very practical and important function in aiding engineering design and managing financial resources.

In the twentieth century, the applications of mathematics have permeated almost every discipline of human knowledge, including the physical and biological sciences, statistics, computer science, engineering, medicine, economics, finance, law and linguistics.

The advances of computer technology in the past two decades have transformed the way mathematics is applied to science and technology. More and more computer intensive methods and algorithms are replacing the traditional analytic solutions to problems. Ever faster and more memory-capacious computers have made it possible to conduct more in-depth and refined studies in a shorter period of time. For example, images and special effects in movies can be simulated by solving mathematical equations using computer algorithms.

New emerging scientific problems, which require a multi-disciplinary approach to their solutions, have also influenced the development of mathematics. Recently, the human genome project has produced a draft human genome sequence. The next step is to understand the way biological cells and their genes and proteins behave. Mathematics will be useful in the modelling of biomolecular systems and the analysis

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beneficial programs. Other countries in the region may have groups in areas in which Singapore is not strong. Possibilities for fruitful interaction should be explored.

This all will not be easy. The Singapore IMS will need creative leadership, and enlightened and sympathetic support from funders. But given Singapore's goals and its extraordinary energy, which are so well embodied by the first director, Professor Louis Chen, I have high hopes for it. I am honored for a chance to help, and I look forward to the adventure.

A captivated audience

Speech by Minister

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of biological data in the multi-disciplinary research of this new discipline. It will not only contribute to the quality of life but also shed some light on the perennial question of life itself. This will undoubtedly require new ideas in mathematics.

The Institute for Mathematical Sciences seeks to be modelled after successful mathematical institutes in Europe and North America. Its function is to provide a stimulating environment for scientists of diverse backgrounds, local and foreign, to interact and collaborate in research. It focuses not only on mathematics itself but also on multi-disciplinary research involving the applications of mathematics. Its objective is to solve important scientific problems, produce new results and techniques for theoretical developments as well as applications, and in the process, stimulate interest in the study of the mathematical sciences in educational institutions and train young mathematical scientists. In this, the Institute can look forward to building on the good foundation that our schools have laid in setting high standards especially in Mathematics and Science.

Unveiling the plaque: (From left) Louis CHEN, NUS President SHIH Choon Fong, Minister TEO Chee Hean

I would urge researchers and professors at the Institute to pay particular attention to igniting in our young an interest in the fundamental disciplines, and encouraging them to consider research as a viable career option. The future quality of the Institute and its long-term sustainability depend critically on your ability to nurture a long succession of curious and intense minds to join you in your area of interest.

You will undoubtedly be helped in your venture by the existence of an attractive lounge. I am told that this is where the researchers and scientists will interact, exchange ideas and debate over coffee. Paul Erdös, a prolific mathematician who combined extraordinary talent with great devotion to mathematical research, once said, "A mathematician is a machine for turning coffee into theorems." I hope that this will be an on-going phenomenon at the Institute for Mathematical Sciences.

I understand that the Institute will focus on a different theme or themes on a regular basis and collaborative research will cover a wide spectrum of fields in the course of time in accordance with local needs and international trends. One of the themes of the institute's inaugural programme concerns computer security and data validity, which are crucial for fast, reliable, and secure communication, and are of importance to Singapore.

Through its programmes, the Institute hopes to bring to Singapore talents who, after a period of familiarizing themselves with the country, may wish to relocate and work in Singapore. Ultimately, it also aims to help Singapore establish its leadership in the mathematical sciences in the region and beyond.

The Institute will play a unique role in training young scientists, building research capabilities and creating knowledge in our knowledge-based economy. I wish you every success in this endeavour.

Excerpts of an article *IMS: Opening Moves* written by LEONG Yu Kiang for the Official Opening of IMS

Full text available at http://www.ims.nus.edu.sg/opening/index.htm

Not long ago, mathematics was commonly regarded by the general public as a reclusive activity pursued relentlessly and obsessively by a small number of individuals within the cloisters of universities. Mathematicians then seemed to be detached from and unperturbed by the fervent activities of their scientific counterparts who were busily establishing bigger and bigger research centres and research institutes during the political rivalry of the cold war and the ensuing technological competition of the post-Sputnik era. After all, mathematics has always been a low capital, low risk but high yield enterprise. Until recently, few mathematicians since Newton have asked for more than a copious supply of paper and pencil. Even the computers which they occasionally used to extend the computing power of their brains did not cost half as much as the gadgets and machines of their scientific colleagues. There seemed to be no good reason why mathematics or mathematicians needed institutes.

