The
Pacific Institute for the Mathematical Sciences
Newsletter

http://www.pims.math.ca
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Contents

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- **The Natural Sciences and Engineering Research Council of Canada**
- **The British Columbia Information, Science and Technology Agency**
- **The Alberta Ministry of Innovation and Science**
- **Simon Fraser University**, **The University of Alberta**, **The University of British Columbia**, **The University of Calgary**, **The University of Victoria**, **The University of Washington**, **The University of Northern British Columbia** and **The University of Lethbridge**.

U. Calgary's Richard Cleve Behind IBM Latest Breakthrough in Quantum Computing

IBM announced that it had recently demonstrated the use of a five qubit quantum computer consisting of five fluorine atoms to solve a mathematical problem. This new result confirms predictions of Prof. Richard Cleve of the Department of Computer Science at University of Calgary made earlier this year. This experimental quantum computer was developed at

Please see ***Quantum Computing,*** *page 22.*

The University of Washington Joins PIMS

The Board of Directors of the Pacific Institute for the Mathematical Sciences (PIMS) has approved a resolution to initiate the full integration of the mathematical sciences community at the University of Washington into the operations and management of the Institute. The goal is to develop a world class model for the Mathematical Sciences, that addresses simultaneously the imperatives of Research, of Education and of Technology Transfer.

Tatiana Toro, PIMS-UW Site Director

Please see ***University of Washington,*** *page 8.*

Mathematics and Literature: Cross Fertilization

Contributed by Brett Stevens, PIMS/IBM Postdoctoral Fellow

When one thinks of Mathematics and Literature one often evokes the image of *Alice in Wonderland* and the logic games and paradoxes that permeate Alice's voyage. It is indisputable that Lewis Carroll's use of mathematics in his novels was profoundly original and ground-breaking. However mathematics did not play a determining role in the plot or creation of the work, nor can it be said that *Alice in Wonderland*, or most other novels containing mathematics, have in any way contributed to mathematics research. Indeed, the relationship between mathematics and literature is most often seen as a one way relationship, literature using mathematical ideas as symbolism, and not a profoundly deep one at that. In this article I will tell the story of deep cross-fertilization between literature and mathematics, both directions: research level mathematics guiding novel creation at the profoundest levels and literature spurring active and important research.

Beckett's play *Quad*

Please see ***Mathematics and Literature,*** *page 9.*

Director's Notes

Nassif Ghoussoub, FRSC

The integration of the mathematical sciences community at the University of Washington into the operations and management of PIMS is destined to provide a formidable boost to the Institute's mandate of promoting all aspects of the mathematical sciences. Indeed, a partnership between the 6 major universities in this region:

- will build on already existing substantial joint efforts and links between the scientific communities of Western Canada and the US Pacific Northwest and open up a whole new era of scientific collaborations between the mathematical communities of the two countries. We note that there are already more than 10 Pacific Northwest Seminars in Statistics, Geometry, Probability, Mathematical Biology, Number Theory, Optimization, Topology, PDE, Numerical Analysis and Combinatorics/Graph Theory.
- will be crucial for developing continental resources for the mathematical sciences like PIMS-K: The International Research Center in Kananaskis. Located in the Canadian Rockies, this center will offer a North-American counterpart to the highly successful program of the *Mathematisches Forschungsinstitut Oberwolfach* in Germany. More than 1000 US mathematical scientists are expected to participate in the Center's activities every year and we expect that the University of Washington would lead the US involvement and participation in these activities.
- will help in developing more focused research centers like the *PIMS Center for Inverse Problems and Imaging*, the *PIMS Center for Theoretical Mathematical Biology*, the *PIMS Center for Scientific Computing*, the *PIMS Center for Probability Theory and its Applications* and many other developing collaborative research groups spanning the 6 PIMS universities;
- will stimulate the creative activities of the mathematical scientists in our region while increasing considerably the visibility of their efforts on a larger stage. The infrastructure and experience of the PIMS organization should greatly enhance current efforts at communicating and disseminating the latest advances in the mathematical sciences;
- will break the relative geographic isolation of the research environment at the University of Washington within the US, which is due to the great distances to other US universities. This primary reason for the creation by the 5 Western Canadian Universities of the scientific critical mass embodied by PIMS, applies almost verbatum to justify the need for the much closer ties with the University of Washington;
- will provide a much needed organizational and infrastructural support to the various existing scientific and educational initiatives at the University of Washington. This can be accomplished by an institute whose structure is well adapted to the geographic realities of Western Canada and of the US Pacific Northwest;
- will generate new and innovative scientific and outreach activities in the Pacific Northwest, especially those already proven effective and valuable at PIMS. In particular, our Institute has been particularly successful at developing collaborative projects and links with various industrial partners thanks to its training and problem-solving programs;
- will ensure the position of Western Canada and of the US Pacific Northwest on the international scientific map and would make our region a major rendez-vous point between the scientists of North America and those from Pacific rim countries.

I am confident that with this partnership, we are building a world class model for the Mathematical Sciences that will successfully support Research, Education and Industrial Outreach. The overwhelmingly positive reaction that we have already received from all over the world, in response to this development, confirms that we are heading in the right direction.

TD Bank Financial Group and TD Securities Donate to PIMS Prizes

PIMS thanks the Toronto Dominion Bank Financial Group and TD Securities for providing $10,000 for the three PIMS Prizes in Research, Education and Industrial Outreach. These prizes will be officially awarded at the banquet of the CMS Winter meeting on December 11 in Vancouver.

The *PIMS Research Prize* is given for a particular outstanding contribution to the mathematical sciences, disseminated during the past five years. The *PIMS Education Prize* rewards individuals who have played a major role in encouraging activities which have enhanced public awareness and appreciation of mathematics as well as fostering communication among various groups and organizations concerned with mathematical training at all levels. The *PIMS Industrial Outreach* recognizes individuals who have employed mathematical analysis in the resolution of problems with direct industrial, economic or social impact.

MITACS Moves Headquarters to SFU

MITACS Press Release

The Mathematics of Information Technology and Complex Systems NCE (MITACS) has announced that it will be moving its headquarters from the University of Toronto to Simon Fraser University. The move is slated to take place on November 1, 2000. "This is the beginning of an exciting new era in mathematical research for SFU," said Dr. Bruce Clayman, Vice-President, Research at SFU. "With this move, Simon Fraser University is taking a leadership role in the fields of applied and industrial mathematics."

MITACS, a federally funded Network of Centres of Excellence (NCE), is devoted to industry-university research in the mathematical sciences. The network currently represents a $3.7 million annual investment by the federal government matched by $1.5 million annually by Canadian industry.

Dr. Arvind Gupta, MITACS Program Leader and SFU associate professor of computing science appreciates the role that the University of Toronto played in getting MITACS off the ground. "The University of Toronto has been a terrific host, and we plan to continue working closely with its senior administration." The driving factor behind the decision to move the MITACS' headquarters to SFU was the advantage of having the scientific and administrative leadership under a single roof. "By bringing together the MITACS staff in one location, MITACS is in an excellent position to initiate new programs and projects."

Dr. Clayman says that both "MITACS and SFU will benefit from the headquarters' relocation. The university will support the network by providing it with major administrative and infrastructure facilities. At the same time, MITACS will enrich the university by establishing a forum for dynamic and productive encounters among university researchers, graduate students and industry representatives."

MITACS will be sharing the SFU facility with the SFU site office of the Pacific Institute for the Mathematical Sciences (PIMS), one of Canada's three mathematical sciences institutes. Dr. Nassif Ghoussoub, Director of PIMS, is enthusiastic about the new proximity of MITACS to PIMS. "PIMS is proud to have played such a pivotal role in the creation of MITACS."

Dr. Gupta notes that MITACS has grown in less than two years to include more than 200 scientists at 26 universities working with over 300 students. "Today's knowledge-based economy increasingly relies on mathematical ideas for new product development. MITACS scientists are working with more than 75 Canadian companies, industries, financial institutions, hospitals, government departments, and foundations on problems ranging from fuel cell design to the prevention of the spread of infectious diseases."

About MITACS: Launched in October 1998, MITACS, a federal Network of Centres of Excellence, is a joint project of Canada's three Mathematical Institutes: the Centre de recherches mathḿatiques (CRM), the Fields Institute for Research in Mathematical Sciences, and the Pacific Institute for the Mathematical Sciences (PIMS),. The network consists of 23 research projects addressing five key sectors of the economy that will be crucial for Canada in the 21st century: biomedical, commercial/industrial, information technology, trade/finance, and manufacturing. Each project brings together industrial and university scientific expertise from across the country.

Thirteen PIMS Industrial Postdoctoral Fellows for 2000–01

This year, thirteen PIMS Industrial Postdoctoral Fellowships have been created. PIMS Industrial PDFs are jointly supervised by PIMS scientists and their industrial counterparts. The fellows act as a conduit for the dissemination of knowledge between the industrial partner and the university research group.

The fellowships are jointly funded by industrial partners and PIMS through support provided by *The Alberta Ministry of Innovation and Science* and *The British Columbia Information Science and Technology Agency.*

PIMS Industrial Fellowships Awarded:

PIMS/InSilico PDF: Alexandra Chavez-Ross

PIMS/Schlumberger RA: Sviatoslav Pelipenko

PIMS/Powerex PDF: Simon MacNair

PIMS/Maple PDF: Janez Ales

PIMS/IBM PDF: Brett Stevens

PIMS/Mathsoft PDF: Matias Salibian-Barrera

PIMS/VisionSmart PDF: Wei Sun

PIMS/Quatronix PDF: Michael Segal

PIMS/Nortel PDF: To be announced.

PIMS/Lockheed-Martin PDF: HongWei Long

PIMS/Paprecan PDF: Joseph Mmbaga

PIMS/PanCanadian PDF: To be announced.

PIMS/Transalta PDF: To be announced.

Report on the Second PIMS Fluid Dynamics Summer School

Contributed by Bruce Sutherland,
Dept. of Mathematical Sciences, University of Alberta

The Second Annual PIMS Fluid Dynamics Summer School ran from July 30 to August 11, 2000. In this two week long workshop, 26 students from around the world gathered at the University of Alberta. Most participants were graduate students in the early stages of their research programs. The students attended a series of advanced lectures taught by specialists at the university and three world-renowned invited lecturers: P. F. Linden (University of California, San Diego) speaking on the fluid mechanics of natural ventilation, J. C. McWilliams (University of California, Los Angeles) speaking on convection in a rotating environment, and F. T. W. Nieuwstadt (Delft University) speaking on recent advances in understanding turbulence.

Each morning the students attended lectures on a range of topics in fluid dynamics including wave theory, stratified flows, turbulence modelling, physical oceanography, climate modelling and computational fluid dynamics. During the afternoons the participants were given hands on experience running research-level numerical codes and they performed laboratory experiments. Both the simulations and experiments were designed to complement the lectures and so help students develop an intuition for fluid dynamics phenomena, how they are mathematically modelled, and how reliable approximate solutions can be.

The students spent some of their extra time researching and ultimately giving brief presentations on the results of one of their experimental or numerical labs. The presentations, which concluded the summer school, helped give the students experience in preparing succinct conference-style talks.

The school was a great success. Only two other institutions in the world run an annual summer school in fluid dynamics: the University of Cambridge and Woods Hole Oceanographic Institution. The feedback from students who had also attended these other workshops said that the PIMS Fluid Dynamics Summer School was most interesting because of its emphasis on modern experimental and numerical methods as well as the high quality of lectures.

The PIMS Fluid Dynamics Summer School is an annual event sponsored by the Pacific Institute for the Mathematical Sciences, with additional support from the Institute for Geophysical Research, the Applied Mathematics Institute and the Environmental and Industrial Fluid Dynamics Laboratory. Next year it will be held from May 26 to June 8, immediately before the PIMS sponsored conference “Wave Phenomena III”. It is hoped that graduate students attending the summer school will remain for the second week to be immersed in talks by leading experts on a range topics under active research.

Summer school information is available on the web at **www.pims.math.ca/fdss** or by email to fdss@math.ualberta.ca.

Participants in the 2nd Annual PIMS Fluid Dynamics Summer School

IAM-CSC-PIMS Undergraduate Math Modelling Camp

PIMS at the University of British Columbia and Simon Fraser University
February 21–22, 2001

The Pacific Institute for the Mathematical Sciences (PIMS) along with the Institute of Applied Mathematics (IAM) at the University of British Columbia and the soon to be established PIMS Centre for Scientific Computing (CSC) at Simon Fraser University are sponsoring an undergraduate workshop on problems in applied mathematics for senior undergraduate students. The workshop is planned to run for two days, during which time faculty mentors will outline a set of problems to the students, who will then have the option of choosing one or more problems to work on during the workshop. The mathematical tools used in the workshop will be accessible to 3rd and 4th year undergraduates in mathematics, applied mathematics, physics and applied science. For registration information and more details please see **www.pims.math.ca/industrial/2001/suimw**.

