The Pacific Institute for the Mathematical Sciences Newsletter

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Contents

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Tom Brzustowski, NSERC President, at First MITACS Annual General Meeting

June 6, 2000

"Mathematics is the language of high technology. Indeed it is, but I think it is also becoming the eyes of science."

Please see ***Brzustowski,*** *page 4.*

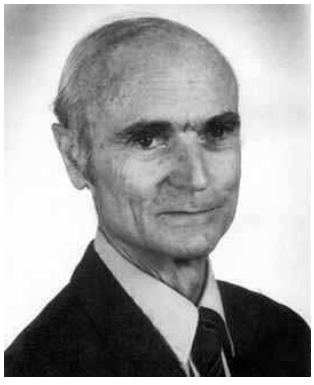
PIMS to Develop Oberwolfach-Style Center in Canadian Rockies

Plans are well underway for the establishment of a permanent facility in the province of Alberta to support an important component of our scientific program. The Board of directors of the Pacific Institute for the Mathematical Sciences has given the green light for the immediate development of the PIMS International Research Center at Kananaskis (PIMS-K). The purpose is to create a center for scientific interaction at the most advanced level of mathematical research and their applications. The focus is on providing a most fertile ground for incubating innovative ideas leading to future groundbreaking research projects. The proposed model is inspired by the highly successful program of the *Mathematisches Forschungsinstitut Oberwolfach* in Germany which had created and nurtured a place where world experts can look forward to meet, interact and create. This center will become a unique resource for all of North America providing a mathematical research environment that is distinct from other centers existing or foreseen on the continent. It is time for North America to develop its own Oberwolfach.

H. S. M. Coxeter on Escher at *Changing the Culture III*

The Third Annual Changing the Culture Conference, with the theme of *Visualising Mathematics*, organised and sponsored by PIMS, was held on Friday, April 28th, 2000 at the SFU Harbour Centre Campus.

The highlights of the program were two plenary lectures. In the morning, Walter Whiteley from the Mathematics Department of York University presented his innovative ideas under the title *Visual Work and the Mathematics Classroom.* In the afternoon, one of the world's best known geometers, H. S. M. Coxeter, shared his memories of his friendship with M.C. Escher and discussed mathematical concepts evident in examples of Escher's intricate creations.



H. S. M. Coxeter

Please see ***Changing the Culture,*** *page 2.*

Director's Notes

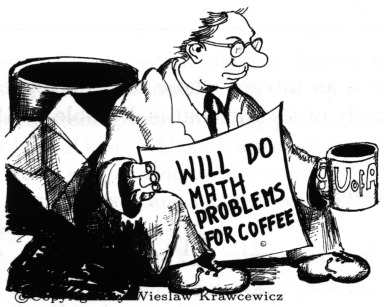
Nassif Ghoussoub, FRSC

It is so great to see the PIMS educational activities taking off after a 3-years period where the institute's main emphasis has been on its scientific programme and on industrial outreach. We have finally reached the stage where each one of the 3 designated PIMS mandates is receiving the full attention and the needed support of our organization. The readers of this newsletter will notice the wide variety and the sheer numbers of these activities. We are particularly proud with the originality and novelty of some of these projects, and especially those that wouldn't exist without PIMS. The institute is very grateful to Klaus Hoechsmann and Krisztina Vásárhelyi for their tremendous creative efforts in developing the *Mathematics is Everywhere Campaign* and to Wieslaw Krawcewicz and his colleagues for conceiving and leading the *Pi in the Sky* magazine.

We are well on our way to establish a North-American Oberwolfach in the Canadian Rockies. This major project is going to happen thanks to the tremendous support it has been receiving from the PIMS community of mathematical scientists, the senior administrators at the University of Calgary and the University of Alberta as well as from the Board of directors of PIMS. NSERC senior officials have also shown a keen interest in this groundbreaking initiative. So, what is PIMS-K?

PIMS-K is to be a center for scientific interaction: A place where promising ideas develop, where lines of thought converge even when coming from different backgrounds or different motivations, where people interested in similar problems would unite their potentials and join their efforts in order to work on common research projects. Unlike the typically large conferences held all over the world where the emphasis is on presenting ready research, the emphasis at PIMS-K will be on interaction in order to stimulate the creative process but also to improve the chances of *progress by coincidence*, i.e., when new ideas and projects sometimes emerge —often in a most unexpected way— from a meeting of the minds.

PIMS-K is to be a center for incubating new research projects: Leading representatives of particularly relevant research areas from all over the world will be invited to the Center offering them the opportunity to completely concentrate on their research activities. World experts are to present in-progress research results, especially new methodologies and ideas with a focus on initiating substantial and innovative future research projects.



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PIMS-K is to be a center for training: A place that plays an important role in the education of young mathematical scientists. The Pacific Institute will promote the participation of aspiring researchers, post-doctoral fellows as well as graduate students in the worskhops. The center will host summer schools in which young scientists are introduced to new and particularly attractive research areas. It will host training sessions for school and high school teachers as well as training camps to prepare young mathematicians for national and international mathematical competitions.

The PIMS community is very excited about the plans for the establishment of PIMS-K. We expect that the whole world community of mathematical scientists will be as enthusiastically supportive.

Continued from page 1.

Changing the Culture

Close to one hundred participants were welcomed at the conference, which was designed to bring together mathematicians, mathematics educators, students, and school teachers from all levels to work together in narrowing the gap between those who do enjoy mathematics and those who don't.

Conference participants were given the opportunity to attend two out of four workshops, each dealing with some aspect of teaching geometry. In a discussion led by Bill Casselman of UBC, high school geometry was re-examined in light of the Geometry Resource Package released by the BC Student Assessment and Program Evaluation Branch in September 1999. Malgorzata Dubiel of SFU, is one of Canada's leading exponents in constructing geometric models on the crucial hands-on level. Her workshop included pop-up fractals, origami, polyhedra, and more. The remaining two workshops introduced two new software packages. Cinderella is a constructive geometry program along the lines of Geometer's Sketchpad but with an enlarged and redesigned arsenal of tools. June Lester of the University of New Brunswick demonstrated this new tool. Rob Scharein of UBC introduced his *KnotPlot* program in the fourth workshop. *KnotPlot* may be dowloaded from the PIMS web site at **www.pims.math.ca/knotplot/download.html**.

During a panel discussion entitled *Role of Visualization in Teaching Mathematics* Peter Borwein (SFU), Sue Haberger (Centennial Secondary), Nancy Heckman (UBC), Susan Oesterle (Douglas College) and Walter Whiteley (York University) discussed their personal strategies to incorporate visualisation in teaching mathematical concepts in the classroom.

New MITACS Projects

In March 2000, two new projects were awarded funding from the MITACS NCE, with startup of research activities to begin in July. Both projects will be managed through the PIMS offices.

Pseudodifferential Operator Theory in Seismic Imaging

Leaders: Dr. M. Lamoureux (U. Calgary), Dr. G. Margrave (U. Calgary)
Members: R. Aggarwala (U. Calgary), W. Allegretto (U. Alberta), J. Bancroft (U. Calgary), L. Bentley (U. Calgary), P. Binding (U. Calgary), A. Calvert (SFU), R. Ferguson (Chevron), S. Gray (Veritas D.G.C.), C. Laflamme (U. Calgary), P. Lancaster (U. Calgary), L. Lines (U. Calgary) , E. Nyland (U. Alberta), M. Slawinski (U. Calgary), M. Sacchi (U. Alberta), J. Sniatycki (U. Calgary), D. R. Westbrook (U. Calgary)
Industrial Affiliates: Consortium for Research in Elastic Wave Exploration Seismology, including AEC, BP-Amoco, Chevron, Pan Canadian, Petro-Canada, Talisman, Veritas D.G.C., Imperial Oil, Shell and others.
Problem Statement: The theory of geoseismic imaging (migration) is built upon fundamental solutions to either the scalar or elastic wave equations for acoustic propagation within a solid. There are many imaging methods in use today and most are based upon, and limited by, mathematical techniques that have been in common use in physics since the early part of this century. Examples include Kirchhoff migration, based on Green's function theory, f-k migration, based on separation of variables, and finite difference methods. Despite the existence of a large body of literature in the mathematics community concerning the use of pseudodifferential operators with hyperbolic partial differential equations, there has been very little application of these techniques in geophysics. Work already completed at CREWES has shown that pseudodifferential operator methods are potentially superior to any other imaging technique.

This project is designed to develop a seismic imaging theory and numerical methods based on pseudodifferential operators and Fourier integral operators. It is expected that these methods will improve the accuracy, relative to existing techniques, of estimation of the earth's subsurface parameters. The potential benefits to the petroleum industry and to the Canadian economy from higher fidelity seismic images are substantial. Current petroleum reservoir recovery rates are around 40% of the oil-in-place. If such images lead to better reservoir and pore fluid definition, they could improve recovery rates by a few percent. Even such a small improvement is literally worth billions of dollars.

Goals of the research are to improve the theoretical foundation for existing acoustic one-way wavefield extrapolators, extend the theory to predict higher-order one-way extrapolators and two-way extrapolators in fully anisotropic and inhomogeneous elastic media. Techniques to develop stationary phase or other approximations to the oscillatory integrals and create efficient numerical approximations to the pseudodifferential operators based on the theoretical development will be undertaken. Numerical code developed from the theory will be tested in a variety of settings. For example, physical modelling data could be compared to the forward-modelled numerical data and could be migrated with the inverse code. Real seismic datasets from industry will also be used.

Mathematical Modelling in Pharmaceutical Development

Leader: Dr. J.A. Tuszynski (U. Alberta)

Members: Dr. G. de Vries (U. Alberta), Dr. G. A Dumont (UBC), Dr. M. Klobukowski (U. Alberta), Dr. B. MacLeod (UBC), Dr. J. Muldowney (U. Alberta), Dr. K. Rubenson (UBC), Dr. J. Samuel (U. Alberta), Dr. Y. Tam (U. Alberta), Dr. D. Wiens (U. Alberta), Dr. D. Bevan, Dr. D. Quastel, Dr. C. Ries, Dr. M. Sutter, Dr.M. Walker, Dr. J. Wright

Industrial Affiliates: Drs. Y.K. Tam and D. Ridgway (Kinetana), Dr. R.R. Koganty (Biomira, Inc.), Mr. Willaim Gough (Universal Dynamics Technologies), Dr. M. Huzmezant (M.I.H. Consulting Group), Dr. W. de Brouwer (Starlab, Belgium).