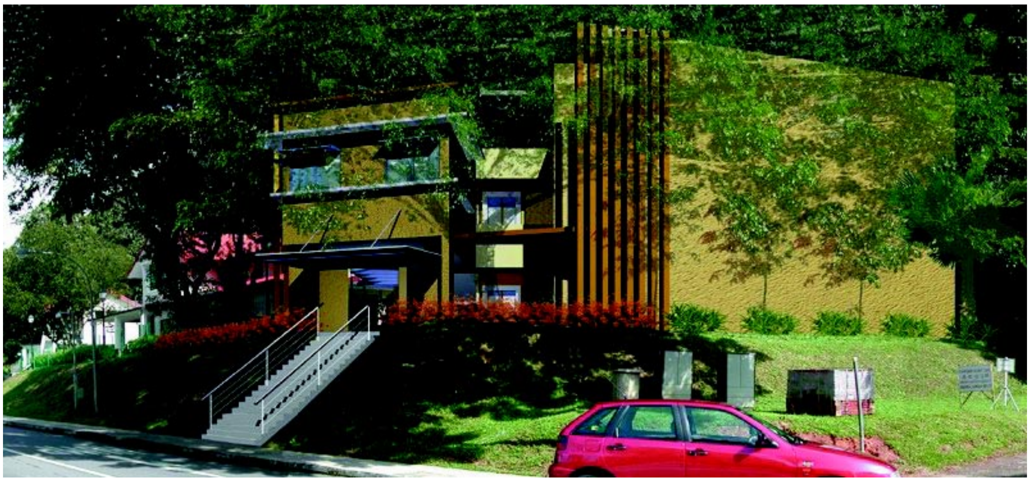
All this changed when dedicated institutes were established in Europe and the United States according to customized needs and succeeded in drawing in both talent and funds. Scientific breakthroughs were routinely reported from these institutes, attracting even more grants and talent, which, in turn, churned out more results, and so on … The technological, if not scientific, revolution began to revolve around these institutes. Although mathematicians were sometimes roped in for specific tasks, the agenda were not theirs. Yet it was relatively recent that mathematicians started to set up their own research institutes and chart their own directions for research in specialized areas and across disciplines. Directors of these institutes are ever mindful of the need to return to the sources of origin of mathematical ideas in the real and physical world and of the importance of the servicing role of mathematics in other disciplines and in society.

IMS was officially declared open by the unveiling of a plaque by the guest-of-honour Rear Admiral Teo Chee Hean, Minister for Education, at the end of a speech which gave the audience a humorous glimpse of his university experience with mathematics and mathematicians at Imperial College in London. It is not often that the Minister deviated from his prepared speech. This informality undoubtedly added to the congeniality of the occasion. He recalled how, when confronted with a problem in another field, mathematicians would invariably make a link with some general mathematical theory and consider its solution as a special case at best and "trivial" at worst.

Of course, there is no denying the power of general mathematical theories in reducing many problems in other fields to "special or trivial cases". But the point is that the over-confidence (hopefully not arrogance) that can be generated by the mathematician being consulted may not be conducive towards a dialogue between two different "cultures". Do we want scientists to reinvent the mathematical wheel or, more sensibly, to seek out those mathematicians who are receptive to more down-to-earth problems? Will this species of mathematicians become an endangered one given that mathematicians are generally known to be fiercely independent and highly idiosyncratic? And it does not help either to know that the pinnacle of excellence in mathematics has never been measured in terms of successes in applications to disciplines outside mathematics. If mathematicians working in scientific research institutes could produce fruitful results, one cannot help wondering what sort of creative sparks could be generated between interacting masters of the two seemingly different cultures.

Houses 3 (right) & 4 at Prince George's Park

New Look for IMS



Architect's impression of the new block

During the past two years, much of the institute's activities were held in borrowed premises. Come this July, IMS will get a new look if everything proceeds according to schedule. Under construction next to house no. 3 is a modest building that will provide much needed space for future activities. It will house one lecture theater (seating capacity of about 80) and 4 offices for 10 more visitors. This will bring the Institute's physical facilities to one lecture theater, one seminar room, one lounge, one meeting room and (single and shared) offices for up to 22 visitors.

A Word from the Editor

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one's fingers literally. Their actual distribution is no longer obstructed by physical, geographical or temporal barriers. Rather than being diminished in importance, the role of newsletters is being redefined in a more aggressive way. Like the cell phone which can now do all sorts of things in addition to what it is supposed to do originally, the scientific newsletter has become more than just a faithful depository of news and events. It now seeks to inform and influence, to form new views and change outdated ones without compromising the high scientific standards of truth and knowledge.