3rd PIMS Fluid Dynamics Summer School

PIMS at the University of Alberta
May 27 – June 8, 2001

Held at the University of Alberta to take advantage of the large and active group of researchers in theoretical, experimental and computational aspects of fluid dynamics working there, this summer school is aimed at graduate students. The participants will attend a comprehensive series of lectures and will be given hands-on experience performing and analyzing experiments in the *Environmental and Industrial Fluid Dynamics Laboratory,* as well as running numerical simulations using research-level codes. Topics will include fluid dynamics fundamentals, industrial and environmental flows, geophysical fluid dynamics, turbulence modelling and computational fluid dynamics. Subjects will be taught at a graduate level.

Invited Speakers:
T. G. Shepherd (University of Toronto)
H. J. S. Fernando (Arizona State University)

Minicourse Lecturers:
John C. Bowman (UA): *Turbulence Modelling*
Andrew B. G. Bush (UA): *Climate Modelling*
Peter Minev (UA): Computational *Fluid Dynamics*
T. Bryant Moodie (PIMS and UA): *Wave Theory*
Bruce R. Sutherland (UA): *Stratified Flows*
Gordon E. Swaters (UA): *Physical Oceanography*

For additional information and online registration, please visit **pims.math.ca/fdss**.

CAIMS/SCMAI 2001

University of Victoria
June 7-9, 2001

The annual meeting of the Canadian Applied and Industrial Mathematics Society will be held June 7-9, 2001 at the University of Victoria, in Victoria, British Columbia. The 6 sessions of plenary speakers are:

Applied Dynamical Systems,
chaired by Jerold Marsden (Caltech).
Mathematical Biology,
chaired by Hal Smith (Arizona State).
Computational Biology, chair T. B. A.
Neural Networks & Neural Dynamics,
chaired by Nancy Kopell (Boston).
Geophysical Fluid Dynamics,
chaired by Grae Wooster (Cambridge).
Data Compression,
chaired by Bin Yu (Berkeley).

A limited number of fellowships for graduate students and post-doctoral fellows will be available (details to follow in later announcements). CAIMS/SCMAI is supported in part by PIMS and MITACS.

For additional information please consult the website **www-sci.pac.dfo-mpo.gc.ca/osap/CAIMS2001**.

4th PIMS Graduate Industrial Math Modelling Camp

PIMS at the University of Victoria
June 11–15, 2001

The fourth PIMS Graduate Industrial Math Modelling Camp will be held at the University of Victoria. The format of the camp calls for students to work together in teams, under the invitation of invited mentors. Each mentor will pose a problem arising from an industrial or engineering application and guide his or her team of graduate students towards a solution of the problem. Participants in the Grad Modelling Camp are supposed to attend the Industrial Problem Solving Workshop during the following week. Additional information regarding the programme and registration procedure will be made available on the PIMS website.

5th PIMS Industrial Problem Solving Workshop

PIMS at the University of Washington
June 18–22, 2001

The fifth PIMS Industrial Problem Solving Workshop will be held at the University of Washington, the newest partner university in PIMS. The format of this workshop is based on the highly successful *Oxford Study Group Model,* in which problems of relevant and current interest to the participating companies are posed to the workshop participants by experts from industry. The participating graduate students and academics will spend five days working on the problems and results will be published in the workshop's proceedings. Graduate students wishing to participate in the *Industrial Problems Solving Workshop* are encouraged to attend the *Graduate Modelling Camp* as preparation. More details on the workshop will be announced on the PIMS website over the coming months.

The Mandelbrot Set, the Farey Tree, and the Fibonacci Sequence

Lecture by Prof. Robert L. Devaney
PIMS at the University of Victoria
October 20, 2000

Professor Robert L. Devaney received his BA from Holy Cross College and his PhD from the University of California at Berkeley in 1973. He has taught at Northwestern University, Tufts University, and the University of Maryland before coming to Boston University in 1980. He served as Chairman of the Department of Mathematics from 1983 to 1986 and is a member of the dynamical systems group at BU.

His main area of research is dynamical systems, specifically including Hamiltonian systems, complex analytic dynamics, and computer experiments in dynamics. He is the author of over sixty research papers in these fields. He is also the author or editor of ten books on various aspects of dynamical systems theory. These include *An Introduction to Chaotic Dynamical Systems,* a text for advanced undergraduate and graduate students in Mathematics and researchers in other fields; *A First Course in Chaotic Dynamical Systems,* written for undergraduate college students who have taken calculus; and *Chaos, Fractals, and Dynamics: Computer Experiments in Modern Mathematics* and the series of four books collectively called *A Tool Kit of Dynamics Activities,* both aimed at high school students and teachers.

A winner of numerous prestigious teaching awards, Prof. Devaney has delivered over 950 lectures on dynamical systems and related topics in 49 states in the US and on six continents worldwide. Several of these lectures are available on videotape from Science TV or Key Curriculum Press. He has also been the “Chaos Consultant” for the Huntington Theater’s presentation of Tom Stoppard’s play *Arcadia.*

In this lecture several folk theorems concerning the Mandelbrot set will be described. It will be shown how one can determine the dynamics of the corresponding quadratic maps by visualizing tiny regions in the Mandelbrot set as well as how the size and location of the bulbs in the Mandelbrot set is governed by Farey arithmetic.

The lecture will be videotaped and accessible via streaming video from **www.pims.math.ca/video**. More information about Prof. Devaney can be found on his homepage, **math.bu.edu/people/bob**.

PNW Numerical Analysis Potlatch

Vancouver Museum, Vancouver, BC
October 28, 2000

Speakers at the the fourteenth Pacific Northwest Numerical Analysis Potlatch are Ricardo Carretero (PIMS-PDF, SFU): *Metastability and blow-up in reaction diffusion systems: some computational challenges,* Oliver Dorn (UBC): *A level set approach for shape reconstruction in electromagnetic cross-borehole tomography,* Sharon Filipowski (Boeing): *Applications of nonsmooth optimization in industry,* Leslie Greengard (Courant Institute): *Robust Algorithms for Computational Engineering,* Sorin Mitran (University of Washington): *Algorithms for computing bubbly flows,* and Frank Stenger (Utah): *A unified approach to solving PDEs.* Furthermore, in celebration of the *Fast Multipole Method* being voted one of the top ten algorithms of the Century, we are hosting a workshop on Fast Multipole Methods in conjunction with the Numerical Analysis Potlatch. This workshop runs on October 29, from 9:00am to 3:00pm, also at the Vancouver Museum.

See the webpage **www.math.sfu.ca/~mrt/potlatch** for registration information.

Third Annual PIMS PDF Meeting

PIMS at Simon Fraser University
December 9–10, 2000

At this workshop, PIMS Postdoctoral Fellows give talks on their research and have a opportunity to meet and discuss with fellows from the other PIMS sites. The workshop is open to mathematical scientists from any of the PIMS sites, who are encouraged to attend and learn about the wide range of research being conducted by PIMS PDFs. This year the meeting immediately precedes the CMS Winter Meeting, which is also held in Vancouver.

Wave Phenomena III

PIMS at the University of Alberta
June 11–15, 2001

The theme of this conference is *Waves in Fluids from the Microscopic to the Planetary Scale.* The daily programme will consist of four or five plenary lectures each of approximately forty minutes in length. They will be followed in the afternoon by parallel sessions of contributed papers, each of approximately twenty minutes in length.

Local Organizing Committee: Andrew B. G. Bush (U. Alberta), T. Bryant Moodie (PIMS and U. Alberta), Bruce R. Sutherland (U. Alberta), Gordon E. Swaters (U. Alberta).

Plenary Speakers: Peter G. Baines (CSIRO), David Benney (MIT), Jerry L. Bona (U. Texas at Austin), Carlo Cercignani (Politecnico di Milano), Harindra Fernando (Arizona State), Roger Grimshaw (Loughborough), Emil J. Hopfinger (CNRS/UJF/INPG, France), Herbert Huppert (Cambridge), Dick S. Lindzen (MIT), Michael Longuet-Higgins (University of California, San Diego), Andrew Majda (Courant Institute), Michael McIntyre (Cambridge), James C. McWilliams (University of California, Los Angeles), Robert Miura (UBC), Alan Newell (University of Warwick), W. Richard Peltier (University of Toronto), S. George Philander (Princeton), Raymond Pierrehumbert (University of Chicago), Peter Rhines (University of Washington), Colin Rogers (University of New South Wales), P. L. Sachdev (Indian Institute of Science), Theodore G. Shepherd (University of Toronto), Melvin Stern (Florida State University), Steve A. Thorpe (University of Southampton), John A. Whitehead (Woods Hole Oceanographic Institute).

For information on registration, visit the webpage **waves3.math.ualberta.ca**.

Frontiers in Mathematical Physics Workshop on Particles Fields and Strings

PIMS at Simon Fraser University

July 16–27, 2001

This workshop is the sixth in the *Frontiers in Mathematical Physics Series.* As in previous years, it is jointly sponsored by PIMS and the **Asia Pacific Center for Theoretical Physics**. This workshop will aim to explore the consequences of recent breakthroughs in the rapidly developing areas of superstring theory and nonperturbative gauge field theory.

Superstring theory has been and will continue to be a tremendous source of new ideas in mathematics, particularly in geometry. In the past, it has had an impact on, and received crucial insights from mathematical fields as diverse as Kac-Moody algebras, algebraic geometry, random matrix theory, quantum cohomology and mirror symmetry, non-commutative geometry, topology of four manifolds, and K-theory.

It also has led to tremendously important developments in theoretical physics. It is the only theoretical framework which provides an apparently consistent quantum theory of gravity. It has given mathematical explanation to long-standing puzzles like the origin of the radiation emitted by black holes, which was discovered by Hawking thirty years ago and which remained enigmatic until very recent times. It also provides some highly speculative "theories of everything" which describe all matter and its interactions and which are candidates for descriptions of nature beyond presently accessible energy scales.

This activity has become particularly important in light of anticipated high energy physics experimental breakthroughs which should occur within this decade. It could well be known by the year 2003 whether nature at its most basic level exhibits supersymmetry, which is the basic premise behind the pursuit of superstring theory as a "theory of everything", or whether nature is more complicated and has some other structure.

One of the crucial issues in modelling the nature and interactions of elementary particles is the behavior of gauge field theories at strong coupling. There has recently been significant mathematical progress in this issue coming from superstring theory. There are a remarkable set of dualities between superstring theories in various background spacetimes and various kinds of gauge field theories. This promises powerful new computational tools, the beginnings of which are just emerging now and will take some time to gain their full impact. These developments in string theory and in quantum field theory will be the cornerstones of mathematical physics for some time to come.

Organizing Committee: K. S. Viswanathan, chair (Simon Fraser University), Taejin Lee (Kangwon University, Korea), Yuri M. Makeenko (Niels Bohr Institute, Copenhagen/ITEP, Moscow), John Ng (TRIUMF), Chaiho Rim (APCTP), Alexander Rutherford (PIMS), Gordon W. Semenoff (University of British Columbia), Howard Trottier (Simon Fraser University).

Preliminary List of Speakers:
Arkady Tseytlin (Ohio State University)
Amanda Peet (University of Toronto)
Rob Myers (McGill University)
Savdeep Sethi (University of Chicago)
Vijay Balasubramanian (Harvard)
Ludwig Faddeev (Steklov Institute of Mathematics)
Richard Szabo (Niels Bohr Institute)
Roman Jackiw (MIT)

To register for the workshop please see the webpage **www.pims.math.ca/fmp/2001**. The deadline for registration is **March 1, 2001**.

International Conference on SCIentific Computation And Differential Equations (SCICADE)

Coast Plaza Hotel, Vancouver, BC

July 29 – August 3, 2001

This PIMS-sponsored meeting is concerned with scientific computing involving the numerical solution of ordinary differential equations, partial differential equations, dynamical systems and differential algebraic equations. The numerical techniques that will be emphasized include optimization and optimal control, chemical and mechanical engineering, stochastic differential equations and level-set methods. There will also be an emphasis on software, molecular dynamics, computer graphics and robotics.

Local Organizing Committee: Uri Ascher (UBC), Bob Russell (SFU), Steve Ruuth (SFU), Manfred Trummer (SFU), Brian Wetton (UBC), Jim Varah (UBC).

Scientific Committee: Uri Ascher (UBC), Georg Bock (Heidelberg), Kevin Burrage (University of Queensland), Arieh Iserles (Cambridge), Linda Petzold (University of California, Santa Barbara), Bob Russell (SFU).

