A Tribute from the Chair

The Keyfitz Factor

As I write we are entering the final month of Barbara Keyfitz’s term as the Director of the Fields Institute. And what a term it has been! Growth in both the volume and the scope of the Institute’s mathematical activity. A happy place to be for visitors and staff. Strengthened relationships with clients and sponsors and mathematical communities. Has this steady progress come about by chance? Not at all. It owes a great deal to the wisdom and the energy of its Director, Barbara Keyfitz, and working with Barbara for five years has revealed to me the keys to her success.

The Fields Institute is a much more substantial institution today than it was five years ago, with a much heftier impact on mathematics thanks to the wisdom of Barbara’s vision and the strength of her imagination. The introduction of summer programmes built on interdisciplinary themes, and the novel approach incorporated in the Institute’s postdoctoral fellowship programme are two instances of Barbara’s understanding of what is needed to make this a top-notch institute.

A successful institute does not exist in a vacuum. Rather, its success depends upon the strength of its relations with mathematicians, with its sponsors and funding sources, and with the international mathematical community. Barbara has worked

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Thematic Program on Arithmetic Geometry, Hyperbolic Geometry and Related Topics

JULY – DECEMBER 2008

Organizers: John Bland (Toronto), Caterina Consani (Johns Hopkins), Stephen Kudla (Toronto), Min Ru (Houston), Paul Vojta (Berkeley), Pit-Mann Wong (Notre Dame)

On the face of it, there is very little relation between arithmetic geometry and complex hyperbolic geometry. The former deals with properties of rational numbers, such as whether a polynomial equation admits any rational solutions, and if so, how many? The latter deals with whether there exist non-constant entire maps of the complex plane into the zero set of a polynomial equation. Perhaps the most famous example is the Fermat curve $X^n + Y^n = Z^n$.

Given this perspective, Faltings’ theorem appears all the more remarkable: a Riemann surface of genus $g$ has only finitely many rational points over any given number field if and only if $g \geq 2$; these are precisely the Riemann surfaces which are uniformized by the unit disc, and thus admit a metric of negative curvature (a hyperbolic metric), and admit no non-constant entire maps of the complex plane into the surface. (Indeed, such a map would lift to a map into the unit disc, giving a bounded entire function, contradicting Liouville’s theorem.)

The correspondence between results in arithmetic geometry and its relative,

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Roger Bacon once said that “...nothing magnificent in the science can be known without mathematics......if we ought to come to certitude without doubt and to truth without error in the other sciences, it is necessary that we place the foundations of knowledge in mathematics.”

Throughout the history of mathematics, the interaction with the sciences has posed the challenges which have led to the development of new mathematical methods and techniques which in turn, have contributed to dramatic advances in the sciences. It appears that in the 21st century, we are on the brink of reaping the rewards of the rapidly developing synergy between mathematics and the biomedical sciences. Nowhere is this more apparent than in the nascent field of mathematical oncology, where the interaction of these disciplines heralds the possibility of the eradication of a disease that has been the scourge of humanity from time immemorial. Cancer is one of the most devastating diseases in the industrialized nations and according to the World Health Organization (WHO), it is poised to surpass cardiovascular disease as a worldwide killer. Thus, for this reason alone, the fight against cancer would appear to be of major importance and a worthwhile endeavour, both from the societal viewpoint of improving public health and from a socio-economic viewpoint (to avoid a significant drain on economic resources). In addition, as pointed out by several eminent researchers, one of the great scientific revolutions of this century will undoubtedly be brought about by the mathematization of the Life Sciences and Medicine.

More and more mathematicians are becoming involved in mathematical oncology and contributing to a deeper understanding of the complexities and mechanisms of cancer. However, as is abundantly clear, this is a far from easy task and numerous fundamental conceptual issues remain to be elucidated and resolved. What is the right framework in which to study cancer? What are the critical biological mechanisms and corresponding scales? Is the study of cancer a multi-scale problem? These were the types of basic questions that formed the backdrop to the inaugural summer thematic program on “Mathematical & Quantitative Oncology” that was held July-August, 2008 at the Fields Institute. The program was coordinated by the Centre for Mathematical Medicine (CMM) but was a multi-institutional and international venture, involving the Ontario Institute for Cancer Research (OICR) and the Vanderbilt Integrative Cancer Biology Center (VICBC). The opening workshop on “Growth and Control of Tumours” (July 2-4, 2008) brought together cancer biologists, clinical researchers and mathematical scientists to address a broad range of topics from recent developments in the cancer stem cell hypothesis, to advances in the development of targeted drug therapies and novel drug delivery systems, as well as the optimization of combination therapies. Fortuitously, the talks were an excellent balance between theory and experiment and had an underlying unifying theme in that they addressed specific aspects of the multi-scale, multi-factorial nature of cancer. The workshop also set the stage for the highly interdisciplinary nature, and balance of theory and experiment that characterized the rest of the thematic program.