We have named the Institute's newsletter "Imprints" firstly because we hope that it will give various facets of the Institute in print (whether virtual or real) and secondly because IMS is embedded in it linguistically and hopefully also imprinted in the reader's mind. We will not be presenting the newsletter as an official mouthpiece of the Institute. We will air views expressed by others, without prejudice to them or to the Institute, and we state right from the start that unless explicitly and unequivocally stated, all views expressed in this newsletter do not necessarily reflect the views and official policy of the Institute.

Since the activities of the Institute straddle so many disciplines, it is inevitable that views and decisions taken may occasionally touch on controversial issues and go against conventional wisdom. It is a risk that the organizers of the activities will have to take in order to break potentially new ground. It is a risk that will be taken in good faith. And it is in this spirit that we hope the newsletter will be launched.

My task as editor of this first issue has been greatly helped by the comments and suggestions of an ebullient director and his incisive deputy. Thanks to San Yee for her efforts in preparing the final copy. We would also like to thank World Scientific for providing the expertise of Aileen Goh and Ye Qiang in preparing the preliminary and final artwork for the newsletter. If there is something that can be done to improve the next issue and make it serve the scientific community better, please let us know and send your views and comments to me at matlyk@nus.edu.sg . Many thanks in advance.

Past Programs in Brief

1. Coding Theory and Data Integrity (July – December 2001)

Website: http://www.ims.nus.edu.sg/Programs/coding/index.htm

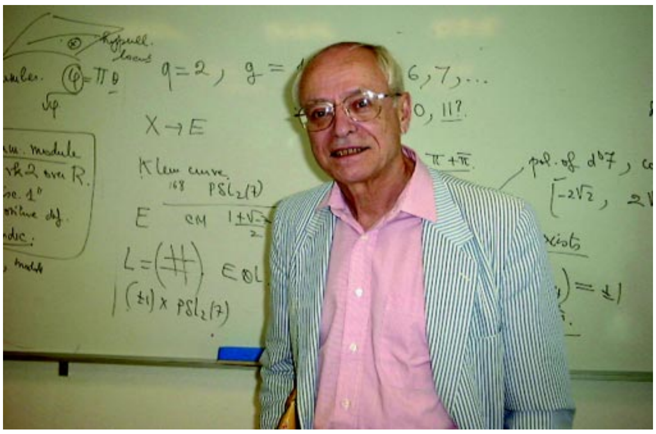
Chair:
Harald Niederreiter
National University of Singapore

IMS held its inaugural program "Coding Theory and Data Integrity" from July to December 2001. It consisted of three parts: (i) *Mathematical Foundations of Coding and Cryptology,* (ii) *Coding and Cryptology and* (iii) *Applied Cryptology.* Its 3 workshops and 48 tutorial lectures were respectively conducted by 42 and 12 speakers, with an average participation rate of 50 per session.

In addition to the invited seminars, a special inaugural lecture was given by Jean-Pierre Serre (Collège de France) on "Codes, Curves and Weil Numbers", and two public lectures given by N.J.A Sloane (AT&T Shannon Lab) and James Massey (Lund University, Sweden) on "Claude Shannon (1916-2001): Founder of Information Theory and Digital Communication" and "Cryptographic Magic" respectively.

The program was fully funded by Defence Science & Technology Agency (DSTA).

Lecture notes arising from the tutorials have now been published as Volume 1 of the Institute's Lecture Notes Series: *Coding Theory and Cryptology*, edited by Harald Niederreiter, Singapore University Press and World Scientific, December 2002.



Jean-Pierre Serre giving a colloquim lecture

2. Post-Genome Knowledge Discovery (January – June 2002)

Website: http://www.ims.nus.edu.sg/Programs/genome/index.htm

Co-chairs:
Simon Tavaré
University of Southern California
Limsoon Wong
Institute for Infocomm Research, Singapore

The program focused on the computational and statistical analysis of sequence and genetic data, the mathematical modeling of complex biological interactions, the study of the interplay between genes and proteins and the study of the genetic variability of species.

About 60 guest scientists from 15 countries visited the institute during the program. There was research collaboration among local and foreign biologists, bioinformaticians, computer scientists, mathematicians and statisticians. On the average, about 80 participants attended each workshop or tutorial.

In addition to the 38 tutorial lectures and 7 workshops, several seminars were given by IMS visitors, and 4 public lectures and 4 school lectures were jointly organized by IMS, Department of Mathematics, and Singapore Mathematical Society with the co-operation of the respective schools.