SCICADE is also sponsored by *The Natural Sciences and Engineering Research Council of Canada, The Society for Industrial and Applied Mathematics,* and *The Fields Institute for Research in Mathematical Sciences.*

For further information and online registration please see **www.pims.math.ca/scicade**.

PIMS Conference on Theoretical and Numerical Fluid Mechanics

Vancouver, BC

August 20–25, 2001

This meeting will bring together leading researchers from several areas of fluid dynamics to share recent developments, discuss their significance, and bring into focus new directions and problems. The topics to be considered will share a unifying theme, in that their theoretical starting points are in the mathematical theory of the Navier-Stokes equations. Specifically, we will focus on: Nonlinear Fluids, Turbulence, Viscous Compressible Flow, Classical Navier-Stokes Problems, and Numerical Methods for these various types of problems.

Organizers: Giovanni P. Galdi (Pittsburgh), John Heywood, chair (UBC), Rolf Rannacher (Heidelberg).

For further information please see the webpage **www.pims.math.ca/pde/fluid.html**.

Second Pacific Rim Conference on Mathematics

Institute of Mathematics, Academia Sinica, Taipei
January 4–8, 2001

This international conference focuses on the areas of Combinatorics, Computational Mathematics, Dynamical Systems, Integrable Systems, Mathematical Physics, and Nonlinear Partial Differential Equations. Plenary Speakers and special sessions with Invited Speakers in these areas will be featured. Contributed papers in any area of mathematics are welcome.

Plenary Speakers: I. Affleck (University of British Columbia), L. C. Evans (University of California, Berkeley), G. Fan (Academia Sinica-Beijing), J. Feldman (University of British Columbia), S.-S. Lin (National Chiao Tung University), L. Simon (Stanford University), S. Smale (City University of Hong Kong), G. Strang (Massachusetts Institute of Technology), K. Takasaki (Kyoto University), Y. Yamada (Kobe University), Y. Yi (Georgia Institute of Technology), X. Zhu (National Sun Yat-Sen University).

Organizers: S.-N. Chow (National University of Singapore), L. C. Evans (University of California, Berkeley), F. C. Liu, Chair (Academia Sinica, Taipei), M. Mimura (Hiroshima University), R. M. Miura (University of British Columbia), N. Trudinger (Australian National University), R. Wong (City University of Hong Kong).

Sponsors: Institute of Mathematics, Academia Sinica, Tapei; Liu Bie Ju Centre for Mathematical Sciences, City University of Hong Kong; Pacific Institute for the Mathematical Sciences; National University of Singapore; University of California at Berkeley; Australian National University; University of New South Wales.

The conference website is **www.sinica.edu.tw/math/html/conference/prcm2001**.

Second Canada-China 3 × 3 Congress

Vancouver, BC
August 20–25, 2001

The **3 × 3 Canada-China Initiative**, the **Centre de Recherches Mathématiques**, the **Fields Institute for the Mathematical Sciences**, the **Pacific Institute for the Mathematical Sciences** and the **MITACS Network of Centers of Excellence** are pleased to announce the Second Canada-China 3 × 3 Conference. This congress builds on the success of the *First Canada-China* 3 × 3 *Congress* held at Tsinghua University in August 1999 and is aimed at developing further the collaborative research effort between the 2 countries. The congress will revolve around various sessions focusing on: Number Theory, Mathematical Physics, PDE/Differential Geometry, Algebraic Geometry, Probability Theory, Signal Processing/Wavelet, Computational and Applied Analysis, Combinatorial Optimisation, Topology, Operator Theory/Functional Analysis, Mathematical Biology, Mathematical Statistics and Mathematical Finance.

Organizing Committee: N. Ghoussoub (PIMS Director and National Math. Coordinator for the 3 × 3 Canada-China Initiative), A. Gupta (MITACS Program Leader), B. Hart (Director, Fields Institute), J. Hurtubise (Director, CRM), K. C. Chang (Peking University), L. Peng (Peking University), D. Cai (Tsing Hua University), X.-W. Zhou (Nankai University), J.-X. Hong (Fudan University).

2001 Canada-China Initiative

This is aimed at developing further the collaborative research effort between the 2 countries. Funds have been set aside by **The 3 × 3 Canada-China Initiative,** the **Centre de Recherches Mathématiques,** the **Fields Institute for the Mathematical Sciences,** the **Pacific Institute for the Mathematical Sciences** and the **MITACS Network of Centers of Excellence** to support the local and travel expenses within Canada of selected Chinese mathematical scientists who are planning extended visits to Canadian Universities around the dates of the **Second Canada-China Congress.**

Applications for support of visiting Chinese mathematical scientists should be addressed to: Director, Pacific Institute for the Mathematical Sciences, 1933 West Mall, University of British Columbia, Vancouver, BC V6T 1Z2, Canada (Email: director@pims.math.ca).

University of Washington

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The Board of Directors of PIMS and the senior administration at the University of Washington are extremely supportive of this groundbreaking collaborative effort between Canada and the US and are fully committed to the development of the new PIMS that will include the University of Washington as a full participating member. They have contributed seed money to jumpstart the joint scientific effort during the first year of operations and are calling on the National Science Foundation (NSF) and the Natural Sciences and Engineering Research Council of Canada (NSERC) to assist in the development of this important bi-national scientific effort.

This partnership will build on already existing substantial joint efforts and links between the scientific communities of Western Canada and the US Pacific Northwest and it is expected to open up a whole new era of scientific collaborations between the mathematical communities of the two countries. It will be instrumental for the development of continental resources for the mathematical sciences like PIMS-K: The International Research Center in Kananaskis, as well as other more focused collaborative research centers.

The University of Washington will be joining the five founding partners of PIMS: The University of Alberta, The University of British Columbia, The University of Calgary, The University of Victoria and Simon Fraser University. In addition, the University of Northern British Columbia and the University of Lethbridge are affiliate members of PIMS.

Dr. Tatiana Toro will act as the first PIMS-UW site director.

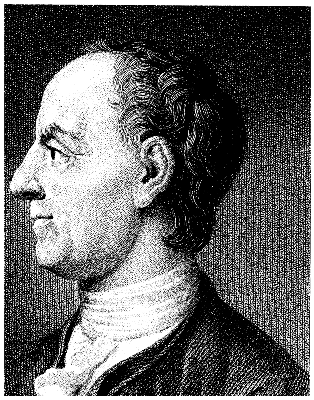
Mathematics and Literature

Continued from page 1.

I. Leonard Euler, Oulipo and Georges Perec

The story begins with a game, very much like what might be found in *Alice in Wonderland.* Leonhard Euler asked the following question in 1782:

Thirty-six officers are given, belonging to six regiments and holding six ranks (so that each combination of rank and regiment corresponds to just one officer). Can the officers be paraded in a 6×6 *array so that, in any line (row or column) of the array, each regiment and each rank occurs precisely once?* [1]



Leonard Euler

Smaller versions of this problem are fun to try with a deck of cards. From the deck of card remove the 1,2 and 3 of three suits and try to arrange them in a 3×3 square such that every row and column has each suit and each number just once (also try with the 1,2,3 and 4 of all suits and if you have a deck of cards for playing the French card game Tarot, then you can also try with the 1,2,3,4 and 5 of the five suits). Since he represented the regiments with Greek letters and the ranks with Latin letters these squares became known as Græco-Latin bi-squares.

Euler believed that the answer to his question was "no", and that no $n \times n$ Græco-Latin bi-square existed when $n \equiv 2 \bmod 4$. There is a simple construction for a $q \times q$ Græco-Latin bi-square where q is a prime power: Index the rows and columns by the elements of the Field of order q and the "officer" in cell (i, j) is in "regiment" $i + j$ and has "rank" $i + 2j$. MacNeish proved that if a solution exists for a $n \times n$ square and a $m \times m$ square that a solution can be constructed for a $nm \times nm$ square.[2] The prime power field construction and the 4×4 solution that you found with your deck of cards now confirm that a solution exists for all $n \times n$ Græco-Latin bi-squares when $n \not\equiv 2 \bmod 4$. In addition to this, in 1900, G. Tarry, a math teacher in a girl's school was able to prove that in fact Euler had been correct for the 6×6 square; it is not possible. He did this by dividing the problem into many cases and then given the checking of each case to his students as homework. This is possibly the first instance of distributed computing to solve a computationally hard problem, predating the Internet by 90 years!

For the first half of the century it looked as if all the evidence was supporting Euler's conjecture until 1960 when Bose, Shrikhande and Parker used Wilson's construction to prove that Græco-Latin bi-squares exist for all n except $n = 2$ and 6. In particular they exhibited a 10×10 Græco-Latin bi-square. [3]

00	47	18	76	29	93	85	34	62	51
86	11	57	28	70	39	94	45	02	63
95	80	22	67	38	71	49	56	13	04
59	96	81	33	07	48	72	60	24	15
73	69	90	82	44	17	58	01	35	26
68	74	09	91	83	55	27	12	46	30
37	08	75	19	92	84	66	23	50	41
14	25	36	40	51	62	03	77	88	99
21	32	43	54	65	06	10	89	97	78
42	53	64	05	16	20	31	98	79	87

A 10×10 Græco-Latin bi-square.

This was such an unexpected and exciting result that a colour format of the solution was on the cover of *Scientific American.*

At this same time, in France, the mathematician François Le Lionnais and the writer Raymond Queneau were founding the *Ouvroir de Littérature Potentielle (Oulipo),* or *Workshop for Potential Literature* which focused on the the question "what are the possibilities of incorporating mathematical structures in literary works?" and eventually included in it's scope all writing that was "subjected to severely restrictive methods".[4] Several years after the publication of the 10×10 square, three members, George Perec, Claude Berge and Jaques Roubaud, devised a method of applying Græco-Latin squares to literature. George Perec describes the method in simple terms:

Imagine a story 3 chapters long involving 3 characters named Jones, Smith, and Wolkowski. Supply the 3 individuals with 2 sets of attributes: first headgear — a cap (C), a bowler hat (H), and a beret (B); second, something handheld — a dog (D), a suitcase (S), and a bouquet of roses (R). Assume the problem to be that of telling a story in which these 6 items will be ascribed to

George Perec

[1] P. J. Cameron, *Combinatorics: Topics, Techniques, Algorithms,* Cambridge University Press, Cambridge, 1994.
[2] T. Beth, D. Jungnickel, and H. Lenz, *Design Theory,* Cambridge University Press, Cambridge, 1985.
[3] C. J. Colbourn and J. H. Dinitz, editors, *The CRC Handbook of Combinatorial Designs,* CRC Press, Boca Raton, 1996.
[4] Harry Mathews and Alastair Brotchie, editors, *Oulipo Compendium,* Atlas Press, 1998.

the 3 characters in turn without their ever having the same 2. The following formula:

	Jones	Smith	Wolkowski
chapter 1	CS	BR	HD
chapter 2	BD	HS	CR
chapter 3	HR	CD	BS

– which is nothing more than a very simple 3 × 3 *Græco-Latin bi-square – provides the solution.* [5]

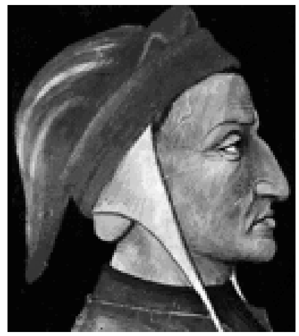
The plot of the story can simply be read off the table: In chapter one Jones is wearing a cap and holding a suitcase, and so on. In *Life, a User's Manual*, [6] Perec did the same thing using twenty-two 10 × 10 Græco-Latin bi-squares corresponding to such things as who to plagiarize in the chapter, fabric types, furniture, shapes, and even instructions to remove some of the plot details generated! Additionally the chapters are in the order of a re-entrant chess knights path on top of the square. He permuted the rows and columns of the 10 × 10 Græco-Latin bi-squares in a way which he did not reveal and so we are still in the dark about all the sets of attributes that he did use. It would be a wonderful graduate project in either mathematics or literature to do the detective work and reverse-engineering required to deduce the squares and attributes that he used! Perec is also well known for the longest Palindrome ever written, 5000 letters and for having written a novel entirely without the letter "e".