Events rapidly gathered momentum with numerous short and long term researchers visiting in July, culminating in the highly successful Society for Mathematical Biology Conference (SMB2008) held July 30-August 2. The meeting brought together 330 mathematical and biomedical scientists. The conference opened with the inspiring plenary talk on “mechanochemistry and motility” delivered by L. Mahadevan of Harvard University. This led to the var-

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Fields Welcomes Matthias Neufang as Interim Deputy Director

THE FIELDS INSTITUTE is pleased to welcome Matthias Neufang, Professor of Mathematics at Carleton University, to the Institute’s staff. Matthias will be serving as our Interim Deputy Director from January to July 2009.

Matthias Neufang brings a wealth of knowledge and experience to his new position at Fields. His PhD was granted Summa Cum Laude by the University of Saarland in 2000 for a thesis entitled Abstract Harmonic Analysis and Module Homomorphisms on von Neumann Algebras. This work was done under the supervision of G. Wittstock. This was followed by a PIMS postdoctoral fellowship at the University of Alberta under Tony Lau. He is currently Associate Professor at Carleton University where he has served as Director of the Ottawa–Carleton Institute of Mathematics and Statistics and as Graduate Director of the Carleton School of Mathematics and Statistics. He is currently Associate Dean of the Faculty of Graduate Studies and Research at Carleton University.

He is a member of the Advisory Board of the Centre for Research in Operator Algebras at the University of New Brunswick, as well as member of the Board of Directors of the Canadian Mathematical Society. He is also Chair of the Canadian Mathematical Society Publications Committee and a member of the NSERC Pure and Applied Mathematics Grant Selection Committee.

His research has been recognized by NSERC in the form of a Discovery Accelerator Supplement and he was also a member of the group awarded an NSERC LSI grant. He has held visiting scholar positions at Heidelberg, MSRI, Centre Emile Borel, Oberwolfach and Rutgers.

Emily Baillie

CLAY SENIOR SCHOLAR LECTURE

HENRI GILLET: What is infinity factorial (and why might we care)?

ON NOVEMBER 25, FIELDS WELCOMED Henri Gillet of the University of Illinois at Chicago to speak as part of the thematic program in Arithmetic Geometry, Hyperbolic Geometry and Related Topics. Not surprisingly, the intriguing title attracted a large number of well-seasoned mathematicians to the lecture, in addition to the undergraduates for whom it was designed. Gillet began by boldly stating that

\[ \infty! = 1 \cdot 2 \cdot 3 \cdots n \cdots = \sqrt{\pi} \]

and

\[ 1 + 1 + 1 + \cdots + 1 + \cdots = -\frac{1}{2} . \]

The general question then is: how can one assign a (finite and useful) value to a divergent product or divergent sum? Since any product of positive numbers can be converted into a sum by taking the logarithm, Gillet concentrated on answering this question for infinite series. In our first course in calculus, we learn that an infinite series

\[ a_0 + a_1 + \cdots + a_n + \cdots \]

can be assigned a sum as the limit of the sequence of partial sums

\[ s_0 = a_0, s_1 = a_0 + a_1, \cdots, \]

\[ s_k = a_0 + a_1 + \cdots + a_k, \cdots \]

if the limit exists, of course. But in the 18th century, the distinction between convergent and divergent series was not at all clear – it was only to be clarified later in the 19th century. For example as illustrious a mathematician as a Bernoulli brother reasoned that since the partial sums of

\[ 1 - 1 + 1 - 1 + \cdots \]

are 1, 0, 1, 0, … the sum of the series is \( \frac{1}{2} \), or at least should be. This answer is consistent with another 18th century argument: since the geometric series

\[ 1 + r + r^2 + \cdots = \frac{1}{1-r} \]

if \( |r| < 1 \), substituting \( r = -1 \) gives

\[ 1 - 1 + 1 - 1 + \cdots = \frac{1}{2} \]

as before. The fact that both methods gave the same answer must have been pretty convincing.

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The lectures began by highlighting two roles played a central role, as did the number

\[ \Omega = \int_1^\infty \frac{dx}{\sqrt{1-x^2}} \]

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defined by a very similar-looking integral. The number \( \pi \) occurs in many special values of the Riemann zeta function

\[ \zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s} \quad \text{Re } s > 1. \]

At age 28, Euler showed that \( \zeta(2) = \pi^2/6 \), and at age 30 he found the Euler product expansion

\[ \zeta(s) = \prod_p \left(1 - \frac{1}{p^s}\right)^{-1}, \]

where at primes \( p \) of good reduction \( L_p(E,s) = (1 - ap p^{-s} + p^{1-2s})^{-1} \) and \( ap = p + 1 - |E(F_p)| \). Then the far-reaching conjecture of Birch and Swinnerton-Dyer suggests that \( L(E,1) \) should be a certain nonzero rational multiple of \( \Omega \).

More generally, if \( E \) is an elliptic curve over a number field \( k \), then its set \( E(k) \) of rational points over \( k \) has the structure of a finitely-generated abelian group, and if \( r \) is the rank of this group, then the Birch and Swinnerton-Dyer conjecture asserts that \( L(E,k,s) \) has a zero of order \( r \) at \( s = 1 \), and the leading coefficient of its power series is a certain nonzero rational multiple of a factor coming from periods of \( E \) over the archimedean places of \( k \), and a factor coming from heights of a generating set of \( E(k) \).