Other Affliates: Canadian-European Research Initiative on Nanostructure (Belgium), Drs. P.L. Christiansen and E. Mosekilde (Inst. of Math. Modelling, Danish Technical University), Dr. Y. Engelborghs (Biomolecular Dynamics, K. University of Leuven), Dr. M. Kimmel (Stats, Rice University) Jim Laukes (Psychology, U. Arizona), Dr. E. Unger (Molecular Biotechnology, Jena, Germany).

Problem Statement: In order to be useful as a drug, a chemical must possess two important characteristics: 1) it must exhibit sufficient binding to the target receptor, i.e. it must have efficacy at the site of action, and 2) sufficient quantities of the chemical must reach the site of action and remain there long enough for the desired therapeutic effect, i.e. it must have desirable pharmacokinetics. This requires the drug to be absorbed into the body, distributed to the site of action, and remain in the body long enough for its benefits to emerge.

In each of these areas, mathematical modelling has an important and underappreciated role to play. This project will study several interrelated problems in drug discovery and development, linked by a common theme of applying physical principles, mathematical modelling, computer-intensive simulations and statistical validation methods to problems of interest to our industrial affiliates and pushing the boundaries of the applied mathematical sciences. The various subprojects that will be developed by our group range from pharmacokinetics, the study of the absorption, distribution, metabolism, and excretion of drugs in the body to molecular modelling of the action of specific anti-cancer drugs.

The ultimate objective is to provide an integrated approach to the preclinical drug evaluation process with a molecular analysis of drug interactions with proteins and enzymes as the first element, followed by pharmacokinetic modelling performed at a statistical level. Thus the goal is to fully integrate mathematical modelling into the pharmaceutical development process - from potency at site of action to bioavailability and prediction of whole-body kinetics, eventually to population statistics of potency and toxicity. Finally, using the recent advances of process control analysis the UBC node intends to automate anaesthetic drug administration.

Speech of Tom Brzustowski, NSERC President, at the First MITACS Annual General Meeting, Toronto, June 6, 2000

Reprinted with the kind permission of T. Brzustowski

For once, I don't want to talk about research funding — I want to talk about research. I want to share with you some observations and thoughts about mathematics, and I ask you to accept them as the observations of a sympathetic non-mathematician whose perspective is undoubtedly limited.

I feel that I'm seeing the emergence of a new applied mathematics. From my experience as an engineer, the old applied mathematics went something like this: The behaviour of some particular form of matter under particular circumstances —call it a "phenomenon"—was described by a "law" expressed by an equation. The combination of such phenomena that was a useful representation or something real and interesting was described by a set of equations that had to be solved. It was assumed that issues such as the existence of a solution had already been settled by somebody else; the goal was to see the details.

The research involved solving the—generally transient and nonlinear—equations with initial and boundary conditions that reflected the reality of the situation being described. If solutions previously developed for other problems could be cobbled together to provide the needed solution, so much the better. The mathematics might not be new, but the practical result was.

But sometimes something entirely new was needed, with little intuition to provide guidance. To help develop some feeling for the expected solution, clever people developed linearizations, limiting cases, quasi-steady approximations, etc., and the occasional closed-form solution of some related problem. A result of this kind was sometimes important enough to be called somebody's laws on its own. But the challenge was to get the solution to the full problem, in whatever way worked.

In newer applied mathematics that I encountered in my own research, the difficulties had increased in two ways that seem to be fundamental; first, the laws describing the phenomena being described were incompletely known, even if the framework of equations in which they were imbedded was well established. Indeed such laws sometimes need to be formulated in a way that reflects the mathematical requirements of solving the governing equations more than the physics of the processes taking place. One example are the various laws of turbulence plugged into the Navier-Stokes equations that relate the long-time average values of various products of velocity fluctuations to the local mean velocity components. A closure condition for the whole set of equations often drives the formulation of the turbulent transport terms.

The second difficulty that I view as fundamental has to do with scale—many important problems involved interacting phenomena occurring on several scales, a feature that rules out the convenient use of similarity parameters.

The example that comes to my mind most readily has to do with the burning of gas blown out of what is known as a "flare stack"- a great big vertical pipe, for those outside of the oil and gas industry. The diameter of the stack provides one length scale and the mean velocity of the gas flowing out of provides one velocity scale. But there is always a wind blowing, and the wind speed provides another velocity scale. More than that, the average size of the turbulent gusts in the wind defines yet another length scale. So the bending over of the gas jet in the wind and the mixing of the gas with the flowing air is a problem with two length scales and two velocity scales. But flares are built to burn the escaping gas, and chemical reactions take place on yet a third scale-within a thin flame whose thickness is determined by the mean free path of molecules and the rate of the chemical reaction. That defines yet a third pair of scales, much smaller than either of the first two. And yet the momentum exchange, the mixing, and the combustion are all related. Such processes are now solved numerically, and the design of a useful grid is always a challenge.

Let me now generalize this: the new applied mathematics enables scientific prediction. I don't think there's anything very new in that statement, except for the fact that more people in more fields are now aware of it.

It seems to me that science engages in two very different activities. One is establishing facts, the other is making predictions.

Facts are not easily established in science. They emerge by agreement of the scientific community from a sequence of experiments in which a hypothesis is tested, errors analyzed, experimental design improved, and so on. Sometimes the design of the experiment is changed radically as new theories and new experimental methods become available, but the sequence continues. It seems to me that there is a largely similar process in mathematics, with the large difference that the correctness of a mathematical proof can be verified with the inherent uncertainty of experimental science.

Scientific prediction is something entirely different. It is the output of a model, a construct that incorporates the relevant facts, an appropriate mathematical structure deriving from some theoretical basis, and the necessary algorithms. It is calibrated for the situation of interest, and should be validated whenever the results of controlled experiments become available. The model receives measure-

ments and observations as input, and produces predictions of useful quantities that are expensive to measure or can't be measured at all.

Whether the output of the model is used to predict the stability of a building in an earthquake, or the population dynamics of an endangered fish species to determine appropriate fishing quotas, of the tax burden on the future workforce of the health care costs of the ancestors to guide tax policy, some form of applied mathematics is always at the heart of the process of making the prediction.

But there is more to the new applied mathematics that is different still, and I shall introduce it in a very different way that is not limited by my own experience.

I shall say a few words about creativity: My favourite definition of creativity is "seeing what others have not seen, and making it visible." Michelangelo saw David in the block of marble, Kekule dreamed about a serpent swallowing its tail and described the ring molecule of benzene, Einstein saw gravity as curved surfaces in space-time, and Jeans saw a phase space of twice 6×10^{23} dimensions in describing the motion of gas molecules in space.

That leads me to describe the new applied mathematics very boldly as the key to creativity in those fields of science where understanding is drowning in a flood of data- where new ways of seeing are required to break through the cognitive barriers to understanding in the face of the enormous amount of data produced by modern measurement techniques.

Bioinformatics is an obvious example, and one discussed the most. But think of the mathematics behind the explosively growing field of medical imaging. Think of the reams of data coming from satellites that observe the earth, think of the time series of stock prices, think of the millions of numbers produced from the computer models of the flow of air over aircraft wings, think of the spectra of millions of stars, and many, many other sources of vast amounts of data that need to be turned into information, and eventually knowledge.

The new applied mathematics helps scientists in all these fields see what the data mean. Sometimes the seeing is metaphorical, as in seeing new relationships- correlation's to start with, then causal links-e.g.: inferring the existence of planets around distant stars from the wobble in the stellar motion, but sometimes the seeing will be much more physical- as in maps of the water temperature field in the Pacific that produces El Nino, or as in the real-time view of the human brain responding to stimuli.

I think I heard this first from Peter Borwein: "Mathematics is the language of high technology." Indeed it is, but I think it is also becoming the eyes of science.

At the **First Canada-China Congress,** August 23–27, 1999, in Beijing, Dr. Tom Brzustowski, President of the Natural Sciences and Engineering Research Council of Canada (NSERC) is shown with the Canadian and Chinese delegations.

Report on the 3rd PIMS Graduate Industrial Math Modelling Camp

PIMS-SFU,
May 23–27, 2000

Contributed by Mary Catherine Kropinkski and Keith Promislow.

Over 40 graduate students from 17 different universities from across Canada and the United States participated in the **Third PIMS Graduate Industrial Mathematical Modelling Camp** (GIMMC). The five mentors hailed from major companies and universities around the world. GIMMC 2000 inaugurated the new PIMS-SFU and MITACS facilities, which proved ideally suited to the event. After the initial presentations by the mentors the students formed teams, each working on one of the five problems. Four days, and nights, of intensive effort culminated in the Saturday group presentations and GIMMC awards.

Don Schwendeman, a long-time organizer of the industrial working groups at Rensselaer Polytechnic Institute, presented a problem involving the activation of the catalytic bed in an automotive catylitic converter. As the engine exhaust passes over the bed, the catalyzed reactions release heat, which in turn increases the rate of reaction. The goal was to understand the transient profile of catalytic activity down the length of the bed.

Rachel Kuske, from the industrial math program in the math department of the University of Minnesota, lead a group studying effective control of a coupled CPU and RAID disk controller. The goal being to efficiently distribute read and write task to an array of sub-processors.

Brett Stevens, a PIMS-SFU post-Doc affiliated with IBM Watson, directed his team through a study of optimal packing of information in gray codes, including the shortest covering n-word.

Colin Please of the University of Southampton presided over his team studying the effect of an electric power station on thermal distributions in a river or estuary.