II. Literature Motivating Research Level Mathematical Questions: Samuel Beckett, Dante and Purgatory

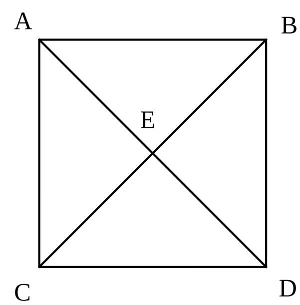
In the previous section, I gave one direction of influence: from math to literature by telling the story of Euler's 36 Officers problem, the history of its development and its impact on the creation of Georges Perec's Novel *Life, a User's Manual*. This gives a potent example of how math can be applied to literary creation at a deep and structural level. In this section, I want to provide you with an example of the influence proceeding in the other direction: literature motivating important and difficult mathematical questions.

Since we will be delving into religious themes I will start this story with an anecdote about mathematics and religion. Denis Diderot was one of the first famous and self-proclaimed atheists in the 18th century. In 1773, when he was visiting the court of Empress Catherine of Russia he was challenged to a debate on the existence of God by Leonhard Euler, who was at that time employed by the Russian court. Knowing that Diderot was not knowledgeable about mathematics and himself a religious man, Euler challenged "Sir, $(A + BN)/N = X$, therefore God exists. Refute that!" Diderot had no response.

One of the most influential religious works of all time is Dante's *Divine Trilogy*, documenting Virgil and Dante's travels through Hell, Purgatory and Paradise. This work has influenced many modern writers, most notable T. S. Elliot, Ezra Pound, James Joyce and Samuel Beckett. One aspect of the religious symbolism in the *Divine Trilogy* is the meaning of movement. Individuals move in very different ways depending on whether they are damned or saved. As John Freccero discusses, *the directions given by Dante on the purely literal level are entirely consistent and that in imitating the further traditional pattern of "descent" before "ascent" the pilgrim's left-ward journey spiraling clockwise down through Hell is, with respect to "absolute up" (the Southern Hemisphere), actually a movement upward and to the right and continues after the turn-around (conversion) at the earth's center, in the same absolute spiral direction to the right up the Mount of Purgatory.* [7]


Dante

The connection between Dante's symbolism of movement and Samuel Beckett has been made in regards to his late play *Quad*. [8] In *Quad* there are four actors, 1,2,3 and 4. They traverse a square



and follow the following paths

actor 1	AC	CB	BA	AD	DB	BC	CD	DA
actor 2	BA	AD	DB	BC	CD	DA	AC	CB
actor 3	CD	DA	AC	CB	BA	AD	DB	BC
actor 4	DB	BC	CD	DA	AC	CB	BA	AD

The figures then follow the following schedule of who is on stage

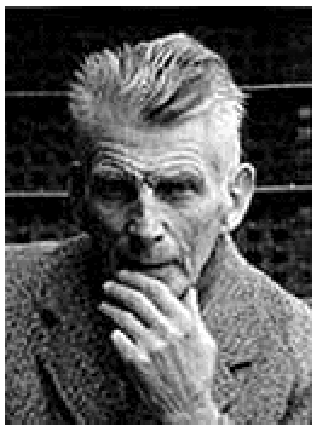
1	13	134	1342	342	42
2	21	214	2143	143	43
3	32	321	3214	214	14
4	43	432	4321	321	21

[5]Harray Mathews and Alastair Brotchie, editors, *Oulipo Compendium,* Atlas Press, 1998.
[6]Georges Perec, *Life, a User's Manual,* Harvill Press, London, 1986.
[7]John Freccero, *Dante's pilgrim in a gyre.*
[8]Samuel Beckett, *Collected Shorter Plays of Samuel Beckett*, Faber and Faber, London, 1984.

where the play then begins to repeat. Each actor traverses the square once in his prescribed pattern of sides and note that the actors leave the stage in the same order that they arrived and thus it is always the actor who has been on the longest who leaves, although any actor may enter.

The figures are always turning left, moving in an anti-clockwise direction. But they arrive at the sides in a clockwise order. Thus they can be seen to be moving both clockwise and counter-clockwise at the same time. This movement in both direction simultaneously was first pointed out as a possible connection to Dante by Antoni Libera. "Anti-clockwise and clockwise are the directions moved by the inhabitants of the inferno and purgatory respectively in Dante's Divine Comedy, to signify movement away from and towards God, or, to put in another way, away from or towards freedom." [9] Thus the characters in this play at once move towards and away from freedom.

This can be viewed in a more combinatorial way. We equate freedom with achieving all the combinations of a finite system, as Beckett does in the following humorous passages from his novel *Murphy*:



Samuel Beckett

He took the biscuits carefully out of the packet and laid them face upward on the grass, in order as he felt of edibility. They were the same as always, a Ginger, an Osborne, a Digestive, a Petit Beurre and one anonymous. He always ate the first-named last, because he liked it the best and the anonymous first, because he thought it very likely the least palatable. The order in which he ate the remaining three was indifferent to him and varied irregularly from day to day. On his knees now before the five it struck him for the first time that these prepossessions reduced to a paltry six the number of ways in which he could make this meal. But this was to violate the very essence of assortment, this was red permanganate on the Rima of variety. Even if he conquered his prejudice against the anonymous, still there would only be twenty-four ways in which the biscuits could be eaten. But were he to take the final step and overcome his infatuation with the ginger, then the assortment would spring to life before him, dancing the radiant measure of its total permutability, edible in a hundred and twenty ways! Overcome by these perspectives Murphy fell forward on his face in the grass, beside those biscuits of which it could be said as truly as of the stars, that one differed from another, but of which he could not partake in their fullness until he had learnt not to prefer any one to any other. [10]

We similarly equate the restrictiveness of the "first-in first-out" nature of the actors' schedule as the opposite of freedom then the characters of *Quad* move "away from and towards freedom" both combinatorially and geometrically.

This raises an interesting mathematical question: "When can all subsets of an n-set be arranged in a circular list such that each one appear just once, two adjacent subsets differ by the inclusion or removal of just one element and the only element that may be removed is the one which has been in the most previous consecutive subsets in the list." Such an object is a type of Gray-Code, a powerful mathematical representation of objects in a circular list such that consecutive members differ in only small ways. [11] Gary-Codes are extremely useful for Digital to Analogue conversion as well as efficient storage and generation of lists on computer. Usually they do not require the "first-in first-out" restriction, but such a restriction always implies that there is a two time costs saving for storing and generating the lists! We call such lists *Beckett-Gray codes* and their power for efficient storage makes them a potent new area of research.

Unfortunately it seems very difficult to find Beckett-Gray Codes. I have been able to prove that for sets of 3 and 4 actors it is impossible to have each combination appear exactly once (notice that Beckett repeats some combinations) but for sets of 5 and 6 actors such a schedule is possible.

$\emptyset$	0	0 1	1	1 2	1 2 0	2 0	2 0 3
0 3	3	3 1	3 1 0	3 1 0 4	1 0 4	1 0 4 2	0 4 2
4 2	2	2 3	2 3 4	3 4	3 4 1	4 1	4 1 2
4 1 2 3	1 2 3	1 2 3 0	1 2 3 0 4	2 3 0 4	3 0 4	0 4	4

A Beckett-Gray Code for a set of 5 actors.

The existence is unknown for all larger sets!

[9] Steeven Conner, *Samuel Beckett: Repetition, Theory and Text,* Basil Blackwell, Oxford, 1988.
[10] Samuel Beckett, *Murphy,* Picador, London, 1973.
[11] P. J. Cameron, *Combinatorics: Topics, Techniques, Algorithms,* Cambridge University Press, Cambridge, 1994.

Thematic Programme in Nonlinear Partial Differential Equations

July – August, 2001 at PIMS-UBC

This thematic programme will consist of five workshops concentrating on several interrelated topics originating in physics, chemistry, biology and material sciences as well as in geometry. The common feature of these topics is that they involve the interplay between nonlinear, geometric and dynamic components of partial differential equations. Our goal is to bring together some of the best researchers on these topics for an extended period of time at the Pacific Institute in Vancouver. There will be emphasis on: Viscosity methods in partial differential equations, Phase Transitions, Concentration Phenomena and Vortex Dynamics, Variational methods in partial differential equations as well as Geometric PDEs.

Programme Committee: Jingyi Chen (UBC), Michael Crandall (UC, Santa Barbera), Nassif Ghoussoub (PIMS & UBC), Maria J. Esteban (U. Paris-Dauphine), Changfeng Gui (UBC), Pierre-Louis Lions (U. Paris-Dauphine), Wei-Ming Ni (U. of Minnesota), Paul Rabinowitz (U. of Wisconsin), Panagiotis Souganidis (U. of Texas, Austin), Gang Tian (MIT).

Workshop on Viscosity Methods in Partial Differential Equations

July 2–10, 2001

This workshop will focus on the theory of viscosity solutions of differential equations and its applications. Viscosity solutions are the correct class of weak solutions of fully nonlinear -first and second- order, possibly degenerate partial differential equations. They provide the tools necessary for the analysis and further understanding of such equations.

Minicourse Lecturers

Craig Evans (UC, Berkeley)
R. Jensen (Loyola University, Chicago)
P. L. Lions (Université Paris-Dauphine)
P. Souganidis (U. of Texas, Austin)
A. Swiech (Georgia Tech)
T. Zariphopoulou (U. of Texas, Austin)

Confirmed Lecturers to Date

O. Alvarez (Université Rouen)
M. Arisawa (Tohoku U.)
M. Bardi (Padua)
E. N. Barron (Loyola, Chicago)
X. Cabré, (Barcelona)
M. Crandall (UCSB)
I. Capuzzo Dolcetta (Roma)
M. Falcone (Roma I)
H. Ishii (Tokyo)
P. Juutinen (Jyväskylä)
M. Katsoulakis (U. Mass.)
S. Koike (Saitama)
J. Manfredi (Pittsburgh)
A. Tourin (Toronto)
E. Rouy (Tours)

Workshop on Phase Transitions

July 11–18, 2001

This workshop will focus on problems in phase transition such as formation and evolution of grain boundaries in alloys, vortex states in superconducting materials, and related areas.

Minicourse Lecturers

Henri Berestycki (Pierre et Marie Curie)
David Kinderlehrer (Carnegie Mellon)

Confirmed Lecturers to Date

F. Alessio (SISSA)
N. Alikakos (Tennessee)
P. Bates (Brigham Young)
X. Chen (Pittsburgh)
Q. Du (Iowa)
M. Falcone (Roma I)
A. Farina (U. P. Jules Verne)
P. Fife (Utah)
F. Hamel (CNRS)
D. Hilhorst (Paris-Sud)
T. Ilmanen (ETH, Zürich)
Y. Li (Iowa)
C. S. Lin (N. Chung Cheng U.)
M. Mimura (Hiroshima, Japan)
P. Montecchiari (SISSA)
Y. Nishiura (Hokkaido, Japan)
P. Padilla (UNAM, Mexico)
Y. Qi (Hong Kong)
X. Ren (Utah)
J. Rubinstein (Technion, Israel)
R. Schaetzle (ETH, Zürich)
M. Schatzman (Lyons)
P. Sternberg (Indiana)
Y. Tonegawa (Keio, Japan)
L. Wang (Iowa)

Workshop on Concentration Phenomena and Vortex Dynamics

July 19–27, 2001

Concentration phenomena have been discovered in many different areas. Mathematically they appear in the forms such as vortices in Ginzburg-Landau equations, spike-layers in biological diffusions, etc. This workshop will focus on the up-to-date advances in these phenomena and the variational methods involved.

Minicourse Lecturers

Fang Hua Lin (Courant Institute)
Wei-Ming Ni (University of Minnesota)
Michael Struwe (ETH, Zürich)

Confirmed Lecturers to Date

P. Bauman (Purdue)
V. Benci (Pisa)
F. Bethuel (Paris XI)
X. Chen (Pittsburgh)
N. Dancer (Sydney)
P. Felmer (U. de Chile)
Z. Chao Han (Rutgers)
R. Jerrard (Illinois)
Y. Li (Rutgers)
Y. Lou (Ohio)
X. Pan (Singapore)
T. Riviere (ENS-Cachan)
I. Takagi (Tohoku, Japan)
G. Tarantello (Roma)
X. Wang (Hong Kong)
J. C. Wei (Hong Kong)
M. Winter (Stuttgart)
J. Xin (Arizona)
E. Yanagida (Tokyo, Japan)
S. Yotsutani (Ryokoku, Japan)
A. Aftalion (ENS, France)
S. Martinez (Minnesota)
J. McKenna (Connecticut)
Ninomiya (Ryukoku)
E. Noussair (Australia)
C. Sulem (Toronto)
M. Ward (UBC)
Y. S. Choi (Connecticut)

Workshop on Variational Methods

July 30 – August 7, 2001

This session will deal with modern variational methods which have been at the core of mathematics for a long time, yet still experiencing major development: Various infinite dimensional extensions of Morse theory, new "gluing" techniques and useful duality methods. Variational methods have had enormous new applications in the study of problems in phase transition, Hamitonian systems, pattern formation, fluid dynamics, Riemannian geometry, and other areas.