The public lectures given were:

(i) "Highlights of an emerging field: Computational biology"
by Franco Preparata, Brown University

(ii) "Unraveling genes: the role of mathematics and statistics"
by Warren Ewens, University of Pennsylvania

(iii) "How similar are humans and chimpanzees at the genomic level?"
by Wen-Hsiung Li, University of Chicago

(iv) "Back to the future: ancestral inference in molecular biology"
by Simon Tavaré, University of Southern California

The program was fully funded by Biomedical Research Council (BMRC), Singapore.

Digital evidence of a new interactive Lie Group

Courtesy Chengbo Zhu

3. Representation Theory of Lie Groups (July 2002-January 2003)

Website: http://www.ims.nus.edu.sg/Programs/liegroups/index.htm

Co-chairs:

Jian-Shu Li

Hong Kong University of Science and Technology

Eng-Chye Tan

National University of Singapore

The representation theory of Lie groups is the systematic study of symmetries and ways of exploiting them. It is an important discipline in modern mathematics and has strong connections with and applications to such diverse fields as number theory and mathematical physics.

The program brought together the world's leading experts and promising researchers to examine recent progress and future directions in the field.

The program attracted 53 mathematicians from 13 countries. The impressive roster of overseas participants, many of whom are mathematicians of high international stature, include Benedict Gross (Havard University), Roger Howe (Yale University), George Lusztig (MIT), Wilfried Schmid (Havard University), David Vogan (MIT) and Nolan Wallach (University of California at San Diego).

Many collaborations between the local and foreign participants were initiated, renewed and strengthened during the program. The program was partially funded by a research grant of Eng-Chye Tan.

The Institute is greatly encouraged by some of the following feedback from our participants:

"I have really enjoyed the beautiful and impressive lectures given here in IMS. It is a good experience to have stimulating discussions with some of the best mathematicians in the world, in tea-time or after lunch."

"I learned a great deal from the lectures and from the long discussions every day – altogether more mathematics than I've done at a conference in many years. I look forward to returning."

"The creation of IMS in Singapore is an impressive feat."

"IMS is becoming one of the great centers of mathematics in the world."

Current Program

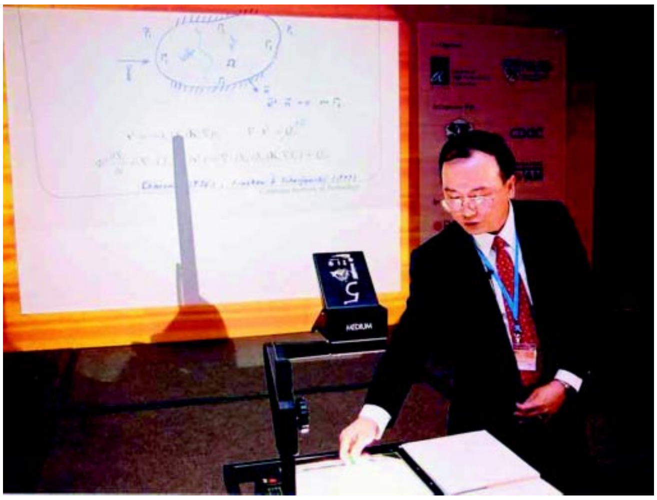
Advances and Mathematical Issues in Large Scale Simulation (December 2002 – May 2003)

Website: http://www.ims.nus.edu.sg/Programs/lss/index.htm

Chair:
Khin-Yong Lam
Institute of High Performance Computing, Singapore

High Performance Computing (HPC) has enabled engineers and scientists to solve complex, multi-disciplinary problems in which issues of scale are pervasive due to major advances in basic and applied simulation sciences as well as the availability of large scale computational capability. This program on large scale simulation focuses on two sub-themes, namely multiscale simulation and fast algorithms.

The program, jointly organized with IHPC, kicked off with an International Conference on Scientific and Engineering Computation from 3-5 December 2002. Thomas Hou (California Institute of Technology) and Roland Glowinski (University of Houston) were the plenary speakers for this inaugural conference. A total of about 200 technical papers were received from 184 conference participants.



Thomas Hou delivering a lecture Courtesy IHPC

Roland Glowinski receiving a memento from Mong King Lim, Deputy President, NTU Courtesy IHPC

Jian-Ming Jin (University of Illinois at Urbana-Champaign) and Christian Hafner (Swiss Federal Institute of Technology) conducted tutorials on "Advanced Finite Element and Hybrid Fast Methods for Computational Electromagnetics" and "Efficient and Accurate Boundary Methods for Computational Optics" respectively.

As a precautionary measure necessitated by the occurrence of SARS in March-April 2003, the program activities of April and May have been postponed to a later date to be announced in due course.