David Ross of Eastman Kodak, Rochester, New York, led the fifth group in studying the optimal design of a micro-electrical-mechanical systems (MEMS) actuator. MEMS are microscopic machines currently used to deliver ink in printers or, embedded in a patient, can painlessly administer regular doses of medication.

After the GIMMC 2000, the students continued on to the **4th PIMS Industrial Problem Solving Workshop** (IPSW) at the University of Alberta. It is hard to characterize GIMMC 2000 as anything other than a great success. Students and mentors worked enthusiastically the whole week, as reflected in the stellar presentations and writeups. Special praise must be reserved for the PIMS and MITACS staff at SFU, Sadika Jungic, Nadja Rence, and Nicole Fogale who demonstrated great poise and energy. Indeed it was certainly to the staff and students that one experienced mentor referred with the comment that GIMMC 2000 was far and away the best workshop of its kind in which they had ever participated.

Report on the 4th PIMS Problem Solving Workshop

University of Alberta,
May 29 – June 02, 2000

Contributed by Jack Macki.

More than 70 participants spend a full week working intensely on five problems posed by industrial companies from across North America. The fourth annual Industrial Problem Solving Workshop was hosted by the Department of Mathematical Sciences at the University of Alberta in Edmonton, May 29-June 2, 2000. Among the participants were 40 graduate students who had spent a week at a training camp hosted by Simon Fraser University. The students were truly representative of Canadian Universities. There were students from Memorial University, McGill, Concordia University, McMaster University, University of Guelph, York University, University of Toronto, University of Western Ontario, University of Manitoba, University of Saskatchewan, University of Regina, University of Alberta, University of Calgary, University of British Columbia, Simon Fraser University, University of Victoria, and from New York University in U. S. A. Participating faculty also spanned the country. The problems posed were:

From Michelin Tire: How do you find the vibration characteristics of each of the many layers of a tire when you can only determine the composite vibrations after the tire is made? One trick is to build many tires with the various layers rotated by specific amounts. What is the least amount of tires we need to construct? Michelin mathematician Bill Mawby came all the way from Michelin's research group in South Carolina to spend the week with the team. Would you believe prime numbers play a role? The team which worked on this one, ably led by mentor Professor Michael Lamoureux of the University of Calgary, made significant progress in solving this problem. Bill said that he could see direct savings of up to $500,000 a year from their work.

From Stern-Stewart Financial: How can we reward managers of firms for making decisions which involve reduced returns now for greater returns in the long run, maybe even after they have left? This problem generated considerable debate and intense analysis among three different subgroups, and each subgroup presented a report. Their mentor was Professor Jeff DeWynne from Oxford University, and expert on financial modelling. In addition, Dr. Dan Calistrate, Stern Stewart consultant and U. of Calgary Professors Gordon Sick and Tom Cottrell all played a major role in the work.

From Imperial Oil: If you have a huge oilfield with, say, 3,000 wells, which wells should you choose for steam injection to enhance the production of the field? Applied mathematicians in group immediately did the right

thing—"Let's start with two well...". At the end, substantial progress was reported. The group was ably led by mentor Huaxiong Huang of York University. Imperial Oil sent three representatives for the full week, and company representative Glynis Carling kept the group entertained with her marvellous sense of humour.

McMillan-McGee corporation of Calgary: How do we most efficiently apply induction heaters in oil well shafts to increase the flow? Owner Bruce McGee is a U of A Engineering graduate, so he participated enthusiastically during the week. Led by mentor Dr. David Ross of Eastman-Kodak in Rochester, New York, the group developed some important new ideas and made significant progress.

VisionSmart of Edmonton: Using two cameras to take digital images of a tennis ball as it begins its flight, how accurately can we predict the future trajectory? This group was assisted by mentor Professor John King, head of the Theoretical Mechanics Group at Nottingham University. They ended up doing a lot of basic trig and geometry (what is the optima placing of two cameras?), some engineering (use a laser to sight the cameras), and a lot of physics —people were busy reading articles on the trajectory of a ball when it is spinning. President Dan Kenway and company representative Wolfgang Engler spent the full week assisting the team, and progress was excellent.

On the last day, we received a pleasant surprise from the Canadian Mathematical Society. With some help from one of its spies present at the workshop, the CMS had selected UBC's Kyle Biswanger to win the CMS Leadership Award for his contributions to the workshop. Congratulations Kyle!

The week ended with presentations, followed by a pizza party. The PimSlips award for the funniest comment during the week went to: "Let's pick a prime, ... say 21 .....that's not a very good prime," which gives you an idea of how exhausted people can get!

All in all it was a great week, and we look forward to IPSW 5!

PIMS Postdoctoral Fellows for 2000–01 Academic Year

The selection in the 2000 competition was made by David Boyd (Chair), Nick Pippenger (UBC), Charmaine Dean (SFU), Terry Gannon (U. Alberta), B. Salkauskas (U. Calgary) and Pauline van den Driessche (U. Victoria).

1. **Siva Athreya**
   Department of Mathematics, UBC
   Sponsor: Ed Perkins, Martin Barlow, John Walsh
2. **Ji-Guang Bao**
   Department of Mathematics, UBC
   Sponsor: Nassif Ghoussoub
3. **Nils Bruin**
   Department of Math. and Statistics, SFU
   Sponsors: Peter Borwein, David Boyb, Imen Chen, Rajiv Gupta, Nike Vastal
4. **Ricardo Carretero**
   Department of Math. and Statistics, SFU
   Sponsor: Keith Promislow
5. **Yin Chen**
   Department of Mathematical Sciences, U. Alberta
   Sponsors: Anthony Lau, Laurent Marcoux
6. **Wai-Shen Cheung**
   Department of Math. and Statistics, U. Calgary
   Sponsors: Peter Lancaster
7. **Antal Jarai**
   Department of Mahtematics, UBC
   Sponsor: Gordon Slade
8. **Benjamin Klopsch**
   Department of Mathematical Sciences, U. Alberta
   Sponsor: Akbar Rhemtulla
9. **Luis Lehner**
   Department of Physics, UBC
   Sponsors: Matt Choptuik, Bill Uhruh
10. **Sam Lightwood**
    Department of Math. and Statistics, U. Victoria
    Sponsors: Chris Bose, Ian Putnam
11. **Matthias Neufang**
    Department of Mathematical Sciences, U. Alberta
    Sponsor: Volker Runde
12. **Gengsheng Qin**
    Department of Mathematics, U. Victoria
    Sponsor: Min Tsao
13. **Miro Powojowski**
    Dept. of Geology and Geophysics, U. Calgary
    Sponsor: Laurence Bentley
14. **Jorgen Rasmussen**
    Department of Physics, U. Lethbridge
    Sponsor: Mark Walton
15. **Sujin Shin**
    Department of Math. and Statistics, U. Victoria
    Sponsors: Christonpher Bose, Ian Putnam
16. **Ladislav Stacho**
    School of Computer Science, SFU
    Sponsor: Tom Shermer
17. **Joachim Stadel**
    Department of Physics, U. Victoria
    Sponsors: Arif Babul, Julio Navarro
18. **Sumati Surya**
    Department of Physics, U. Alberta
    Sponsors: Kristin Scleich, Don Page, Eric Woolgar
19. **Bert Wiest**
    Department of Mathematics, UBC
    Sponsor: Dale Rolfsen
20. **Yuqing Yang**
    Department of Mathematics, UBC
    Sponsors: Yue-Xian Li, Robert Muira
21. **Yoji Yoshi**
    Department of Mathematical Sciences, U. Alberta
    Sponsors: Bruce Allison, Arturo Painzola, Terry Gannon
22. **Konstantin Zarembo**
    Department of Physics, UBC
    Sponsor: Gordon Semenoff

Pacific Northwest Seminar Series

These are regular annual or biannual meetings that bring together various regional groups of mathematicians in areas represented by strong communities in British Columbia, Alberta, Washington, Oregon and Northern California. They are strongly encouraged and supported by PIMS since they greatly promote communication and interactions among the mathematical scientists in Western Canada and the U. S. Pacific Northwest. Please visit the PIMS web site for more information on upcoming PNW seminars.

PNW Probability Seminar,

University of Washington,
March 4, 2000

PIMS is a regular sponsor of the Pacific Northwest Probability Seminar. The organizers of the PNW Seminar series are Martin Barlow (UBC), Richard Bass (UW), Chris Burdzy (UW), Ed Perkins (UBC), and Ed Waymire (OSU). The speakers at the last seminar, held at the University of Washington on March 4, were:

Christian Borgs (Microsoft Theory Group): *Partition function zeros: A generalized Lee-Yang theorem*

Xiaowen Zhou (University of British Columbia): *Sample path continuity of continuous-site stepping-stone models*

West Coast Optimization Seminar,

PIMS-SFU,
May 12–13, 2000

The West Coast Optimization Meeting takes place twice each year, usually in April and November, and alternates between Vancouver and Seattle. In Vancouver, SFU/CECM and UBC/Math share the hosting duties, with local contacts Jonathan M. Borwein and Philip D. Loewen. In Seattle, UW/Math and UW/Applied Math contribute the organizational personnel: R. T. Rockafellar and J. V. Burke do most of the work. The speakers at the last meeting on May 12–13 were:

Heinz Bauschke (Okanagan University College): *How JPEG Works*

Jim Burke (University of Washington): *Variational Analysis of Spectral Functions*

Lisa Korf (University of Washington): *Pricing Contracts Contingent on a Market: A Mathematical Programming Perspective*

Ivaylo Kortezov (SFU): *Some Generic Results on Non-attaining Functionals*

Yuri Ledyaev (Western Michigan University): *Sub- and Supergradients of Envelopes, Semicontinuous Closures and Limits of Functions*

Martin Puterman (UBC): *The Censored Newsvendor and the Optimal Acquisition of Information*

Jim Zhu (Western Michigan University): *Generalized Extremal Principle and its Applications*

PNW Geometry Seminar,

PIMS-UBC,
May 6–7, 2000

The most recent meeting of the PNW Geometry Seminar was highly successful. This seminar is held every quarter during the academic year, rotating among the University of British Columbia, Oregon State University, University of Oregon, Portland State University, University of Utah, and the University of Washington.