Minicourse Lecturers

Yann Brenier (Ecole Normale Supérieure)
Maria Esteban (Paris-Dauphine - CEREMADE)
Eric Séré (Paris-Dauphine - CEREMADE)

Confirmed Lecturers to Date

T. Bartsch (Giessen)
V. Benci (Pisa)
P. Bernard (ENS, France)
U. Bessi (ENS, France)
S. Bolotin (Russia)
B. Buffoni (EPFL)
K. C. Chang (Peking)
I. Ekeland (France)
P. Felmer (Univ. de Chile)
G. Friesecke (Oxford)
N. Ghoussoub (PIMS)
C. Gui (UBC)
H. Hofer (New York)
L. Jeanjean (Franche-Comté)
C. Le Bris (CERMICS)
Y. Y. Li (Rutgers)
Y. Long (Nankai)
P. Majer (Parma)
R. McCann (Toronto)
P. Montecchiari (Trieste)
P. Rabinowitz (Wisconsin)
K. Tanaka (Waseda U.)
G. Tarantello (Roma)
S. Terracini (Milano)
Z. Q. Wang (Utah)
V. C. Zelati (Napoli)

Workshop on Geometric PDEs

August 8–17, 2001

This workshop will focus on PDE problems arising from geometry particularly in the study of Kahler-Einstein manifolds, minimal surfaces, scalar curvature, harmonic maps, and related areas.

Minicourse Lecturers

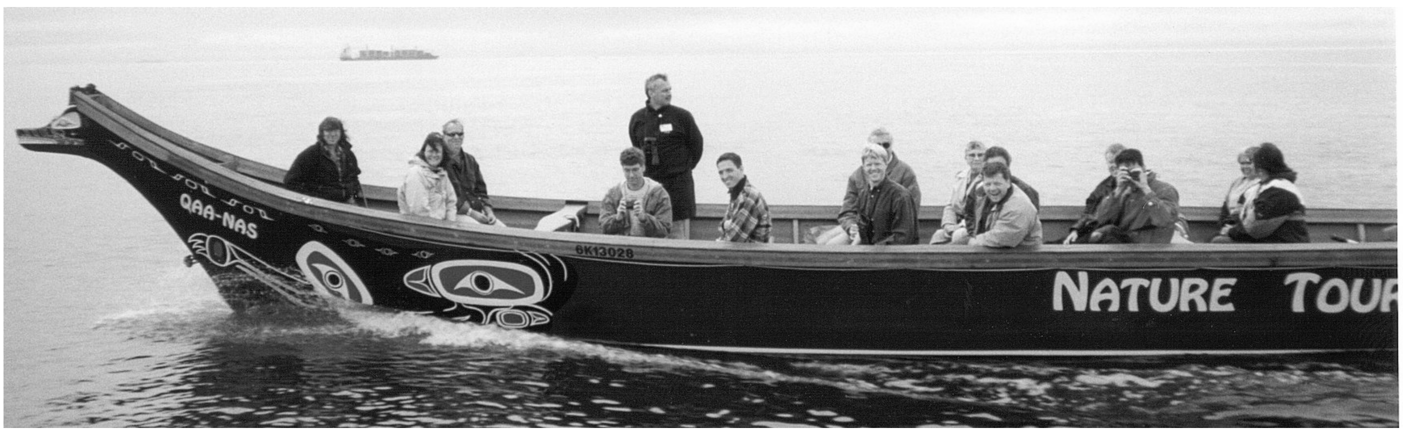
Rick Schoen (Stanford)
Cliff Taubes (Harvard) (tentative)
Gang Tian (MIT)

Confirmed Lecturers to Date

A. Chang (Princeton)
J. Cheeger (New York)
J.-Y. Chen (UBC)
X. Chen (Princeton)
G. Daskalopoulos (Brown)
J. F. Escobar (Cornell)
P. Guan (McMaster)
E. Hebey (Cergy)
H. Hofer (New York)
T. Ilmanen (ETH, Zürich)
N. Kapouleas (Brown)
J. Li Jiayu (Beijing)
P. Li, Peter (UC, Irvin)
C. S. Lin (Taiwan)
R. Mazzeo (Stanford)
B. Minicozzi (Johns Hopkins)
Y. G. Oh (KIAS, Korea)
D. Phong (Columbia)
D. Pollack (U. Washington)
J. Wang (Minnesota)
M. Wang (McMaster)
R. Wentworth (UC, Irvine)
Y. Long (Nankai)
G. Tarantello (Roma)
Z. Q. Wang (Utah)

PIMS Thematic Workshops at UVic and SFU Conclude Fields-PIMS Thematic Year on Graph Theory and Combinatorial Optimization

This past summer, PIMS hosted four workshops at UVic and SFU as part of the Fields-PIMS Thematic Year on Graph Theory and Combinatroial Optimization. The first workshop on **Dynamic Graph Problems** from June 4–10 at PIMS-UVic was organized by Valerie King (UVic) and Monika Henzinger (Google Inc.). It included talks by Bob Tarjan (Princeton): *Parametric and Kinetic Heaps,* Stephen Alstrup (IT University of Copenhagen): *Trees* and *Improved Algorithms for Finding Level Ancestors in Dynamic Trees,* Faith Fich (University of Toronto): *Lower Bounds for Dynamic Graph Problems,* David Eppstein (Univ. of California, Irvine): *Computational Geometry,* Leo Guibas (Stanford University): *Kinetic Data Structures,* Pino Italiano (Univ. degli Studi di Roma): *Fully Dynamic Transitive Closure: Breaking Through the* $O(n^2)$ *barrier,* Roded Sharan (Tel Aviv University): *A Fully Dynamic Algorithm for Proper Interval Graph Recognition,* and Mikkel Thorup (AT & T Research): *2-Edge and Biconnectivity (Including Applications in Matching Theory)*, *Tree Packing and General Dynamic Edge Connectivity* and *Applications to the Internet.* Slides for some of these talks are available from the web page **www.pims.math.ca/graph2000/dynamic**.

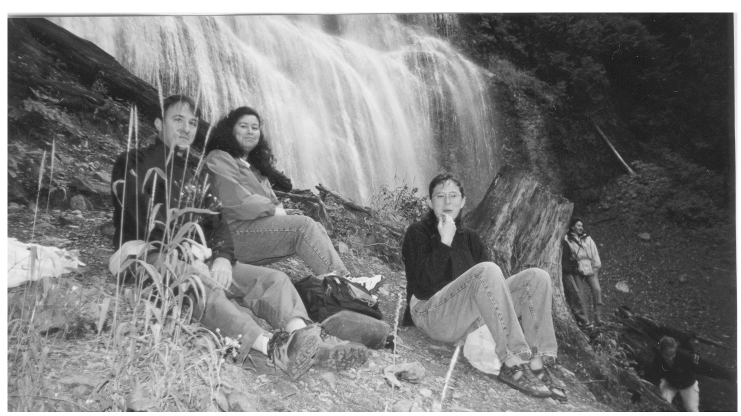


Participants in the **PIMS Workshop on Dynamic Graph Problems** head to sea.

The next workshop in the programme was on **Graph Decompositions.** It was held in the newly inaugurated PIMS facility at SFU and organized by Brian Alspach (University of Regina), Reinhard Diestel (Universität Hamburg), Herbert Fleischner (Austrian Academy of Science), Ron Gould (Emory University) and Chris Rodger (Auburn University). This workshop focussed on the cycle double cover conjecture, cycle decompositions, Gyarfas-Lehel conjecture, isomorphic factorizations, ascending subgraph decomposition, algorithmic aspects of edge decompositions, Hamilton decompositions, and orthogonal factorizations. The invited speakers at the workshop were H. D. Gronau (Universität Rostock), R. Gould (Emory University), C. Rodger (Auburn University), D. Bryant (University of Queensland), M. Šajna (University of Ljubljana), H. Fleischner (Austrian Academy of Sciences), E. Dobson (Mississippi State University), M. Ellingham (Vanderbilt University), and J. Liu (Eastern Michigan University).

The **Workshop on Flows, Cycles, and Orientations**, held from July 3–14 at PIMS-SFU, was organized by Luis Goddyn (SFU). About 40 researchers from around the world attended the workshop, which consisted of lectures by invited speakers interspersed with working discussion sessions. The invited talks were Matt DeVos (Princeton): *I. Antiflows* and *II. Flow Choosability,* Bertrand Guenin (Univ. of Waterloo): *Even Cycle Matroids,* Petr Hlineny (Fields Institute): *Crossing Numbers,* Kathie Cameron (Wilfred Laurier): *Parity of Nodes,* Winfred Hochstäettler (Köln): *Dirac condition for Matroids,* Mohamed Kobeissi (Univ. J. Fourier): *Cycles in Hypercubes,* Sean McGuinness (Univ. of Umeå): *CDC for oddness four,* Deryk Osthus (Humboldt

Please see ***Graph Theory,*** *page 15.*



Enrique Garcia (U. of Ohio), Laura Chavez (SFU), and Cindy Loten (SFU), graduate student participants in the **Workshop on Flows Cycles and Orientations,** relax on an outing to Bridal Veil Falls.

Graph Theory

Continued from page 14.

Univ.): *Thomassen's conjecture,* Riste Skrekovski (Univ. of Ljubljana): *Nowhere Zero Flows,* Miki Tarsi (Tel-Aviv University): *Cycles and Flows,* Dirk Vertigan (Lousisiana State Univ.): *Matroids,* Doug West (Univ. of Illinois): *Alon-Tarsi on Hypergraphs,* C.-Q. Zhang (W. Virginia Univ.): *Flows and Covers,* and Xuding Zhu (Nat. Sun Yat-sen Univ.): *Range of Flow Numbers.*

Jack Edmonds and Adrian Bondy discuss with participants in the **Workshop on Colourings and Homomorphisms**.

The **Workshop on Colourings and Homomorphisms** was held from July 17–28 at PIMS-SFU. Organized by Pavol Hell (SFU), Jing Huang (UVic), Rick Brewster (Capilano College) and Gena Hahn (Montreal), it attracted over 70 participants. Among the principal speakers were Michael Albertson (Smith College): *Extending graph colorings,* Noga Alon (Tel Aviv Univ.): *Acyclic coloring, strong coloring, list coloring and graph embedding,* Adrian Bondy (U. Claude Bernard): *Colourings and orientations of graphs,* Graham Brightwell (London Sch. of Econ.): *Dismantlability,* Karen Collins (Wesleyan): *Applications of the No-homomorphism lemma,* Jerrold Griggs (U. South Carolina): *Channel Assigments with Distance Conditions,* Joan Hutchinson (Macalester College): *A 3-color theorem for some graph evenly embedded on orientable surfaces,* Tommy Jensen (U. of Hamburg): *25 Pretty colouring problems,* Bojan Mohar (U. of Ljubljana): *Some topological methods in graph coloring theory,* Jarik Nesetrild (Charles U., Prague): *Extension properties and universality of the coloring poset,* Andre Raspaud (U. Bordeaux I): *Homomorphisms and Oriented Coloring,* Bruce Reed (CNRS, U. Paris VI): *Graph colouring via the probabilistic method,* Norbert Sauer (U. of Calgary): *The homomorphism lattice of graphs,* Claude Tardif (U. of Regina): *Cones over a graph,* Peter Winkler (Bell Labs): *Random homomorphisms,* and Xuding Zhu (Nat. Sun Yat-sen U., Taiwan): *Circular perfect graphs.*

Many of the lectures in the **Workshop on Flows, Cycles, and Orientations** and the **Workshop on Colourings and Homomorphisms** were taped. We are in the process of making audio files and in some cases video files available over the internet, along with scans of the speaker's slides. The lectures will appear on the webpage **www.pims.math.ca/video**.

Frontiers in Mathematical Physics Workshop on String Cosmology

The **Frontiers in Mathematical Physics Workshop on String Cosmology** was held from July 24 – August 4 at PIMS-UBC. It was organized by Robert Brandenberger (Brown Univ.), Chaiho Rim (APCTP), Alexander Rutherford (PIMS), Bill Unruh (UBC) and Ariel Zhitnitsky (UBC). The workshop was jointly sponsored by PIMS, the Asia Pacific Center for Theoretical Physics (APCTP) and the Canadian Institute for Advanced Research (CIAR).

The workshop focused primarily on exploring applications of string theory and nonperturbative gauge field theory to the cosmology of the early universe. The schedule of the workshop consisted of two formal lectures per day, with many lively discussions between the lectures and often well into the night. Participants were provided with office and computer facilities, which facilitated a productive working environment at the workshop.