Some words of encouragement from our invited participants:

"I'm very impressed by the level of scientific programs operated by IMS."

"IMS is an excellent place for academic exchange on topics related to applied mathematics and its applications."

"It was for me an extraordinarily successful visit; with colleagues from IHPC, NUS and NTU who attended the IMS seminars and workshops we already have initiated collaborative activities, which I hope will lead to insightful and applicable results."

Next Program

Stein's Method and Applications: A Program in Honor of Charles Stein (28 July - 31 August 2003)

Website:
http://www.ims.nus.edu.sg/Programs/stein/index.htm

Co-chairs:
Andrew Barbour
University of Zürich

Louis Chen
National University of Singapore

Due to the broad range of its applications, Stein's method has become particularly important, not only in the future development of probability theory, but also in a wide range of other fields, some purely theoretical and some extremely practical. This program aims to re-focus interest on understanding the essence of the method and on the various open problems associated with it. Its further development will hinge on the interaction between different aspects of the method. Thus the program hopes to foster collaboration in the many fields of application now being studied.

Charles Stein at Stanford February 2000 Courtesy Louis Chen

Programs in the Pipeline

2003

In view of the logistic delays and preventive measures brought about by SARS in March-April 2003, most of the Institute's activities from April to July 2003 will be postponed.

Statistical Methods in Microarray Analysis (1 - 30 June 2003) POSTPONED

Website: http://www.ims.nus.edu.sg/Programs/microarray/index.htm

Chair:
Terry Speed
University of California at Berkeley and Walter & Eliza Hall Institute of Medical Research, Australia

Co-chairs:
Ming-Ying Leung
University of Texas at San Antonio
Louxin Zhang
National University of Singapore

The development and applications of the microarray technology have given rise to many problems that need to be addressed by the collective knowledge and skills of the mathematical and biologist scientists. This program aims to study the many new statistical methods developed and tailored to microarrays in the last few years. Its main objective is to bring together a group of leading researchers in microarrays to discuss their current work and exchange ideas among themselves as well as with local researchers and to address the main statistical challenges in the future.

Mathematics and Computation in Imaging Science and Information Processing (July - December 2003)

Website: http://www.ims.nus.edu.sg/Programs/imgsci/index.htm
Refer to website for changes in dates.

Co-chairs:
Amos Ron
University of Wisconsin-Madison
Zuowei Shen
National University of Singapore
Chi-Wang Shu
Brown University

The objective of the program is to conduct multidisciplinary studies involving mathematical perspectives and the foundation of imaging science and information processing. The program will emphasize particularly on the applications in imaging science and information processing of the recent developments in the areas of approximation and wavelet theory, numerical analysis and scientific computing, and data analysis.

2004

Markov Chain Monte Carlo: Innovations and Applications in Statistics, Physics and Bioinformatics (1 - 26 March 2004)

Website: http://www.ims.nus.edu.sg/Programs/mcmc/index.htm

Chair:
Wilfrid Kendall
University of Warwick

Co-chairs:
Faming Liang
National University of Singapore and Texas A&M University
Jian-Sheng Wang
National University of Singapore

The purpose of this program is to bring together people who work on innovative developments and applications in statistics, physics, and bioinformatics. The program aims to encourage cross-fertilization between workers in rather different developments and also to challenge the theoretical capacity of these methods by exposing them to statistical and bioinformatical applications.

Econometric Forecasting and High-Frequency Data Analysis (1 April - 15 May 2004)

Website: http://www.ims.nus.edu.sg/Programs/econometrics/index.htm

Co-chairs:
Roberto S. Mariano
Singapore Management University and University of Pennsylvania
Sam Ouliaris
National University of Singapore
Yiu Kuen Tse
Singapore Management University

This is a program jointly organized with the School of Economics and Social Sciences, Singapore Management University. Econometric forecasting has seen new dimensions recently due to developments in non-stationary time series, systems of equations and nonlinear dynamics modeling while the advances in high-frequency data (HFD) analysis has recently accelerated with availability of financial intra-day trade data.

Geometric Partial Differential Equations (3 May - 26 June 2004)

Website: http://www.ims.nus.edu.sg/Programs/pdes/index.htm

Co-chairs:
Xingwang Xu
National University of Singapore
Paul Yang
Princeton University

Combining geometric insights and analytic techniques together have generated many fruitful ideas and surprising results. The advances of the analytical results on nonlinear partial differential equation have helped to accelerate research on differential geometry for the last forty years. On the other hand, geometry has provided subtle and elegant equations for investigation. The objective of the program is to initiate and conduct investigations into nonlinear partial differential equation arising from geometric questions, especially those related to the scalar curvature problem, Q-curvature problem and Sigma curvature problem.