The organizers of the most recent meeting held on May 6–7 were Jim Carrell (UBC) and Jingyi Chen (UBC). The speakers were:

Gang Liu (UCLA): *The Equivalence of Ring Structures in Floer and Quantum Cohomology*

Stephan Stolz (Notre Dame): *Metrics of Positive Scalar Curvature*

Rahul Pandharipande (CalTech): *Integrals over the moduli space of curves*

Paul Yang (Princeton and USC): *A Fully Nonlinear Equation in Conformal Geometry and 4-manifolds of Positive Ricci Curvature*

Jim Carrell (UBC): *Which Schubert Varieties are Smooth*

This meeting is co-sponsored by PIMS and the National Science Foundation of the United States.

PNW PDE Conference,

PIMS-UBC,
May 20, 2000

The first Pacific Northwest meeting on Partial Differential Equations was held at the PIMS facility at the University of British Columbia. Future meetings will be held at the University of Washington, and at other universities in the Pacific Northwest. The organizers were Richard Froese (UBC), Nassif Ghoussoub (PIMS and UBC) and Gunther Uhlmann (U. Washington). The speakers were:

Daniel Tataru (Northwestern): *Local well-posedness for nonlinear hyperbolic equations*

Tatiana Toro (U. Washington): *Potential theory and regularity of non-smooth domains*

Juncheng Wei (Chinese U. of Hong Kong): *On A Simple ODE and Anisotropic Curvature Flows*

Western Canada Linear Algebra Meeting,
University of Manitoba,
May 26–27, 2000

The Western Canada Linear Algebra Meeting (W-CLAM) is a biannual sequence of meetings on linear algebra and related fields. Previous meetings have been held in Regina, Lethbridge and Kananaskis. The objective is to foster research in linear algebra and its applications. At the last W-CLAM meeting on May 26–27, principal speakers were Hans Schneider (University of Wisconsin), Bryan Shader (University of Wyoming), Henry Wolkowicz (University of Waterloo)

Northwest Dynamics Symposium,
University of Victoria,
May 6–8, 2000

This workshop covered a variety of topics, including ergodic theory, symbolic dynamics, topological dynamics, aperiodic tilings and K-theory. The principal speakers were Mike Boyle (U. Maryland), Bob Burton (Oregon State U.) Robert Moody (U. Alberta) and Dan Rudolph (U. Maryland). The organizers were Chris Bose (UVic), Doug Lind (U. Washington) and Ian Putnam (UVic).

Second International Workshop on Scientific Computing and Applications,
Kananaskis, Alberta,
May 28 – June 1, 2000

The Second International Workshop on Scientific Computing and Applications continued the tradition of the highly successful workshop held at the City University of Hong Kong in December 1998. The aim was to bring together mathematicians, scientists and engineers working in the field of scientific computing and its applications to solve scientific and industrially oriented problems. The workshop was sponsored by PIMS and the University of Alberta. It was organized by P. Minev and Y. Lin (U. Alberta).

The invited speakers were:

W. Allegretto (U. Alberta)
O. Axelsson (Catholic U. Nijmegen)
R. Ewing (Texas A&M)
M. Fortin (U. Laval)
K. Y. Fung (Hong Kong Polytechnic U.)
P. Gresho (Lawrence Livermore Laboratory)
R. Lazarov (Texas A&M)
B. Lee (NRC, Ottawa)
S. L. Lyons (Mobil Technology)
W. Sun (City University of HK)
T. Tang (Hong Kong Baptist U.)
Zhong-Ci Shi (Academia Sinica)

Meeting in Honour of Cindy Greenwood,
University of British Columbia,
June 2, 2000

This was a meeting to commemorate the retirement of Professor P. E. Greenwood of the Dept. of Mathematics, UBC. Lectures were presented by Ildar Ibragimov (St. Petersburg) and Jim Pitman (Berkeley).

Cindy Greenwood

CECM/MITACS/PIMS Live Collaborative Mathematics on the Net,
Simon Fraser University,
June 19–20, 2000

This one and a half day workshop brought together people from academia and industry involved in mathematical computation, visualization, teaching and learning. This includes issues relating to communication, publication, and commerce using the Internet and related technologies. The half-day session on June 20 was dedicated to talks and tutorials on topics in Parallel Computing.

MITACS Workshop on Facilities Location Optimization
PIMS-UBC,
June 21–25, 2000

This highly successful workshop brought together members of the MITACS project, **Facility Location Optimization,** with other researchers in the field to discuss recent developments. The project leader of the **Facility Location Optimization** project is Dr. Binay Bhattacharya (Simon Fraser University). The project investigators are Prosenjit Bose (Carleton University), Mark Keil (University of Saskatchewan), David Kirikpatrick (University of British Columbia), Thomas Shermer (Simon Fraser University), Jack Snoeyink (Univ. of North Carolina) and Godfried Toussaint (McGill University).

Speakers at the workshop were:

Igor Averbakh (Western Washington University), Robert Benkoczi (SFU), Sergei Bespamyatnikh (UBC), Binay Bhattacharya (SFU), Prosenjit Bose (Carleton University), David Bremner (University of New Brunswick), David Breton (SFU), Will Evans (University of Arizona), Daya Ram Gaur (SFU), Jiawei Han (SFU), Matya Katz (Ben-Gurion University of the Negev), Mark Keil (University of Sasketchewan), David Kirkpatrick (UBC), Juan A. Mesa (Universidad de Sevilla), Raymond Ng (UBC), Michael Segal (UBC), Ladislav Stacho (PIMS-SFU), Thomas Shermer (SFU), Jack Snoeyink (University of North Carolina, Chapel Hill) Arik Tamir (Tel Aviv University), and Kum Hoe Tung (SFU).

A Brief Survey of Braid Groups

Contributed by Bert Wiest, PIMS-PDF

"Most of the proofs are entirely intuitive. That of the main theorem in §7 is not even convincing."
— E. Artin on his own 1925 paper on braids

The braid groups were first defined in 1925 by Emil Artin for the purpose of studying knots in 3-space, and more specifically to obtain a presentation of the fundamental group of the knot exterior (but he seems to have had modest expectations as to how far this approach may lead). His definition is ingeniously naive: an n-string braid consists of n pieces of thread spanned between two vertical needles, running continuously from left to right while "interweaving" each other. The end points are lined up on the needles, and two braids are considered equal if they can be deformed into each other while fixing the end points (see figure below). The set B_n of all n-string braids has a natural group structure: if $\alpha, \beta \in B_n$ are two braids, we can put β to the right of α, join the end points of the strings of α to the starting points of the strings of β, pull out the needle in the middle, and that's by definition the braid $\alpha \cdot \beta$.

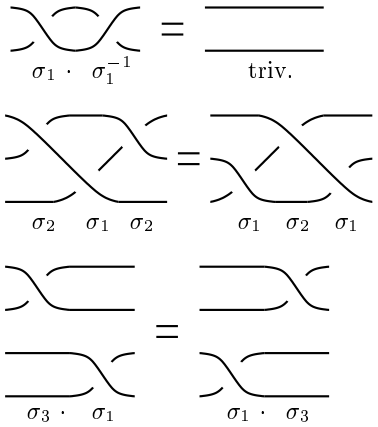
These innocent-looking groups have recently become fashionable. One reason is that they have turned out to be a surprisingly powerful tool in knot theory: one can get a knot or link from a braid by joining the two ends up in a cyclic fashion. Indeed, V. Jones defined his famous knot polynomial using representations of braid groups. From this starting point, via the work of E. Witten, mathematical physicists studied the connections of knots and braids with topological quantum field theories, statistical mechanics, and Yang-Baxter equations.

Here are two alternative descriptions of the braid groups.

1. B_n has a presentation

$$\langle \sigma_1, \ldots, \sigma_{n-1} \| \sigma_i\sigma_{i+1}\sigma_i = \sigma_{i+1}\sigma_i\sigma_{i+1},\ \sigma_i\sigma_j = \sigma_j\sigma_i \text{ , if } |i-j| \geqslant 2 \rangle \,.$$

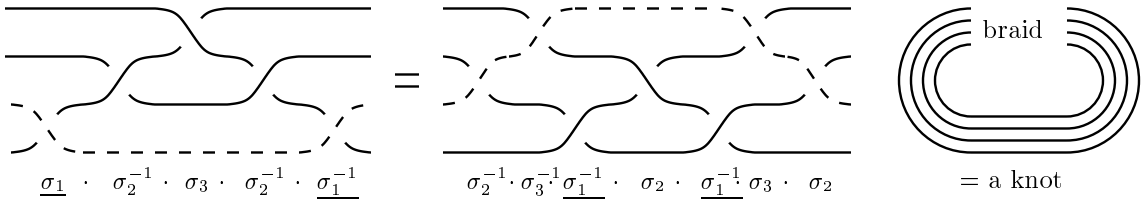
   The geometric meaning of the generators should be clear from the figure below, and the relators say that any deformation of a braid can be decomposed into certain elementary steps; the permitted steps are of the types $\sigma_i\sigma_i^{-1} = \text{triv.}$, $\sigma_1\sigma_2\sigma_1 = \sigma_2\sigma_1\sigma_2$, and $\sigma_1\sigma_3 = \sigma_3\sigma_1$.



Elementary deformations of braids.

2. If D_n denotes the closed 2-dimensional disk with n points from the interior removed, then we consider the set of all homeomorphisms $D_n \to D_n$ fixing the boundary pointwise, up to isotopy (i.e. deformation); composition gives a group structure to this set, and it is a challenging exercise to prove that this is just the braid group B_n!