We were fortunate to have many of the leading scientists in the field speak at the workshop. Among the speakers were Brian Greene (Columbia) who gave a survey of the modern developments in string theory, Paul Steinhardt (Princeton) who spoke on *Questions for String Cosmology from the Perspective of Cosmology,* Herman Verlinde (Princeton) who spoke on *M-theory and Cosmology* and *Holographic RG Flow and the Cosmological Constant,* Burt Ovrut (Pennsylvania) who spoke on *Branes from String Theory* and *Horava-Witten Cosmology,* and Gabriele Veneziano (CERN) who spoke on *Progress in Pre-Big-Bang Cosmology.*

As became clear in the discussions, string theory provides the best framework for developing a theory of the early Universe which can resolve the conceptual problems which the current models of cosmology face. In turn, cosmology may provide experimental/observational confirmation of string theory. Thus, string cosmology, although still in its infancy, is emerging as one of the most interesting and challenging areas of research in physics.

The workshop was heavily over subscribed, with many more applying to attend than we were able to admit. We had 60 participants this year—the maximum number of people that could be accommodated at the PIMS facilities at UBC.

Please see ***Frontiers in Math Physics,*** *page 16.*

Report on Victoria Computational Cosmology Conference

Contributed by Arif Babul, Dept. of Physics, UVic

Held at the University of Victoria from August 21–25, this highly successful 5-day conference known as VC3, brought together some of world's leading computational, theoretical and observational cosmologists — both established, pre-eminent figures as well as young rising stars — to

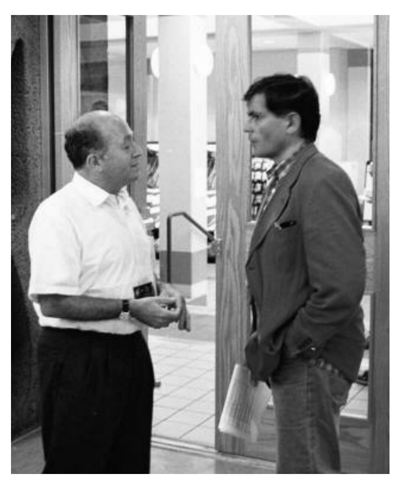
(a) discuss the latest progress in art and science of large-scale numerical simulations of galaxy systems,
(b) assess critically the insight into the formation and evolution of galaxy structures gained through these large numerical experiments,
(c) contrast the state-of-the-art numerical results against relevant, recent observational evidence,
(d) chart the way forward on the computational, algorithmic and scientific fronts.

Originally, the organizers (Arif Babul and Julio Navarro of the University of Victoria and Hugh Couchman of McMaster University) aimed to bring together approximately 70 participants of which 25 were invited speakers. However, due to the range of topics to be discussed, the stature of the invited speakers, and the careful juxtapositioning of computational (theoretical) and observational results offering a potential for lively jostling between the two resulted in the conference gaining the reputation as "the cosmology conference of 2000". The conference attracted over 150 participants and by the end of the week, the conference was drawing rave reviews from the participants; many offered that "they had actually learnt something new each day", a rare and lofty praise.

Invited speakers Rosemary Wyse (JHU) and Leo Blitz (Berkeley) discuss the morning's presentations over coffee with colleagues.

The conference also served as a backdrop for the first meeting of the governing council of the **Canadian Computational Cosmology Collaboration (C4)** to set the priorities for the first year of operations. **C4** draws together the leading numerical cosmologists from across Canada in an effort to determine a computational strategy for carrying numerical study of galaxy formation in unprecedented detail. This effort is undertaken in partnership with three leading numerical cosmology groups in the world: the N-body shop at the University of Washington led by T. Quinn, the University of Durham group led by C. S. Frenk and the Max Planck Institut for Astrophysik group led by S. D. M. White). The venture will require innovation in numerical methods, computational algorithms, in the development and implementation of efficient data structures, and of course, in modelling of the highly non-linear, strongly coupled, physical processes that govern the behaviour of gas, stars and dark matter. The collaboration recently received four year funding by NSERC and I credit the prior support from PIMS for the computational cosmology program at University of Victoria in the form of postdoctoral fellowships as one of the crucial elements underlying the funding of the C4 by NSERC. The primary node of the Canadian Computational Cosmology Collaboration is hosted by University of Victoria

Finally, the conference week was capped by a public lecture — sponsored by the President of University of Victoria — titled *The Evolution of Structure in the Universe* given by Prof. Jeremiah P. Ostriker, the Provost and the Charles A. Young Professor of Astronomy at Princeton University. The public lecture drew a crowd in excess of 1000.



Prof. Jeremiah P. Ostriker (left) (Charles A. Young professor of astrophysics and provost of Princeton University) in intense discussions with Prof. George Efstathiou (University of Cambridge).

Frontiers in Math Physics

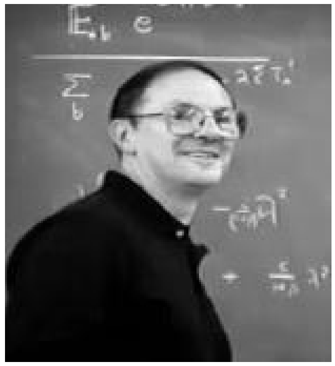
Continued from page 15.

The **Frontiers in Mathematical Physics Workshops,** which have been co-sponsored by PIMS and the APCTP in recent years, has grown steadily in international reputation. It has become one of the events that the international community looks forward to each year. It regularly attracts a number of participants from both inside and outside of Canada, ranging from graduate students in the mathematical sciences to renowned established scientists.

David Brydges: PIMS Distinguished Chair at UBC for 2000

Prof. David Brydges visited PIMS-UBC from Sept. 13 to Oct. 13 as the holder of the first PIMD Distinguished Chair at UBC. Prof. Brydges is the Commonwealth Professor at the University of Virginia. He has made numerous significant contributions to mathematical physics in the areas of quantum field theory and statistical mechanics.

During his visit he delivered four lectures about his recent work on applying rigorous renormalization group methods to the four-dimensional self-avoiding walk problem. The motivating problem was to determine the end-to-end distance of a very long self-avoiding walk on a four-dimensional cubic lattice as a function of the number of steps, n. It is conjectured that the end-to-end distance is a constant times $n^{\frac{1}{2}} \log^{\frac{1}{8}} n$. In the talks, this conjecture was used as pedagogical device to relate some of the standard machinery used in theoretical physics to ideas that are familiar and attractive to mathematicians. The main result in the lectures was a theorem proving the above conjecture on a simplified version of the problem called the "Hierarchical Lattice."



David Brydges

In the first lecture, *Self Avoiding Walk and Differential Forms*, Prof. Brydges reviewed the continuous time simple random walk on a finite lattice. He demonstrated how the self-avoiding walk problem can in principle be solved an extension of "Laplace's Method" that has been developed by physicists. The second lecture, *Mehler's Formula and the Renormalization Group,* introduced an improved method for evaluating the integrals introduced in lecture one using a generalization of "Mehler's Formula." This generalization is known as the "Renomalization Group" in the mathematical physics and theoretical physics literature. The third lecture, *Hierarchical Lattices and the Renormalization Group Revisited,* introduced an approximation of the original lattice problem called the "Hierarchical Lattice." The main advantage of the Hierarchical Lattice approximation is that implementation of the Renormalization Group method becomes much simpler. The log corrections in the four-dimensional end-to-end distance formula was also explained in the context of the Hierarchical Approximation. The final lecture, *Analysis with the Renormalization Group and Outlook,* investigated how the remainder after perturbation theory can be controlled for hierarchical lattices. What is known beyond the hierarchical approximation was also discussed.

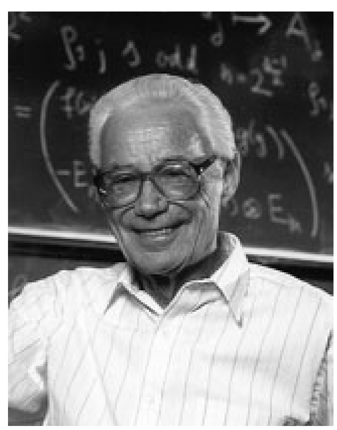
All four of Prof. Brydges' lectures are available in streaming video format from **www.pims.math.ca/video**. Lecture notes for his talks are currently in preparation.

Beno Eckmann Lectures at PIMS-UBC and PIMS-UC

PIMS was pleased to have Prof. Beno Eckmann (ETH, Zürich) pay a return visit to the institute after giving a PIMS Distinguished Lecture at PIMS-UBC in 1998. This time he gave two lectures at PIMS-UBC on Sept. 13 and Sept. 14 and afterwards delivered a PIMS Distinguished Lecture at the University of Calgary on Sept. 21.

Throughout his long and distinguished career, Prof. Eckmann has been at the forefront of the development of group cohomology and many other aspects of algebraic topology. In 1964, he founded the Forchungsinstitut für Mathematik at ETH, Zürich, and was its director for the following 20 years. He was also secretary of the International Mathematical union from 1956 to 1961 and Honourary President of the 1994 International Congress of Mathematicians in Zürich.

Prof. Eckmann's first talk at PIMS-UBC, entitled *The Euler Characteristic — Some Variations and Ramifications,* gave a survey of some developments around the classical Euler characteristic of a finite cell complex, including the Euler-Poincare and Atiyah formula, with application to groups, to four-manifolds and complex surfaces, and to negatively curved Riemannian manifolds. His second talk at PIMS-UBC was on *Projections, Group Algebras, and Geometry of Groups.*



Beno Eckmann

Prof. Eckmann's lecture at PIMS-UC, *Idempotents in Group Algebras, Traces, and Geometry of Groups,* examined the "Idempotent Conjecture of Group Algebras." Specifically, an idempotent α in a ring R is an element satisfying $\alpha^2 = \alpha$. If R has no zero-divisors, then $\alpha = 0$ or $\alpha = 1$. The "Idempotent Conjecture of Group Algebras" states that the same should be true if R is the group algebra CG of a torsion-free group G. The lecture examined various aspects of this conjecture, including some classes of groups (mainly appearing in geometry or topology) for which it has been proven.

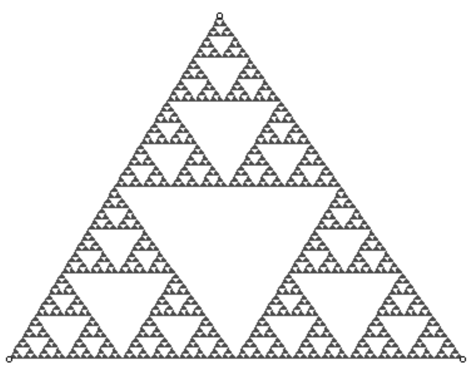
All three of Prof. Eckmann's lectures were videotaped and are available in streaming video format from **www.pims.math.ca/video**.

Constructing Fractals in Geometer's SketchPad™

Contributed by Michael P. Lamoureux, PIMS Deputy Director and University of Calgary Site Director

The new *Western Canada Protocol for Mathematics* requires high school students to be familiar with fractals, which are a type of geometrical object with self-similarity and recursive properties. Many school teachers and their students already use software tools to demonstrate and explore geometric concepts on the computer. In this article, we describe how to teach students to easily build fractals using the familiar Geometer's SketchPad™ software.

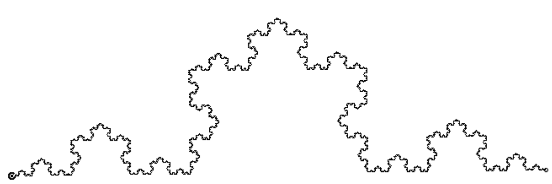
A fractal is a geometric shape the has some basic property of self-symmetry to it: roughly speaking, parts of the shape should look like small copies of the whole. It is a strange notion when you first hear of it, but when you see a few examples, the concept becomes clear. For example, below we show the well-known *Sierpinski gasket,* a very beautiful example of a simple fractal.



Sierpinski Gasket

You can quickly see large triangles in the shape, with repetitions of smaller triangles inside. Indeed, it is not hard to notice the top half of the whole gasket is an exact copy of the whole thing, at one-half the size. Indeed, the gasket is repeated three times in itself, once at each corner, as three smaller copies of exactly one-half the size.

Another example, is something called the Koch curve. Here, the self-similarity may not be immediately obvious, but notice the basic shape of the whole curve as one large bump surrounded by two smaller bumps. This pattern is repeated throughout the curve, at various smaller sizes. It shouldn't take you long before you notice the whole curve is really four copies of itself, at exactly one-third the size.