Wall-Bounded and Free-Surface Turbulence and its Computation (July - December 2004)

Website: http://www.ims.nus.edu.sg/Programs/wbfst/index.htm

Co-chairs:
B. E. Launder
University of Manchester Institute of Science and Technology
Chiang C. Mei
Massachusetts Institute of Technology
Khoon Seng Yeo
National University of Singapore

Turbulence in fluid flow has remained one of the challenging problems of science and engineering today. Although important advances have been made in our knowledge of the process of turbulence since the time of Osborne Reynods more than one hundred years ago, our current ability to accurately predict turbulent events and their properties is still very limited in all but simple flow. This program seeks to foster a greater understanding of turbulence and to improve the ability to predict its characteristics, which are essential for mastering control of turbulent flow and managing turbulence-related energy losses.

Highlights of Other Activities

1. Inter-Faculty Workshop on Financial Mathematics (12 January 2002)

With Department of Mathematics and Center for Financial Engineering, NUS

Details at http://www.ims.nus.edu.sg/activities/cfe/Interfac.htm

2. ICM 2002 Satellite Conference (15 - 17 August 2002)

SSA - Symposium on Stochastics and Applications

With Department of Mathematics, Department of Statistics and Applied Probability and Singapore Mathematical Society

Details at http://ww1.math.nus.edu.sg/ssa/

Making IMS tick: front, left ro right – YEOH San Yee, Agnes WU, Pauline HAN; back, left to right – SUNN Aung Naing, Yeneng SUN (Deputy Director), KP CHUA

3. IMS-BII Population Genetics Workshop (29 November, 2 - 3 December 2002)

With Bioinformatics Institute, Singapore

Details at http://www.bii.a-star.edu.sg/webcast/news/workshop.html

Courtesy Simon Tavaré

Simon Tavaré (University of Southern California) delivered a series of six lectures on "Population Genetics and the Coalescent" at the IMS-BII Population Genetics Workshop

Courtesy BII

Eric Yap (Defence Medical Research Institute, Singapore) gave lectures on "Of Microbes, Mice and Men: Variations on a Genetic Theme"

4. Workshop on Mathematical Finance (17 January 2003)

With Department of Mathematics and Center for Financial Engineering, NUS

Details at http://www.ims.nus.edu.sg/activities/wkmf

From September 2001 to October 2002, eight public lectures were jointly organized by IMS with Department of Mathematics, Centre for Industrial Mathematics, Singapore Mathematical Society or Genome Institute of Singapore on various topics in cryptography and computational biology. In March 2002, four lectures to schools were given by visitors to IMS.

Since July 2001, seven colloquium lectures and about 120 regular seminars were organized by the Institute, some jointly with the Departments of Mathematics, of Economics or of Statistics & Applied Probability. The seven colloquium lectures were given by Bjorn Engquist (Princeton University), Avner Friedman (Ohio State University), Thomas Hou (California Institute of Technology), Robert V. Moody (University of Alberta), Jean-Pierre Serre (Collège de France) and Stephen Smale (University of California-Berkeley).

From 2 March to 23 November 2002, a discussion group on bioinformatics was organized with the Genome Institute of Singapore: details at http://www.ims.nus.edu.sg/prognsem02.htm#conf

Mathematics, Music, Masters: Conversation with Roe Goodman

Excerpts of an interview by Y.K. LEONG
Text of full interview available at
http://www.ims.nus.edu.sg/imprints/interview_goodman.htm

The Editor of *Imprints* interviewed Roe Goodman of Rutgers University on 11 February 2003 at the Department of Mathematics, National University of Singapore while he was visiting IMS and the Department of Mathematics. He was a guest participant in the IMS program on "Representation Theory of Lie Groups". The hour-long interview covered topics that range from teaching and research in mathematics to the influence of masters in mathematics and music.

Goodman's extensive research activities are centered around Lie groups. Together with Nolan Wallach, he has written a 685-page encyclopedic book *Representations and Invariants of the Classical Groups* that is both an introduction to as well as an authoritative reference on the structure and finite-dimensional representation theory of the complex classical groups.