These two descriptions have led to generalisations of braid groups in two different directions. Description 1 suggested the more general definition of Artin groups, which now play an important role in geometric and algorithmic group theory (as examples of groups that "only just fail to be negatively curved"), but also in algebraic geometry, singularity theory, and of course pure group theory (they have the Coxeter groups as natural quotients). Here is an example of an attractive recent result: it is an (intuitively obvious) theorem that the subgroup of B_n generated by the σ_i^2, i.e. the *full* twists of adjacent strings, has only got the obvious commutation relations $\sigma_i^2\sigma_j^2 = \sigma_j^2\sigma_i^2$ if $|i-j| \geqslant 2$, but no others. The analogue of this result for all Artin groups (the "Tits conjecture") has recently been announced by Crisp & Paris.



A deformation between two braids on 4 strings and how to obtain a knot from a braid

Description 2 can be generalised by replacing D_n by any surface with or without boundary or punctures. The mere fact that those groups, called "mapping class groups" have a finite, even elegant, presentation is a very deep theorem (Hatcher & Thurston, Wajnryb,...). This point of view has linked braid groups to Nielsen-Thurston theory, hyperbolic geometry, and ergodic theory. This description was also the basis of a recent spectacular breakthrough by a Berkeley graduate student, S. Bigelow, who proved that braid groups are linear (i.e. they have a 1-1 representation, in this case the "Krammer representation", into a finite-dimensional matrix group). This implies, by a result of Dyker, Formanek & Grossmann, that $Aut(F_2)$ is also linear (contrary, incidentally, to $Aut(F_n)$ for $n \geqslant 3$.)

One of the most tantalizing open problems is whether or not a certain other representation, the "Burau representation", of B_4 is faithful. This is a test case for what may be the most annoying problem in knot theory: is the unknot the only knot with trivial Jones polynomial? If the representation were unfaithful, then the answer would be "no"; huge computer searches have failed to find an element in the kernel, but nobody can prove that none exists.

We end with a very challenging exercise related to the author's research. It is a theorem (also illustrated in the figure on the bottom of the previous page) that any braid can be deformed into one which may contain the letter σ_1 but not σ_1^{-1}, or vice versa; that is, the "bottom" crossings all have the same sign. The exercise is to find such a σ_1-"consistent" braid algorithmically, if possible even in a computationally efficient way. Both points of view (1) and (2) above can be used, leading to very different solutions; but no existing algorithm is known not to exponentially blow up the number of crossings!

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Frontiers in Mathematical Physics Workshop on String Cosmology

PIMS at University of British Columbia

July 24 – August 4, 2000

This workshop is the third in the **Frontiers in Mathematical Physics** series sponsored by PIMS. This year the workshop is again co-sponsored with the Asia Pacific Centre for Theoretical Physics (APCTP). For the first time, the Canadian Institute for Advanced Research (CIAR) is also a sponsor of the workshop.

The goal of the Workshop is to bring together experts in string theory, nonperturbative gauge field theory and cosmology to explore the consequences for cosmology of the recent breakthroughs in fundamental field and string theory. These consequences may lead to a greatly improved understanding of the early Universe, and to the resolution of some fundamental problems for cosmology left unanswered by the present theories.

In addition to the scientific programme, this workshop will also be the occasion of the signing of a Cooperative Agreement between PIMS and the APCTP. With this cooperative agreement, the two institutes will seek to foster academic and scientific exchange between PIMS and the APCTP through such workshops as the **Frontiers in Mathematical Physics** series.

Invited Speakers:

Tom Banks (Rutgers)
Gia Dvali (New York Univ. and ICTP)
Brian Green (Columbia)
Nemanja Kaloper (Stanford Univ.)
Lev Kofman (CITA, Univ. of Toronto)
Andrei Linde (Stanford Univ.)
Rob Myers (McGill Univ.)
Burt Ovrut (Univ. of Pennsylvania)
Soo-Jong Rey (Seoul National Univ.)
Valery Rubakov (Inst. for Nuclear Research, Moscow)
Misha Shaposhnikov (Univ. Lausanne)
E. Shuryak (Stony Brook)
Sang-Jin Sin (Hanyang Univ.)
Dam Son (Columbia Univ.)
Paul Steinhardt (Princeton Univ.)
Neil Turok (DAMTP, Univ. of Cambridge)
Gabriele Veneziano (CERN)
Herman Verlinde (Princeton Univ.)

PIMS Thematic Program in Combinatorics and Graph Theory Attracts World-Class Researchers

PIMS is currently hosting a major thematic program in Graph Theory and Combinatorics at Simon Fraser University, the University of British Columbia and the University of Victoria. Co-sponsored with the Fields Institute, the program was launched at PIMS in the Summer of 1999 with two workshops, moved to Fields for the fall and spring for seven events and finally came back West for five additional workshops.

The inaugural event of the program was the **Workshop on Algorithms and Data Structures** (WADS '99) at the Harbour Centre campus of SFU. Organized by Arvind Gupta and Binay Bhattacharya, the program featured invited talks by Jeff Vitter (Duke), Umesh Vazirani (Berkeley), Charles Leiserson (MIT), Marc Snir (IBM), Nadia Thelman (Geneva). Over 100 international experts participated in this event. Thirty papers were presented from more than 90 submissions.

This was followed by the **11th Canadian Conference on Computational Geometry** (CCCG) held at the University of British Columbia and organized by Jack Snoeyink. Invited talks were given by Victor Klee (Washington), Dinesh Pai (UBC), and Susanne Fortier (Queens). Eighty participants heard more than 30 talks.

The events this summer began at the University of Victoria with a one-week workshop from June 5–9, 2000 on **Dynamic Graph Problems**. The list of invited speakers includes Bob Tarjan (Princeton Univ. and Intertrust), Stephen Alstrup (ITU, Copenhagen), David Eppstein (Univ. of California, Irvine), Faith Fich (Univ. of Toronto) , Leo Guibas (Stanford University), Pino Italiano (Univ. degli Studi di Roma), Roded Sharan (Tel Aviv University), and Mikkel Thorup (AT & T Research). The fifty participants heard tutorials on new topics and presented talks. They also took a break to explore the beauty of the Gulf Islands on a boat tour.

At this point, the Thematic Programme moved to PIMS at Simon Fraser University. The three workshops there are currently being held in the new PIMS-MITACS facility in the East Academic Annex.

The first workshop at PIMS-SFU is **Graph Decompositions** from June 19–30, 2000. Organized by Brian Alspach (University of Regina), this workshop features invited talks by Darryn Bryant (University of Queensland), Edward Dobson (Mississippi State), Mark Ellingham (Vanderbilt), Herbert Fleischner (Austrian Academy of Science), Ron Gould (Emory University), Hans-Dietrich Gronau (Universitat Rostock), Jiuqiang Liu (Eastern Michigan), Chris Rodger (Auburn University), and Mateja Sajna (Capilano College). The format of the workshop is informal with invited talks dovetailed with working sessions. The purpose of this workshop to provide the opportunity for a group of approximately 40 researchers and graduate students from around the world to work together to gain a better understanding of widely accepted problems in the area. The workshop consists of problem-solving sessions, tutorials designed for the non-expert, and a series of invited instructional lectures, the purpose of which is to survey the current status of a variety of important graph decomposition problems, and more specifically, edge decomposition problems. Some of the topics which will be covered include: 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 next workshop, **Workshop on Flows, Cycles, and Orientations,** from July 3–14, 2000. It is organized by Luis Goddyn (SFU). The format of the workshop consists of two formal talks per day, interspersed with periods during which the participants will engage in informal discussions. The invited speakers at the workshop are Matt DeVos (Princeton), Bertrand Guenin (Univ. of Waterloo), Petr Hlineny (Fields Institute), Kathie Cameron (Wilfred Laurier), Winfred Hochstäettler (Univ. zu Koeln), Mohamed Kobeissi (Univ. J Fourier, Grenoble), Sean McGuinness (Univ. of Umea), Deryk Osthus (Humboldt Univ.), Riste Skrekovski (Univ. of Ljubljana), Miki Tarsi (Tel-Aviv University), Dirk Vertigan (Lousisiana State Univ.), Doug West (Univ. of Illinois), C-Q W. Zhang (Virginia Univ.) and Xuding Zhu (Nat. Sun Yat-sen Univ.).

The final workshop on **Colourings and Homomorphisms** is from July 17–28. The chair of the workshop organizing committee is Pavol Hell (SFU). The workshop will consist of a series of invited instructional lectures, addressed to graduate students, and highlighting recent developments in graph colourings and their generalizations — including circular and oriented colourings, and, more generally, graph homomorphisms. Algorithmic, combinatorial, and algebraic issues will all be discussed, as will applications in and connections to constraint satisfaction problems, scheduling, etc. The invited speakers are Mike Albertson (Smith College), Noga Alon (Tel Aviv), Adrian Bondy (Lyon), Joan P. Hutchinson (Macalester College), Tommy Jensen (Hamburg), Bojan Mohar (Ljubljana), Jarik Nesetril (Prague), Andre Raspaud (Bordeaux), Bruce Reed (Paris), Gert Sabidussi (Montreal), Norbert Sauer (Calgary), Claude Tardif (Regina), Bjarne Toft (Odense), Peter Winkler (Bell Labs) and Xuding Zhu (Taiwan).

The **Graph Theory and Combinatorial Optimization Thematic Programme** taking place this summer is part of a year long Special Year on Graph Theory and Combinatorial Optimization jointly sponsored by the Fields Institute and PIMS. The full program on these two subjects has emphasized recent results, open problems, applications, and connections with other parts of mathematics and computer science.

Junior High Math Nights at Mount Royal College

Not only students, but also their parents and teachers met on six consecutive Monday nights at Mount Royal College in Calgary from January 31 through March 27 to engage in mathematical exploration. Organised by Dr. Jean Stringer, the emphasis of these evenings was to dispell the myths that mathematics is a set of facts innate to certain individuals and that mathematics is *not* an experimental discipline. Each evening was dedicated to a different topic.

Facts About Five: This evening was a potpourri of topics about the number five, including 5 by 5 magic squares, Pentagonal numbers, Tessalation of the plane using various polygons including pentagons, compass and straight-edge constructions, and Ramsey theory.

Map Colouring: This evening the question of how many colours are needed to colour a planar map was asked and also applications to some scheduling problems were investigated.