Koch Curve

Elegant as these figures are, they can be a challenge to draw. The fractal properties make them well suited to construction on a computer, but students can quickly become mired in programming details if they try to build a computer program to create these forms. A solution is to use a computerized drawing package that has all the necessary commands to build up a fractal from scratch. Geometer's SketchPad™ is just such a package.

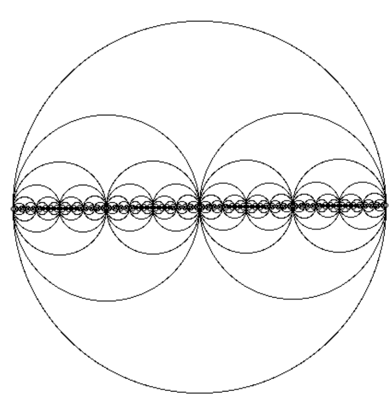
Geometer's SketchPad™ (or GSP) is a handy tool widely used in highschools and colleges for exercises in geometry and for explorations in geometrical constructions on the computer. This software is akin to a "word processor" for geometry, that includes basic objects such as points, lines, and circles, and provides a variety of point-and-click tools to manipulate these objects in geometrically useful ways. The software "knows" how to do many standard straight-edge and compass operations, transformations, and constructions.

What GSP also provides is a simple scripting tool, which allows a student to record a series of geometric constructions, then repeat them over and over again. This repetition, or iteration of basic commands, becomes the tool for building our self-similar fractals.

A key step in every fractal construction is some doubling (or tripling, or more) occurring in each recursion. This leads to exponential growth of the number of geometric elements on the screen — iterating too deeply may cause the computer to have difficulties. It also leads to the interesting properties (visually and otherwise) of the fractal constructions. Once the fractal is built, it is an entertaining challenge to try to measure geometric properties of the resulting shape: length of perimeter, area of the fractal, or number of lines/circles/points in the fractal. However, this is an exercise for another day.

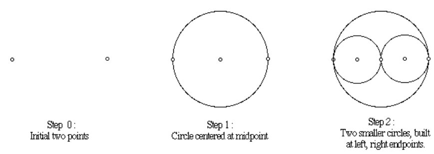
A Simple Fractal With Circles

Since GSP uses circles as one of its basic constructions, it is not surprising that one of the easiest fractals to construct is the following nest of circles.



A Circle-based Fractal

The basic iteration begins with a circle, in which two smaller circles are drawn. To achieve this geometrically, it is convenient to base the first circle on two points, and then base all smaller circles on some constructed pairs of points. The circles are drawn with center at the midpoint of a line segment connecting the pair of points. The fractal iteration is achieved by repeating this circle construction, first on the left endpoint and midpoint of the segment, then on the right endpoint and midpoint of the segment. The first few steps of the iteration are shown below.



First Iterations for Circle-based Fractal

To build the GSP script that accomplishes this, begin with a pair of points. The sequence of steps will be: join two points with a segment, then draw a circle with this segment for its diameter. Use the mid- and endpoints of the segment for the iterations.

We create a script first by opening a new `Sketch` in GSP, then opening a new `Script`. Each of these two commands are found under the `File` menu, and each will open its own window.

In the `Script` window, click on the `Record` button to begin transcribing the graphic operations that will be done in the `Sketch` window.

Now the constructions. Switching to the `Sketch` window, create two points on the screen using the `Point` tool. Draw a segment to connect the two points, either using the `Segment` tool, or using the command under the `Construct` menu. Under the `Construct` menu, create a midpoint for the segment. Now draw the first circle with the circle tool, with center at this new midpoint, and width set to span the segment. (The circle tool will click automatically to the right size as you drag the mouse towards the segment's endpoint.)

Now for the iterations. Shift-click to select an endpoint and the midpoint and on the `Script` window, click on the `Loop` button, to tell the script to iterate on these two points. Then, Shift-click to select the other endpoint and the midpoint, and again click to `Loop` to set another iteration.

Finally, to clean up the picture, click on the line segment and hide it with the `Hide Line` command on the `Display` menu. Then click on the midpoint and hide it as well.

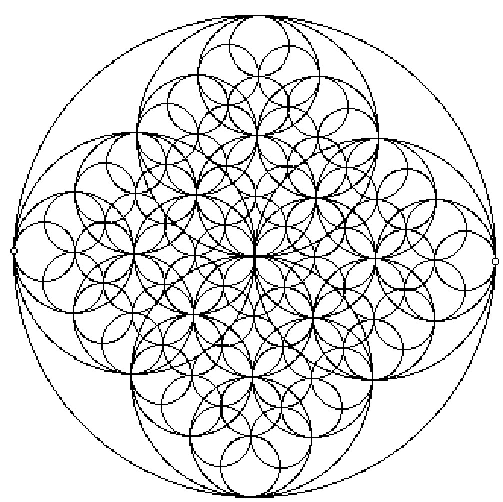
The script is done. Click on the `Stop` button in the `Script` menu, and the script is ready to run. First, clear the `Sketch` window, put on two new points, select them, then click on the `Play` button to start the script. The computer will ask you how many iterations you want to run; try just 1 iteration the first time, to see that the script works as expected. Try again with 5 or 10 iterations, to see the fractal form. The script is

```
Given:
 1. Point A
 2. Point B
Steps:
 1. Let [j] = Segment between Point A and Point B (hidden).
 2. Let [C] = Midpoint of Segment [j] (hidden).
 3. Let [c1] = Circle with center at Midpoint [C]
              passing through Point A.
 4. Recurse on [C] and A.
 5. Recurse of [C] and B.
```

If this is not working for you, look over the script above carefully. Notice it is only five lines long, and uses only two points as initial data. Your script should look something like the this one. Be sure to have two points (only) selected when you `Play` the script. Unfortunately, there seems to be no way to edit a script once you have recorded your actions. It is best to start from scratch if you are having problems.

Once the fractal is made, try dragging around the initial two points — the whole fractal will follow them around. This is part of the power and attraction of using GSP in fractal studies.

With this fractal mastered, it is a simple exercise to extend the construction to the four circle fractal shown below.

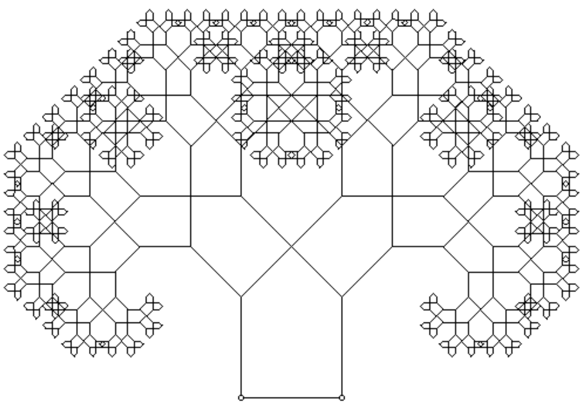


Four-Circles Fractal

This is a mathematician's rendering of a Pysynka, or Ukranian Easter egg. In the basic iteration, rather than two circles, you must draw four smaller circles inside the larger, at right angles to each other. The `Perpendicular Line` command comes in handy here — try it yourself.

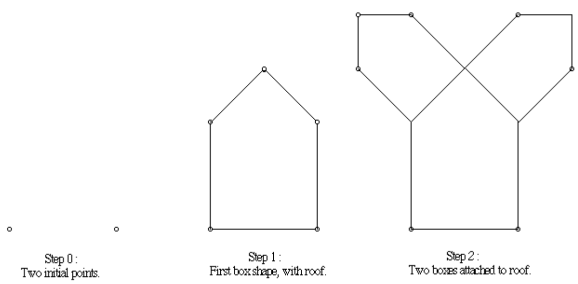
The Broccoli Fractal

Below we show a sample of the well-known broccoli fractal, so-called because of its similarity to a head of real broccoli. Notice the branching bushes of polygons — this is a useful fractal for demonstrating to students methods for computing areas, perimeters, and dimensions of iterated geometric figures.



Broccoli Fractal

The basic iterated figure is a house-shaped polygon, essentially a square with a right-angled roof perched on top. Two smaller copies of the polygon get attached to the short sides of the top, as shown in the figure below.



Basic Broccoli Iteration

Creating the script for this figure is somewhat more complicated, because making a square takes several steps in GSP, as does making triangles.

An abbreviated recipe for recording the script is as follows. Make two initial points and join them with a horizontal segment. Rotate the segment and its endpoint by 90 degrees around the other endpoint, to obtain one vertical side of the square. Reverse endpoints to get the other side of the square. Rotate the sides up by 135 degrees to get the right triangle on top, with extensions past the top vertex of the triangle.

With the top slanted lines at top selected, make an intersection point with the `Construct` menu. Hide the too-long segments in the triangle, and replace with segments of the proper size.

To set the iteration steps, select the two points on one of the the triangle's top legs (order of selection of the points is important), and press `Loop`. Then select the endpoints of the other leg, and press `Loop`. Finally, hide any extra points or lines that were created. The script is done.

Here is a sample script, which can be used as a guide in your own construction of the script.

```
Given:
 1. Point A
 2. Point B
Steps:
 1. Let [j] = Segment between Point A and Point B.
 2. Let [B'] = Image of Point B rotated 90 degrees about
              center Point A (hidden).
 3. Let [j'] = Image of Segment [j] rotated 90 degrees
              about center Point A.
 4. Let [A'] = Image of Point A rotated -90 degrees about
              center Point B (hidden).
 5. Let [j'] = Image of Segment [j] rotated -90 degrees
              about center Point B.
 6. Let [j''] = Image of Segment [j'] rotated -135 degrees
               about center Point [A'] (hidden).
 7. Let [j''] = Image of Segment [j'] rotated 135 degrees
               about center Point [B'] (hidden).
 8. Let [C] = Intersection of Segment [j''] and
             Segment [j''] (hidden).
 9. Let [k] = Segment between Point [C] and Point [B'].
10. Let [l] = Segment between Point [C] and Point [A'].
11. Recurse on [B'] and [C].
12. Recurse on [C] and [A'].
```

Going Further

There are many good books about fractals available in public libraries and at school. With this brief introduction to the iteration method in Geometer's Sketch Pad, any interested students should be able to make wonderful displays of the fractals they can find in books and on line. The Koch curve, and Sierpinski's gasket are always a good place to start.

References:

Benoit Mandelbrot, *The Fractal Geometry of Nature,* (by the man who gave us fractals).

www.keypress.com, the publisher's website for Geometer's SketchPad™.

www.math.ucalgary.ca/˜mikel, this author's website with some fractal resources.

www.math.umass.edu/˜mconnors/fractal/ fractal.html, a curriculum on fractals.

spanky.triumf.ca, the Spanky fractal database.

This article is a condensed version of an article that Michael Lamoureux wrote for Pi in the Sky*, the PIMS magazine on math education.* Pi in the Sky *is available online from* ***www.pims.math.ca/pi****.*

Hypatia's Street Theatre

Contributed by Klaus Hoechsmann,
PIMS Education Officer

This play will be presented at 8:00pm on December 10 at the Frederic Wood Theatre, on the UBC Campus as part of the programme of the CMS Winter Meeting in Vancouver. Written by Klaus Hoechsmann and Ted Galay, it is organized around three mathematical skits. The principal ambition of this play is to show mathematics on stage — not just *talking* about it, but actually *doing* it – in whatever form the public can take. To be honest, this "public" includes most professional mathematicians, because they, too, are easily confused when some one radically alters their frame of reference. The fact that most people cannot dance like Astaire, sing like Domingo, or write like Shakespeare, does not exclude them from these activities. Hypatia's imaginary skits invite us to approach mathematics in the same way.

The first and last skits deal with measuring the earth and the heavens in straightforward but increasingly subtle ways – ranging from common sense to a great leap of the imagination. The second skit demonstrates the importance of ideas, as opposed to canned knowledge and shows how false ideas wither in the light of reason.

Dramatis Personae

Historical: Cyril, Archbishop of Alexandria; Hierax, a religious fanatic; Hypatia, mathematician, astronomer, and philosopher; Orestes, Roman Prefect.

Fictional: Dario and Lydia, disciples of Hypatia; Samuel, junior colleague of Hypatia, Chrysostomos, poet and play-wright.

The Setting

Hypatia, the last of the Alexandrian scholars recorded by history, was brutally murdered by a fundamentalist mob in March of 415 AD. Her father Theon, a mathematician, philosopher, and director of the University (called the "Museum") of Alexandria, had seen to it that his talented daughter received the best available training in all conceivable disciplines from rhetoric through music to mathematics. Blessed with physical strength and beauty, she was by all accounts a model of rectitude and modesty. It is difficult to exaggerate the esteem in which she was held by contemporaries, whether in Athens, Rome, or Alexandria itself.