A mathematical bassoon Courtesy Roe Goodman

Imprints: *Can you share with us some of the excitements of your latest research?*

***Roe Goodman**:* My own research started in the 1960s when I did my PhD thesis with Irving Segal in MIT. Segal himself was primarily interested in the mathematical problems of quantum field theory, viewed in a very broad sense: difficult questions in non-linear partial differential equations and their symmetry groups. My own interests and activities over the years have moved in the direction of representation theory and the symmetry groups although I maintain an interest in application to physics. The thing that attracted me to representation theory is that it lies at the crossroads of all of mathematics. You have the analysis side in connection with partial differential equations and you have algebra and geometry in the Lie groups. One of the things that is exciting about this field, as I have watched it developing over the last 40 years, is to see so many areas of mathematics come into this field - more and more of combinatorics, geometry and algebra - even though the subject started out with a lot of emphasis on analysis. Of course, one of the central things that make mathematics research so exciting is that, over the course of time, you see that problems that first seemed intractable examined by lots of people who find new ways to approach these problems. For example, problems that were originally posed as questions of functional analysis can now be approached using algebraic techniques, which simply avoid some of the difficult, maybe impossible, analytical problems. I have spent quite a lot of time over the last decade telling the story for the next generation, so to speak, in my collaboration with Nolan Wallach. We wrote quite a big book on representation and invariant theory, trying to make the basic results and philosophy of representation theory accessible to the current generation of mathematicians (and we hope to another generation).

I: Are there any unifying trends in the development of your field of research? Do you think that particular problems have to be solved first before some unifying theory can arise, or do you think that essentially new theories and concepts rather techniques need to be proposed before outstanding problems can be resolved?

G: In my field, it seems to be that there is this cycle of solving particular cases and pushing the methods that suffice for those cases as far as possible. At a certain point those methods often turn out to be insufficient or the computational difficulties simply become insurmountable and then there are new approaches that come in. One of the striking things about mathematics is the insistence to understand the subject from the conceptual point of view. For beginners of the subject, it is hard to understand the concepts without actually doing some calculations. But at a certain point, you discover that even if you have a very powerful computer doing symbolic calculations for you, the calculations alone are not going to tell you what the pattern is. You have to discern the pattern, and I think finding the pattern is one of the main purposes of mathematics. Of course being able to come out with an answer that can be translated into some of the applied domains is also very nice when you can get it.

I: In physics there is some kind of blueprint for the development of the subject whereas in mathematics there is no specific blueprint as to how mathematics should develop.

G: That's right. The remarkable thing in mathematics is that you have these extraordinary imaginative people (like Gromov, Langlands) who propose concepts that, to ordinary mortals like us, seem to just come out of the blue. Of course, they have a basis for those ideas but it can take the work of a lot of people to develop the consequences.

I: There is some perception that pure mathematicians look upon practical applications with disdain. How much of this is true? Some of the best mathematical minds like Hilbert and Poincaré have worked in both pure and applied areas. Is it possible to achieve their status in the present age of specialization?

G: Judging by my own experience, it seems hard to establish links with applied science departments like chemistry, computer science and physics partly because the faculties in those departments themselves have quite a high mathematical level and they generally view the kind of mathematics they are using as something that they are reasonably competent with and they don't seem to have an enormous need for mathematicians. Of course, one can try to create the need, and there is also the tendency on the mathematician's side to think, as the phrase goes, "We would rather build fire houses than to put out fires". But there are remarkable counter-examples. My own personal hero is Hermann Weyl, who is not very well known to the general public. He was a student of Hilbert. He gave the first set of lectures on Einstein's general relativity theory in 1917/1918 and published basically the first book on general relativity theory based on those lectures. He also worked as a forerunner in understanding and explaining what was going on in the new quantum theory in the 1920s. Certainly there are many examples of mathematicians who have done this. In recent years someone like Irving Segal is an inspiring example. Another person who comes to mind is Michael Atiyah. As physics becomes more mathematical and uses a wider range of mathematical tools like algebraic geometry, physicists have to turn into mathematicians.

From the point of view of people completely outside of science, and in particular people interested in what is the worth of mathematics to society at large, they would like to see how mathematics can be turned towards more practical things. It is interesting to observe that in my own field involving harmonic analysis as well as representation theory very recent work in wavelet analysis is essential for things like image compression and data analysis. A lot of that grew out of what used to be thought of as quite abstract kind of harmonic analysis and abstract Fourier analysis. It is a question of having links with applied mathematics. There are people like Coifman at Yale, who, when I first knew him in the 1970s, was working in the kind of representation theory and harmonic analysis that I was. He moved into wavelets and has been very successful in promoting its commercial technology.

I: What instrument do you play?

G: The instrument that I play most seriously is the bassoon. Originally I started out as a child playing the cello but then when I was fourteen I switched to the bassoon, which I consider the most non-linear oscillating system that is of any practical use. So every morning when I practice my instrument I perform experiments on a little non-linear oscillator in the form of a bassoon reed.

I: What made you switch from music to mathematics?