Sorting out Sorting: Sorting algorithms, their benefits, and their drawbacks were discussed.

The Secret of NIM: This evening, analysing NIM and similar games with a view towards developing winning strategies was the topic.

Nothing But 0's and 1's: This evening an exploration of number systems with different bases was on the agenda.

Playing with Beads

At the last Math Night at Sunnyside Elementary School in Calgary on May 25, students and parents gathered to play with coloured beads and learn some interesting mathematics in the process.

In five groups of about 20, children and adults constructed strings of coloured beads based on a Fibonacci-like sequence, modulo 10. For instance, if the starting numbers are 1 and 3, the sequence is 1, 3, 4, 7, 1, 8, 9, 7, 6, 3, 9, 2, 1, 3, and the sequence repeats.

Each colour bead represented a different number and the beads were threaded on a string according to the sequence until the starting point was reached. Then the string was tied into a loop to give a bracelet, necklace, a belt, or perhaps a belt for dad.

It did not end there however. Participants were challenged to find the longest or the shortest strings that keep on going and the number of possible different strings.

The evening was a great success with those involved looking forward with anticipation to the next Math Night at Sunnyside to be held during the fall of this year.

Graphing Calculators in the Classroom

The use of graphing calculators in the K-12 classroom has been mandated by the government. However, how this potentially useful tool can be effectively applied in a teaching environment is not necessarily self-evident. With this problem in mind, Professor Michael Stone and Galileo Network head Sharon Friese held a workshop on May 24–26, featuring Professor Stuart Moskowitz of Humboldt State University of California. The event was designed to bring together K-12 teachers, and College and University professors to explore ways that graphing calculators can be used in the classroom to effectively increase understanding of topics at hand.

Cinderella Author Holds Workshop in Vancouver

In recent years the *Geometer's Sketchpad* has become the standard software for teaching geometry in the classroom. Now, however, there is a new program, Cinderella, which provides a useful alternative.

Developed in Germany, Cinderella implements features already familiar to Sketchpad users. In addition, Cinderella is capable of constructions in spherical and hyperbolic geometry. It also has a special theorem prover, and many animation features. Cinderella users can generates Java applets for pasting into web pages.

The author of Cinderella, Ulrich Kortenkamp from Berlin University, held a workshop on June 16^{th}, at the Burnaby Campus of Simon Fraser University. The workshop was dedicated to an introduction to both classroom use and internet features of the software. Participants were given the opportunity to test the software and create example web pages. For more information about Cinderella, please consult its website at **http://www.cinderella.de**.

Elementary Teachers Explore Mathematics

Elementary teachers in Calgary traded places with their students. Instead of standing in front of the blackboard, once a month teachers at Sunnyside Elementary School in Calgary sit in their student's desks and tackle interesting mathematics problems.

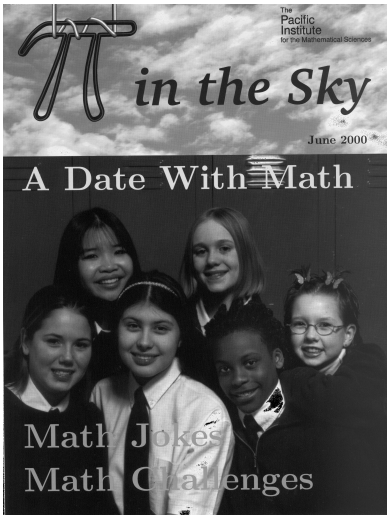
The spring series of the **Monthly Elementary School Teacher Meetings**, took place from January to May and due to its great success, it is rescheduled for the fall. The organizer of the programme, Indy Lagu, PIMS education coordinator at the University of Calgary, recognized the need for change in the basic attitudes of teachers towards mathematics. The possibility to improve attitudes through exposing teachers to mathematical exploration is the inspirational force behind this new programme.

The teachers themselves who participated in the Sunnyside meetings expressed frustration with the frequently encountered negative perceptions of the subject of mathematics and they are eager to participate as agents for change.

Pi in the Sky: PIMS' New Magazine for High School Students and Educators

PIMS is now producing and distributing a mathematical magazine targeted at the Junior and Senior High School students and educators. This new semi-annual publication promotes all aspects of the mathematical sciences. It is widely distributed across BC and Alberta. It is also sent anywhere else in Canada upon request. The first issue is already in the mail and is also available online through the PIMS website at **www.pims.math.ca/pi**. The Editors in Chief are Nassif Ghoussoub (PIMS Director) and Wieslaw Krawcewicz (U.Alberta). John Bowman, also from U. Alberta is the Associate Editor. The rest of the editorial Board consists of Peter Borwein (SFU), Florin Diacu (UVic), Klaus Hoechsmann (UBC), Michael Lamoureux (UCalgary) and Ted Lewis (U. Alberta).

Pi in the Sky is a periodical designated for high school students with the purpose of promoting exciting and lively mathematics, establishing and nurturing interactions with teachers and students, increasing the involvement of high school students in mathematical activities and promoting awareness for careers in the mathematical sciences and to discuss and promote new and/or innovative teaching methods.



First Issue of *Pi in the Sky*

Hypatia's Street Theatre

Frederic Wood Theatre at UBC
December 10, 2000

As a special event at the Winter Meeting of the Canadian Mathematics Society in Vancouver, PIMS will host the premier of a new play about mathematics to be shown to the general public at the Frederic Wood Theatre at UBC. The play, entitled *Hypatia's Street Theatre,* is co-authored by PIMS Education Facilitator, Klaus Hoechsmann and playwright Ted Galay. It represents an experiment of mathematical exposition in a theatrical context.

Hypatia was one of the leading Alexandrian intellectuals of her time: not only an accomplished mathematician and astronomer (books on the works of Diophantus, Ptolemy, Apollonius, Euclid) but also the main proponent of Neo-Platonism. Not content to stay in academe, where she was universally admired, she was known to mingle with the crowds and engage in philosophical discussions. The play imagines her, toward the tragic end of her life, turning away from philosophy — which was increasingly mired in verbiage and ideology — and carrying her message of clarity and openness to the public in the form of mathematical skits.

Sir Christopher Zeeman Gives Victoria Teens A Master Class in Mathematics

Contributed by David Leeming

On March 22, 2000 the renowned British mathematician, Sir Christopher Zeeman gave a lecture at the University of Victoria. It was one of three lectures given by Sir Christopher during his week long visit to UVic. His lecture was entitled *Master Class for Thirteen-Year Olds.* The lecture was sponsored jointly by the University of Victoria and the Pacific Institute for the Mathematical Sciences. Forty-one attended the lecture, including twenty teens from the local school district.

The Mathematics Masterclasses in Britain have grown out of the Christmas Lectures given at the Royal Institution by Professor Zeeman in 1978. Now given in about 50 centers in the U.K., a typical master class lasts for 2–3 hours on Saturday morning and runs for ten weeks. Studies conducted four years later showed that the participants in the Master Classes demonstrated increased confidence and increased problem-solving skill in all branches of science. The objective of the Master Class program is to introduce topics not found in the school syllabus using an approach that allows these young teens access to some university level material.

In a one-hour presentation, Sir Christopher gave the audience a sample of some of the activities that take place in a Master Class. He demonstrated the proof of a theorem relating the sum of angles of a spherical triangle to its area. He did a demonstration on perspective showing the existence and uniqueness of vanishing points and observation points. His demonstration on gyroscopes used an apparatus made from a bicycle wheel, which he brought all the way from England for the presentation. Finally, Sir Christopher demonstrated coupled oscillations using two keys hanging from a thread. His presentations were both informative and entertaining and he engaged many of the students in the audience to assist him with his demonstrations.

Mathematics is Everywhere: But Whom is it Reaching?

People may be divided into two groups: there are those who are instinctively attracted to mathematics and those whose interest is not easily awakened. Reaching both types of people lie at the hearts of many programmes on the PIMS Education Agenda. The **Mathematics is Everywhere** poster campaign is no exception in this regard.

Each month, a snapshot of the familiar world around us is presented: a sunflower, a child playing the violin, a soccerball, the full moon above the city skyline. Nothing here is out of the ordinary. Or perhaps is it? *The moon at Equinox rising over Vancouver? What time was the photo taken?* Not necessarily the sort of thing that moongazers contemplate on a clear spring evening.

The motivating force behind this PIMS project, conceived and created by Klaus Hoechsmann, is the desire to increase public awareness of the surprising ways mathematics is touching many aspects of our lives. At the very least, the hope is to catch the attention of many, capture the imagination of some, and convince a few to dig deeper.

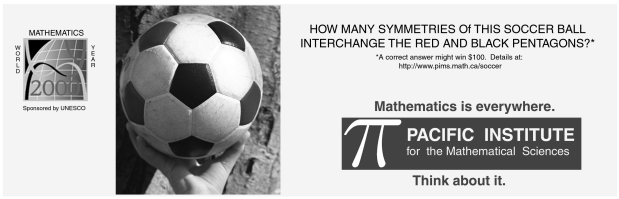
Twelve eyecatching pictures with thought-provoking questions are displayed monthly as posters on selected buslines in Vancouver and Victoria and in secondary schools in Calgary. They are also posted on the PIMS webpage to allow anyone around the world to enter a solution and take a chance at winning the $100 prize. In fact, it is hoped that by the end of the year 2000, which is UNESCO World Mathematical Year, participation in the monthly contest will become truly international.

The questions are designed to highlight a wide range of mathematical topics, such as combinatorics, probability, logarithmic curves, Fibonacci numbers and more. They also vary in level of difficulty to stimulate public interest among all age groups from elementary school students to adults. The questions are posed in such a way that unambiguous numerical answers can be given. Each month, one winner is drawn among the correct answers submitted on the web. However, it is nourishing the mind, rather than nourishing a competitive spirit, that stands out as the primary goal of this project. This is most evident to those who venture to probe the intricate connections that the sometimes deceivingly simple questions conceal. Such an exploration is possible through browsing the informative webpage and the associated links, made available with each month's question.