Though none of her written work has survived, we know that it included books on the mathematics of Diophantus and Apollonius, and probably one on Ptolemy's astronomical system. Even today, these topics would not be easily accessible to the occasional amateur: they indicate that mathematics must have been Hypatia's major focus. She also made a name for herself as one of the main proponents of Neo-Platonism. It is said that she often donned her "philosopher's cloak" and went among the crowds to philosophise with strangers. The present play takes the liberty of imagining this urge to communicate expanded to the more difficult subject of mathematics — through theatrical sketches — motivated by her love for the theatre which is mentioned in some of the writings about her.

Although a play like this cannot avoid distorting history — for instance, by the use of modern idiom and images — it will try to respect major facts and events, as far as these are known. What it cannot undertake, however, is to transplant the general outlook and mind-set of these ancient personages faithfully into the present. Fortunately, most of human psychology is fairly constant over time — though the actions it triggers depend very much on context. This is particularly important to remember in the case of Cyril, Archbishop of Alexandria. Most of Christendom sees in him a Saint — a champion of Church Unity — but some commentators on the Hypatia Affair (and later events like the "Lynching of Nestorius") paint his role in darker hues. It seems that in those early times sainthood was not always synonymous with saintliness.

Outside mathematics, the main historical reference for the play is Edward Gibbon's *Decline and Fall of the Roman Empire*. Around 400 AD, events in the Mediterranean world were tumultuous, to say the least, and it would be foolish to try and outline them here. The three forces which clash in the play are: the rising Church, the waning State, and the dying Hellenic Civilisation — represented by Cyril, Orestes, and Hypatia. Their conflict takes place against the background of a seething populace — an easy prey for upstart demagogues like Hierax.

The Plot

The plot unfolds in Cyril's third year as Bishop of Alexandria, a position which appears, at that time, to have been more important than the Sees of Rome or Constantinople. In the play he resolutely but uncomfortably follows the footsteps of his ruthless uncle Theophilus. His fate is to be a man of action, while his temperament would have been more suited to a life of quiet contemplation. In his drive to forge a unified Christian civilisation, he comes down hard on Jews and Christian heretics, and must still fight rearguard actions with Hellenic elements.

Orestes's dilemma is the power vacuum in which he must maintain an appearance of order. Theodosius I — personal friend to Theophilus — had been the last emperor who ruled the whole Roman Empire, east and west. In the time of the play, the Eastern Emperor was a boy, the Western one a weakling. Historically, Orestes and Cyril knew

*Please see **Hypatia,** page 22.*

Hypatia

Continued from page 17.

each other well enough that they could have been friends, had not Hypatia — according to some of her detractors — bewitched the former.

Hypatia's dilemma is caused by her enormous intellectual capacity, which keeps pulling her into the ivory tower, and her political instinct, which tells her that the fate of Civilisation will be decided on street and market place. She is further motivated by a sense of obligation toward her father Theon. We are still indebted to this father-and-daughter team for some exceptionally valuable scientific work, and it is acknowledged that the daughter on her own ventured into even loftier mathematical fields. What is fictional (but not impossible) is Theon's involvement in the education of both Orestes and Cyril and in the salvaging of treasures from the gutted Serapeum.

Hierax is portrayed as a religious fanatic. According to one chronicler, he was "a Christian possessing understanding and intelligence who used to mock the pagans but was a devoted adherent of the illustrious Father the patriarch, Cyril, and was obedient to his monitions." At any rate, he got himself beaten up after some heckling during a theatrical performance. In this play, he has his own larger agenda: rousing the populace to do God's will as defined by Hierax. Another shady historical figure — one Peter the Reader — is his invisible rival.

Tickets to the performance are complimentary to registrants at the CMS Winter Meeting. Otherwise, tickets will be available for a modest price. To read a copy of the script and for details on how to obtain tickets, please see **www.pims.math.ca/education/drama.html**.

Students have Fun at *Math Mania*

Cordova Bay Elementary School, Victoria
October 3, 2001

Contributed by Irina Gavrilova, PIMS-UVic

There is much more to math than numbers, formulas and algebraic equations. Students, teachers and parents of Cordova Bay Elementary School discovered the fun side of math during popular alternative math education event, "Math Mania", hosted by UVic Site of PIMS. Enthusiastic volunteers from faculty members and grad students provided a series of interactive displays, games, and art designed to show kids and teachers some fun ways to learn math and computer science in everyday devices and concepts. Hands-on activities included bubble-blowing, making geometric models from straws and paper, mathematical puzzles, paradoxes, and assortment of mind-bended games.

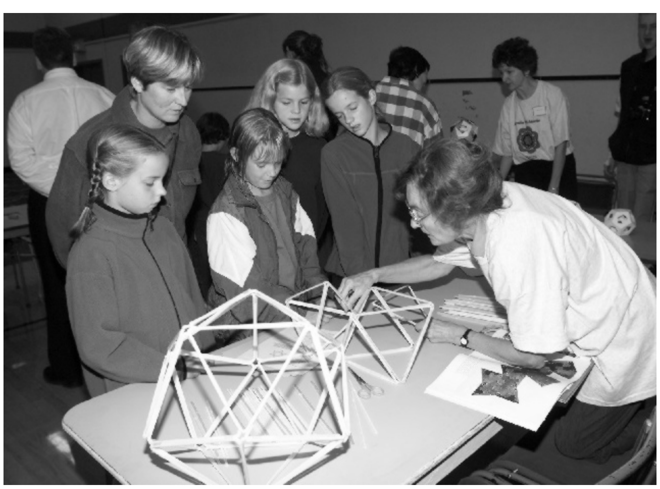


Photo courtesy of *Victoria Times Colonist.*

Pauline van den Driessche (PIMS-UVic) holds the attention of some Cordova Bay elementary students at *Math Mania.*

Quantum Computing

Continued from page 1.

IBM's Almaden Research Center by a team of researchers from IBM, Stanford University and the University of Calgary, under the leadership of Prof. Isaac Chuang of IBM.

Quantum computers were first proposed in the 1970's and 1980's by theorists such as the late Richard Feynmann of California Institute of Technology, Pasadena, Calif.; Paul Benioff of Argonne National Laboratory in Illinois; David Deutsch of Oxford U. in England., and Charles Bennett of IBM's T.J. Watson Research Center, Yorktown Heights, N.Y.. However, it initially appeared that they could never be made practical. This view changed in 1994, when Peter Shor of AT&T Research described a specific quantum algorithm for factoring large numbers exponentially faster than conventional computers — fast enough to break the security of many public-key cryptosystems. Peter Shor received the 1998 Nevanlinna Award for his groundbreaking contributions to quantum computing. A webpage providing links to resources on quantum computing is available at **www.cpsc.ucalgary.ca/Research/quantum/quantum_resources.html**.

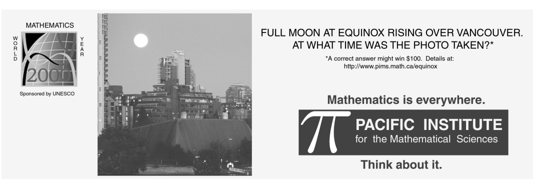
In 1998, Richard Cleve organized the *PIMS Workshop on Network and Computer Security.* The focus of this workshop was to examine ways in which recent results in mathematical cryptography could be used to make commonly used public-key cryptography methods more secure. Public-key cryptography is extensively used for secure communication over the internet. This workshop was unique in that it brought together academic researchers with software developers from industry who are developing cryptographic products.

Recent Winners in *Mathematics is Everywhere*

Contributed by Krisztina Vásárhelyi

The *Mathematics is Everywhere* poster campaign is going strong with five new posters appearing on buses, in schools and on the PIMS webpage during the summer and fall.

In June, a photo of the full moon at equinox rising over Vancouver was presented. As before, each poster was accompanied by relevant information on the PIMS webpage. For the Moon poster a few hints were given about the actual path of the sun around the earth (the ecliptic) and how this produces a discrepancy between the time kept on quartz watches and sundials. The challenge was to use the angle of the moon on the picture to predict the time that the photo was taken. Collin Tsui of Calgary came up with the closest estimate to the actual time of 18:35 PST. Collin is a 17 year old student at Henry Wise Wood High School in Calgary, Alberta. He has a wide range of interests which include aviation, military history, problem solving, computers and the internet and he is actively involved with his school and community as member of the air cadets, the student council, and the track and field team, among others. In his own words, Collin finds the PIMS poster campaign is "an excellent idea to promote mathematics, logic and creative thinking. [It] encourages students to delve beyond classroom mathematics into the much more difficult realm of practical problem solving, which isn't limited to one concept, or one equation".



Poster on the Buses in June

The question for July involved the pH of shampoo. The answer required the use of the logarithmic scale for pH. Other utilisations of the logarithmic scales were introduced such as the Richter scale, musical scales and it was revealed that even the naturally occurring spiral pattern of the nautilus shell is a logarithmic spiral. The winner of the July contest was Wayne Chevier from Burnaby, BC. Wayne is 28 years old and he is interested in languages, mathematics, chess and astronomy. He spotted the poster on the bus and says he quite enjoyed participating in the contest.

Poster on the Buses in July

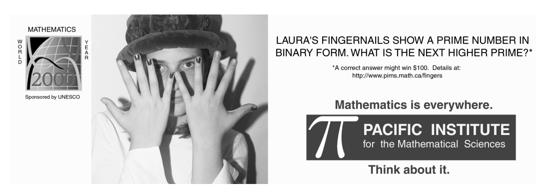
Perhaps an association with combinatorics is not an immediate one when one spots a picture of a colourful pizza on the bus, but in August PIMS set out to change all that. Klaus Hoechsmann writes on the website:

> *Counting things is surely one of the primordial sources of mathematics. Combinatorics has been called the art of "how to count without counting". It is fundamental to statistics and computer science, and has important applications in almost all fields of mathematics (especially number theory, topology, algebra, and discrete mathematics). Many of its problems are easy to state but hard to solve...*

In the case of the pizza, all possible combinations of 8 slices with 2 each of 4 different types of toppings were sought, with the added condition that no two of the same type can be adjacent. Judging from the wide variety of answers, this question was tougher than average but Albert Chan got the right answer. Albert is originally from Missasauga, Ontario and he is presently completing his PhD in electrical engineering at MIT. In his spare time he enjoys tennis and playing the acoustic guitar. His comment on the campaign: "It is not common to see mathematics promoted to the general public, so I think the contest is a nice way to do so".

Poster on the Buses in August

A young lady with fingernails painted black with some of them left unpainted appeared on the September poster. This unusual fashion statement also represents the binary code for a prime number. The task was to find the next prime. Prime numbers are very important now-days in cryptography and coding theory. Direct applications of these techniques can be found from banking machines to complex missile systems. Twenty-two year old Chad Simpson of Vancouver had the winning answer. Chad is a a 4th year student in electrical and computer engineering at UBC. At school he spends much of his time designing and building stereo equipment and electronics for the UBC Formula SAE racing team. In his free time he enjoys outdoor adventure, soaring, auto racing, drumming and photography.



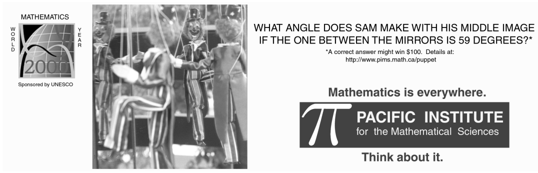
Poster on the Buses in September

Please see ***Math is Everywhere,*** *page 24.*

Math is Everywhere

Continued from page 19.

The current poster for October concerns linear mappings. There are three more posters in the planning and due to the success of the program a calendar of all twelve posters will be published on completion of the campaign in January 2001.



Poster on the Buses in October

Visit the *Mathematics is Everywhere* webpage
www.pims.math.ca/education/everywhere

Herbert S. Wilf: PIMS Distinguished Chair at University of Victoria for 2000

Professor Herbert S. Wilf, Thomas A. Scott Professor of Mathematics at the University of Pennsylvania, is well-known for his research in Combinatorics. He received the Leroy J. Steele Prize of the American Mathematical Society in 1998 (jointly with Doron Zeilberger) for Seminal Contributions to Research.

During his tenure as PIMS Distinguish Chair at the UNiversity of Victoria, he gave two series of lectures on Integer Partitions. The first provided a review of the classical theory of integer partitions and the second investigated recent developments in unified machinery for partition bijections.

A draft copy of Prof. Wilf's lecture notes is available from **www.pims.math.ca/science/2000/distchair/wilf**.

Herbert S. Wilf poses in front of his plane, in which he flew to Victoria with his wife Ruth Wilf. On the left is Brendan McKay (Australian National University).

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*This newsletter is available on the world wide web at **www.pims.math.ca/publications**.*