G: My father was a professional musician, a pianist, and I knew from personal experience the difficulty of making a living as a musician. Most of my adult friends in the orchestra that I played in as a teenager advised me that it would be much better to go into science. But it was hard for me not to go into music and composition because that was what I was most passionately interested in at the time. In retrospect, however, mathematics has been a very rewarding career, and I have still managed to maintain an active musical life.

I: Do you think that part of the problem of overspecialization is a lack of communication between mathematicians and people in other areas like engineering, physics and computer science?

G: Yes, that is certainly a problem and I think that is a real challenge for mathematicians. One can almost feel it as a drawback of mathematics that we have such a perfect system of notation that for us the notation serves all the purpose that we want in the same way as the written language serves our purposes. But students and people outside of mathematics often tend to view mathematics simply as a collection of symbols to push around. When the symbols get too complicated, only the professional mathematicians can read them and then people outside the field just turn off. I don't know how to get around that. I teach engineering students a lot and try to explain the concepts in a way that is acceptable to them. I view that as one of the biggest challenge when I am teaching. Of course, it can be quite frustrating because you know as a professional mathematician that with the benefit of an appropriate concept certain ideas can be quite simple. But this is only true if the person dealing with the concept has mastered it, and for people outside mathematics the notation and concept can be so obscure that it is very hard to get the ideas across. I think that is one area in which mathematics, as a profession, sometimes tends to be too narrow. We don't realize that the mathematical ideas are just too dry when used by students outside of mathematics.

I: There are some people who would attack a problem from first principles. They develop their own understanding of the problem and then develop essentially their own methods for the problem.

G: I think the most spectacular example in my own field is Harish-Chandra who, starting in the late 1940s, simply came into the subject of representations of semi-simple Lie groups on his own. There had been very important preliminary work by the Russian school under Gelfand, but Harish-Chandra started at the beginning and created an incredible edifice single-handedly. For a period of about 25 years, starting from the late 40s to the mid 70s, he was so clearly leading the field. that it was only in the early 70s that there was a significant number of other people working in the field. In his case, the methods were always his own. He took what were, in some way, very classical methods and extended them to serve his needs. It has taken several mathematical generations to go beyond Harish-Chandra's methods. His ideas had tremendous depth. Of course, now more recent approaches to the subject try to understand it by other methods, but he basically set the direction in the field. The results achieved were so precise and profound that everybody in the field has to take his methods into account. A parallel instance in mathematics of someone creating a monumental edifice is in algebraic geometry. Grothendieck created very general machinery that has now become the language of algebraic geometry. So I think the absolutely strongest people in the field simply create the field by using their own methods and then the rest of us have to learn those methods and see what other results can be obtained.

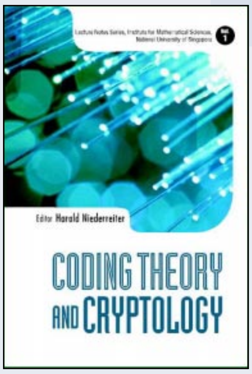
I: Is there a role for perseverance? How much inspiration does one need?

G: Oh, absolutely. I think without perseverance you certainly can't do mathematics. If there are never any ideas that come along, it is pretty discouraging. It is an elusive thing. Solving a mathematical problem is trying to judge at any moment whether the track that you are trying is going to pan out. Of course, perseverance alone may not work, but even if it does, you try to know whether you are moving towards a dead end. That can be very discouraging in mathematics.

Publications

I: Do you think that mathematics is a marathon race that is long, arduous and lonely?

G: I think there is a partial truth in that comment. But there is such a large social element in mathematics, public perception notwithstanding, in the sense that if you only create mathematics in writing and never tell anyone about it, then it is like running a long race where no one is even looking. I like to think that at least there is this aspect of mathematics as a communal effort. As Einstein commented, there are innumerable problems in mathematics. But I think the ones that have a life of their own are the ones that have a significant number of people (which, of course, in mathematics could be a small number) with some real interest in those problems. And then the joint efforts of people working on these problems make it interesting - you get some results yourself and compare yours with what other people have. So maybe instead of thinking that it is a long marathon race, it is more like a situation I observed once, to my surprise, at a rehearsal of the orchestra. A grand piano was on the floor of the concert hall but needed to be on the stage. I certainly couldn't lift it by myself, but with eight people it was very easy to lift the piano onto the stage. So I think hard mathematics problems may have some of that element of joint effort. Of course, it is one thing to get the piano onto the stage and another thing to get a beautiful performance. We do need the gifted mathematician to give the beautiful performance but the joint effort can play an essential role.



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