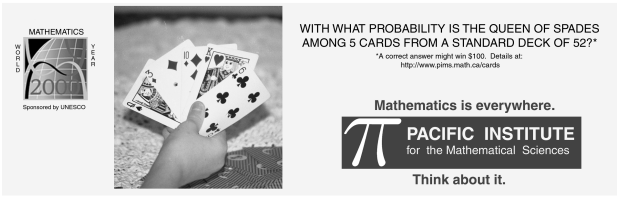
So whom is the poster campaign actually reaching? Evidently, a growing number of people are connecting to the poster website. In February only 193 individuals looked at the "sunflower" page. At the current rate, an estimated 1800 unique connections will be made to the "equinox" website for June. While most connections and entries to the contest were from Western Canada in the beginning, the poster campaign appears to be gaining an international following in recent weeks.

Who are some of the winners?

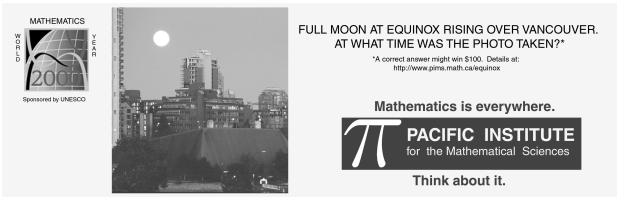
Pam Liem of Vancouver, winner of the February contest "The Sunflower Spiral Count" is an active 14 year old student at Vancouver Technical School, with sports and tambourine dancing as her favourite hobbies. She hopes to pursue studies in Commerce at UBC.



April Poster on the Buses



May Poster on the Buses



June Poster on the Buses

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

Stefan Lukits, winner of the March contest "The Violin String" is a 27 years old pastor at Emmanuel Baptist Church in Vancouver. Prior to his studies in theology at Regent College, Stefan received his training in mathematics in Graz, Austria. He enjoys literature, bicycling, and talking with friends in his free time.

Katy Cheng, winner of the April contest "Soccerball Symmetries" is a 35 year old accounting contractor in Vancouver.

The most recent winner of the "Chance and Randomness" contest for May is **Jordan Wan,** a 15 year old high school student at Aden Bowman Collegiate in Saskatoon. He loves to participate in sports such as basketball and volleyball, play the piano and work on his computer. Jordan says his future plans are not yet clear, but will likely include both math and sciences.

Beside these and the future winners of this Contest series, it is safe to say that all those whose curiosity is aroused by the pictures and are inspired to investigate further will have won something too. Perhaps an insight into a small corner of a mysterious and fascinating world.

Mathematics Projects in the Greater Vancouver Regional Science Fair

Contributed by Nataša Sirotić

At the Greater Vancouver Regional Science Fair (GVRSF) for 2000, there were 25 projects exhibited within the Mathematical Sciences category. These consisted of 13 junior projects (grades 7 and 8), 7 intermediate (grades 9 and 10), and 5 senior (grades 11 and 12). University-Hill Elementary, Point Grey Mini School, and Killarney Secondary School were quite highly represented. Other participating schools were Windermere Secondary, Vancouver Technical, York Hose School, Magee Secondary, Our Lady of Perpetual Help School, Albion Elementary, and Gladstone Secondary.

PIMS initiated the inclusion of a Mathematical Sciences exhibit category within the existing Science Fairs, which are organized and administered by the Science Fair Foundation of British Columbia. PIMS is committed to informing and involving mathematics teachers, giving presentations and workshops to groups of students, helping and providing assistance to students that have undertaken mathematics projects, judging the projects, and supplying the monetary awards.

Projects were judged as gold, silver or bronze based on a point system.

Among the senior level projects, 2 won silver and 3 won bronze designations:

In *Magic Squares* (silver), a project by **Hanson Ng** from Windermere, the algebraic properties of odd magic squares when treated as matrices were investigated. Hanson discovered and proved that the product of two magic-square matrices is always a symmetric matrix.

The *Real Mathematics* (silver), presented by **Frank Chu** and **Harold Kwok** from Killarney, was a study of the movement of a 3D object using the three axial rotations of its center of mass combined with its translation. The students created a computer program for graphic display of a spinning cube using the underlying mathematics of transformations. For the purpose of a more realistic display they delved into yet another area of mathematics, projective geometry. Connecting the points of the object to the "eye" and then calculating where these connecting lines meet the projective plane, the students achieved an impressive "dancing" cube on the computer screen.

The three bronze projects were *Luck or Chance*, a calculation of the odds of winning the 649 Lottery, BC49, and Blackjack, *Applications of the Derivative: Newton's Method*, a study of the Newton's iterative method for numerical approximation of the roots of a function, and *The Old Calculator*, a comprehensive look at the history and use of the abacus.

One gold, two silver and two bronze medals were awarded at the intermediate level:

The gold project, *Code CAE*, by **Vanja Alispahic** and **David Robertson** from Point Grey Mini School, was a study of cryptography and the invention of a genuine encryption method using a time scheme that changed the code with each second. To increase the difficulty of breaking into ciphers, the students successfully implemented other ideas like having the encoded version be independent of the surrounding letters in the original version and not mapping one original to one encoded letter.

Beyond the Bars (silver), by **Adrian Pau** and **Scott MacEachern** from Point Grey Mini School, was a project exploring an alternative to the standard UPC barcode by incorporating the Morse code for coding letters and numbers.

Unraveling the Mathematics of Knots (silver), by **Stefanie Leung** and **Tiffany Yeung** from York House School, was a study of the mathematics of knots. The students displayed knots according to their classification and demonstrated simplifications of knots using Reidemeister moves to determine the minimal crossing number invariant.

The two bronze projects were *Barcode researching*, a study of the working theory and the decoding procedure of the UPC barcode and *Vitruvian Proportions*, a statistics project that tried to determine whether and to what extent the proportions of the human body, given by the Roman architect Vitrivius and depicted by Leonardo's Proportions of Man drawing, actually hold.

At the junior level, 2 projects won gold, 4 silver, 1 bronze, and 1 honourable mention:

Polygon PI (gold), by **Max Thompson** from U-Hill Elementary, was a project that used the squeezing method to find the approximation of PI. Max used the idea of increasing the number of sides of the inscribed and the circumscribed regular polygons and calculating their perimeters to approximate Pi. Using elementary algebra and geometry, he devised the formula that, using the side-length of a regular polygon, calculates the side-length of a regular polygon with twice as many sides. He also displayed charts of how quickly these estimates approach Pi as the number of sides of the polygons increases.

Pythagorean Proofs over the Centuries (gold), by **Lara Sirotić** from OLPH, was a study of various proofs of the Theorem. Lara constructed the dissection puzzles to display how each of the studied proofs works. She also constructed them using the dynamic geometry software and displayed their animations. Several applications of the theorem were also presented.

Calculating the Number of Squares within the Square Grid (silver), by **Mahmoud Bazargan** from U-Hill Elementary, was a project to determine the total number of squares inside a general square grid without counting them.

Fermat's Last Laugh (silver), by **Monica Ray** from Gladstone Secondary, was a project that displayed a great interest and careful study of the history of this famous theorem. Monica used two cubes made out of cent-cubes and

challenged the audience to make a single cube out of them. Then she explained the history of the 350-year quest for the answer to the Fermat's Last Theorem.

Combinations of numbers and letters (silver), by **Tiffany Lu** from U-Hill Elementary, was a project that studied how many total combinations for BC car license plates and Canada ZIP codes are there with and without letter/number repetitions.

Perfect Picks (silver), by **Ben Cline** from Point Grey Mini School, was a project that explored how one can find an optimum strategy for selecting stocks using Game Theory.

The bronze project *Where Do You Get Information* employed statistics to extract information about library services from a survey conducted in several schools.

Third Annual FAME is a Great Success

Contributed by David Leeming

Students in the Greater Victoria School District took part in FAME, the Forever Annual Mathematics Exhibition, at S.J. Willis School on April 27, 2000. There were 65 mathematics-related exhibits, which showed off the accomplishments of 118 students from both elementary and secondary schools. The event was organized (for the third time) by **Wendy Swonnell,** a mathematics teacher at Lambrick Park Secondary School. It was sponsored in part by the Pacific Institute for the Mathematical Sciences. The purpose of FAME is to allow students to present math displays in the same way that science fairs allow students to put science projects on display.

The students chose a wide variety of subjects for their exhibits, including probability, cryptography, Fibonacci sequences, paradoxes, and mathematics and music. Others chose to showcase the accomplishments of such famous mathematicians as Daniel Bernoulli and John von Neumann.

Mathematicians from Camosun College and UVic as well as engineers judged the exhibits, which were split into three levels — intermediate (up to grade 7), junior (grades 8 and 9) and senior (grades 8–10). The top three exhibits in each category were awarded trophies.

Elementary Math Fairs in Edmonton

The yearly Math Fairs in elementary schools in the Edmonton area are gaining in popularity. Initiated upon requests by schools, and supported mainly by PIMS and the Edmonton Public School Board, the Math Fairs were held in previous years at Our Lady of Victories and Parkallen Elementary Schools. This year, Clara Tyner and Terrace Heights Elementary Schools were involved. Demand is growing with requests received from an additional six schools for next year. In fact, the Math Fairs are so popular that planning is underway for a Math Day where several schools can participate.

The Edmonton Math Fairs are unique in that all students in the school participate. This event is about problem solving, not winning and loosing. The schools themselves play a major role in the planning and thus the format can vary from school to school. In some Math Fairs, Education students from the University of Alberta were available to help, primarily by providing a "model" for a Math Fair that students can emulate in planning their own event. The extensive involvement of students both in planning, staging and participating in the Math Fair may be one of the secrets of its success.

Prior to the Math Fair, students choose or are given problems to work on. They work in small groups to solve the problem and subsequently create a table-top display. On the day of the Math Fair, spectators are invited to tackle the problem, with hints and guidance provided by students in charge. The displays are not poster sessions. Rather, the students are actively involved in the presentations.

Mathematics Unplugged IV

The fourth annual Mathematics Unplugged elementary school student conference was given the theme *Mathematics in Our World* with particular focus on the blending of mathematics and social studies.

Mathematics Unplugged is an event that aims to convince kids, even those otherwise inclined, that mathematics can be attractive and what is more, enjoyable and fun. At Westwood Elementary, all of the over 200 students in the school participate in the conference as a regular part of their school day.

Prior to this year's event, students received a brochure with all activities described, and were given the opportunity to select their favourites. On the day, kids arrived prepared with their conference packages and proceeded to their selected sessions, which had intriguing titles such as "All Aboard! Calling all Engineers!", "Measure, Measure, Measure!!!", "In A Giant's Footsteps!!", "Fly Across Canada!!", "Mathematical IMPOSSIBLITIES!", "The Lost Treasures" and "Simply Super Solids".

In the spirit of an "adult" conference, keynote lectures were delivered by Dr. Mike Fellows and Dr. Fran Roasamond about *Dots and Lines: How Scientists Use Dots and Lines for Just About Everything.* These lectures were made possible through the sponsorship of PIMS.

For the first time, a workshop was also organised for parents, which was enthusiastically welcomed. **Mathematics Unplugged** is a success with all participants, supporting the notion that it is possible to make math more relevant and meaningful to a much wider audience than it is commonly assumed.

Westwood Elementary and Pamela Hagen, the originator and organizer of **Mathematics Unplugged,** were recently honoured with *Educational Excellence in Innovative Planning* awards by the Ministry of Education of British Columbia.

PIMS Elementary Grades Math Contest at UBC

For the second time, PIMS welcomed British Columbia students from Grades 5, 6 and 7 to experience mathematics as an exciting sport in the Elementary Grades Math Contest. The event took place on May 13th, a sunny Saturday afternoon, on the UBC Campus. The contest is modelled after the successful MathCounts competition for students in higher grades. The Elementary Grades Math Contest is designed to introduce students to the idea of the mathematics competition with a slightly less competitive flavour than is appropriate for older students.

180 eager youngsters participated in three rounds of competition. The *Sprint Round* consisted of a set of 25 written problems that contestants were to solve within 40 minutes. This was followed by the *Target Round* where the objective was to solve 3 sets of 3 questions in 10 minutes. The highlight of the afternoon was the *Countdown Round*, a fast-paced mathematics duel among pairs of the top 10 contestants in each of three divisions.

The winners in the three divisions were:

Grade 5: #1 Joseph Connor Wagner (Port Guichon); #2 Sebastian Crema (Boundary Community); #3 Serena Ip (Boundary Park)

Grade 6: #1 Sam Wang (Mount Pleasant); #2 George Yuan (Harold Bishop); #3 Charles Leung (St.George's)

Grade 7: #1 Irene Yu (Berkshire Park); #2 Michael Li (MacCorkindale); #3 Paul Collier (Kitchener)

Top 10 students in the Grade 5 division of the PIMS Elementary Grades Math Contest

Top 10 students in the Grade 6 division of the PIMS Elementary Grades Math Contest

Top 10 students in the Grade 7 division of the PIMS Elementary Grades Math Contest

Evenings of Mathematics at SFU

On the 2nd of March, another meeting in the **Evenings of Mathematics at SFU** series was held at the Harbour Centre Campus. About 80 people attended two presentations with different themes.

Keith Promislow, who is a member of the Mathematics and Statistics Department at SFU, as well as a consultant to Ballard Power Systems, spoke about mathematical models of fuel cells which were developed in conjunction with engineers at Ballard.

For a change of pace, **Brett Stevens,** a PIMS/IBM postdoctoral fellow at the Depeartment of Mathematics and Statistics at SFU, illuminated the connection between Samuel Beckett's *Quad* and Dante's *Divine Trilogy* that poses a very deep and hard combinatorial question about Gray Codes. He continued with the illustration of how French Oulipoian author Georges Perec applied Mutually Orthagonal Latin Squares to the plot structure of his novel *Life a Manual*.

Evenings of Mathematics at SFU were initiated by Malgorzata Dubiel of SFU and were made possible by the office of the Dean of Science from 1995 to 1998. With the support of PIMS, the evenings resumed again in 1999 and they take place twice a year, in the spring and in the fall.

Upcoming Education Events

Taiwanese Summer Camp,
August 2000, University of Alberta

Initiated by Andy Liu and Wen-Ssieu Sun, this yearly camp provides an opportunity for taiwanese students to learn both english and mathematics in Canada. This year for the second time, thirty students, mostly thirteen years old, are visiting the University Alberta, where they will be engaged in problem solving in diverse areas of mathematics. On August 4 to 6, a trip to the Rocky Mountains is planned and on August 17, a media day is held with attendance by the Lieutenant Governor of Alberta, Lois Hole.

ESSO/CMS Summer Camp,
August 16–23, 2000, University of Alberta

To identify and nurture future members for the Canadian team for the International Mathematical Olympiad, Esso, CMS and PIMS sponsor this yearly event where students in grades 8 to 10, as well as exceptional elementary grade students are invited based on merit. Topics in Combinatorics, Number Theory, Algebra and Geometry will be covered at the difficulty level of the Olympiad. This year's feature event will be a media day on August 17, with Lieutenant Governor Lois Hole attending. The camps are held alternately at the Calgary and Edmonton PIMS sites.

Annual Meeting of the BCAMT
October 2000, Vancouver

PIMS will staff an information table as in the previous year.

Junior High Math Nights
October/November, 2000,
Mount Royal College, Calgary

As in the spring, 6 consecutive Mondays will be dedicated to various intriguing mathematical topics. This event is organized by Dr. Jean Springer of Mount Royal College.

Math Night at Sunnyside Elementary
Fall, 2000, Sunnyside Elementary School, Calgary

The first Math Night on May 25th was a great success. A second event will take place in the fall. Math Night will be established as a biannual event in coming years.

Mathematical Evenings at SFU
Fall, 2000, SFU Harbour Centre, Vancouver

These evenings are intended as an introduction to particularly interesting aspects of current mathematics for secondary school teachers and students.

Elementary School Teacher Meetings
Fall 2000, Sunnyside Elementary School, Calgary

Following a summer break, monthly meetings for elementary school teachers will resume at Sunnyside School in response to enthusiastic interest from participants.

Family Mathematics Night at West Dalhousie
Fall 2000,
West Dalhousie Elementary School, Calgary

The format of this event is the same as the Sunnyside Math Night. There was a scheduled meeting for April 13th with 150 parents and kids signed up, which had to be cancelled due to a storm. The Math Night will now take place in the fall.

Tournament of the Towns
Fall, 2000, Calgary

This is an international math contest where teams representing cities compete with each other. The Calgary team for the spring contest was organised by Dr. Bill Sands.

Math Day
Fall, 2000, University of Alberta

Inspired by the popularity of Math Fairs, plans are underway to hold a Math Day where more schools can be involved. Supported primarily by PIMS and the Edmonton Public School Board, it is anticipated that a Math Day will be held each year. The first Math Day will probably take place in the Fall of 2000.

Alternative Math Education
Fall, 2000, Victoria

The aim of each meeting is to demonstrate fun methods to teach math and computer science concepts to children and adults.

Hypatia's Street Theatre,
December 10, 2000, Frederic Wood Theatre, UBC

As a special event at the CMS Meeting's Education Session, PIMS will host the premier of a new play about Mathematics to be shown to the general public at the Frederic Wood Theater at UBC.

PIMS Mathematics Enrichment Curriculum,
Calgary

A team of mathematicians led by Dr. Keith Taylor of the University of Saskatchewan will be developing an ensemble of web-based training modules to attract students to mathematics and generally increase the mathematical literacy of students.

PIMS "Mathematics is Everywhere" Campaign
All Year Long, 2000, Vancouver, Victoria, Calgary

A poster campaign is ongoing to promote World Mathematics Year 2000. Posters are displayed on buses in BC and in schools in Calgary. Students of all ages are invited to answer a mathematical skill-testing question with a chance to win a $100 prize. On the PIMS website detailed background information and hints are provided.

PIMS Offers Lectures via Streaming Video over the Internet

PIMS is now offering a new service to the mathematical sciences community: lectures over the internet using on-demand streaming video. The format that we are following is to offer both video of the lecture in Realvideo format and high resolution JPEG images of the speaker's slides, when possible. Our library of lectures is available at **www.pims.math.ca/video**.

Lectures currently or soon to be available are:

Professor Sir Christopher Zeeman
Geometric Unfolding of a Difference Equation
PIMS Distinguished Colloquium, University of Victoria on March 21, 2000


Christopher Zeeman

Professor H. S. M. Coxeter
The Mathematics in the Art of M. C. Escher
Public lecture given at the **PIMS Changing the Culture III**, Simon Fraser University, Harbour Centre on April 28, 2000.

Professor Yuri Matiyasevich
Hilbert's 10th Problem: What can we do with Diophantine equations?
Series of 5 lectures given while he held the PIMS Distinguished Chair, University of Calgary, March and April, 2000.


Yuri Matiyasevich

Professor Sir Andrew Huxley
The Background to the Hodgkin-Huxley Equation
PIMS Distinguished Lecture, PIMS-UBC, Aug. 19, 1999

Professor Israel Gohberg
Infinite Systems Of Linear Equations
PIMS Distinguished Colloquium, University of Calgary, Sept. 30, 1999.

Professor Richard Karp
The Design of Molecular Bar Codes: A Combinatorial Problem from Molecular Biology
PIMS Distinguished Colloquium, Simon Fraser University, May 13, 1999.

Professor Avi Wigderson
A Computational View of Randomness
PIMS Distinguished Colloquium, University of British Columbia, Sept. 10, 1998.

Professor Beno Eckmann
Four-manifolds and group invariants
PIMS Distinguished Colloquium, University of British Columbia, April 23, 1998.

Professor Mitchell Luskin *Modelling, Analysis and Computation of Crystalline Microstructures*
PIMS Distinguished Colloquium, University of British Columbia, Sept. 10, 1998

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