At present, the assertion regarding the ranks is known when \( k = \mathbb{Q} \) and \( L(E,s) \) has a zero of order \( \leq 1 \) at \( s = 1 \); this is a combination of results of Gross and Zagier in 1983; Kolyvagin in 1990; and Wiles, Breuil, Conrad, Diamond, and Taylor in 1999.

The 1999 result is the assertion that all elliptic curves over \( \mathbb{Q} \) are modular: there is an \( N \) for which the modular curve \( X_0(N) \) admits a non-constant morphism to \( E \). Zhang’s third lecture centred on recent efforts to extend the Birch and

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**COPING WITH IMPOSSIBLE PROBLEMS – WITH A SMILE**

In early November, Fields again co-sponsored an RCI “Science on Sundays” lecture on the University of Toronto campus. This fall’s speaker was Margaret Wright, a past-president of the Society for Industrial and Applied Mathematics, who spent much of her career at AT&T Bell Labs and is now Silver Professor of Computer Science and Mathematics, and chair of the Computer Science Department, at New York University. Wright is a renowned mathematical scientist whose field is optimization. In addition to her distinguished career in research and service, Wright is famous for her catchy talk titles – “The ferment in optimization” and “What can we say after we say we’re sorry, or adventures in optimization” are two recent examples. When you attract a large audience with a title like “Coping with impossible problems,” you had better be prepared to deliver the goods, and the RCI talk did just that, telling an important story with enthusiasm and humour.

In her lecture, Wright gave a good sense of what is meant by the term “optimization,” and also of how mathematics contributes to solving real-world problems that involve optimization. Her lecture was enlivened with many references to Sherlock Holmes – especially to his famous statement, “When you have eliminated the impossible, whatever remains, however improbable, must be the truth.”

The abstract goals of optimization can be stated very simply: find the best solution to an equation or inequality.

The abstract goals of optimization can be stated very simply: find the best solution to an equation or inequality: prove that it is the best; and estimate how long it will take to find that solution. This doesn’t sound very exciting. But Wright illustrated her theme with two examples that were nothing short of astounding. The first was a problem presented to her when she was a young researcher working at Stanford University. It involved an engineering problem of recalibrating the Stanford Linear Accelerator (SLAC), a task that needed to be done once a year, and was performed by “knobbers” who turned a set of knobs located along the two-mile beam until the beam was perfectly straight. It was done by trial-and-error and took about six weeks, after which the accelerator was ready to run experiments. The mathematics, and physics, of the situation was clear enough: the knobs controlled magnets that affected the beam in a predictable way. But the problem was still “impossible” in the sense that the controls were located at fixed points which could not be adjusted, and the way that each control changed the beam had to be inferred from data caught by monitoring the system. There were a large number of constraints, and the problem was nonlinear. Wright and colleagues adapted a new kind of algorithm, Sequential Quadratic Programming, or SQP, to solve this problem. They were able to reduce the time it took to calibrate the beam to a single eight-hour shift. As Wright joked, this might have put some “knobbers” out of work, but the scientists were grateful to have their very expensive machine available for productive work for a much longer time.

The second example involved designing indoor wireless communication systems, a project that surfaced during Wright’s career at Bell Labs. The problem is to design an optimal placement of transmitters in a building to assure complete coverage of the space by radio waves. Unlike the SLAC problem, this one featured imperfect knowledge of the physics, and a shortage of data with which to monitor progress towards an optimum. The mathematical key to this problem was a fast ray tracing algorithm that provided a (sufficiently good) approximation to the way radio waves propagate in real office buildings. “Impossible” was turned into “possible” by recognizing that the scale of the problem was human-sized working spaces.

Following this insight, the optimization technique was what is called a direct search algorithm, a method suited to functions that are non-smooth and noisy. In this example, the optimization strategy resulted in a program called “WISE,” which is still in use, and produced an improvement of about 6% (over the engineering design) in typical buildings. Even though that does not sound dramatic, it was very important to the customers. The analysis also produced some insights into the way coverage worked – a byproduct of approaching practical problems with theory, as many applied mathematicians are aware.

One feature of both examples was the requirement that the mathematical group establish the trust of their clients. Like many of Wright’s other comments about the climate of applied research, her perception of the need to convince suspicious clients and co-workers that mathematics can do more than just provide verification of answers that “everyone knows already” struck a chord with those of us who are keen on interdisciplinary collaboration.

In her concluding remarks, Margaret Wright returned to the theme of the joy of collaboration and teamwork. The success stories of her lecture were a vivid example, and her enthusiastic delivery served to dispel the image of an isolated, unsmiling mathematician.

Barbara Lee Keyfitz
Yum-Tong Siu, William Edwood Byerly
Professor of Mathematics at Harvard,
has been a dominant figure in geometric
complex analysis for over a quarter of a
century. His theme of this set of lectures
was multiplier ideal sheaves as an interface
between analysis and algebraic geometry.

Multiplier ideal sheaves identify the loca-
tion and the extent of failure of estimates in
partial differential equations and describe
the degeneracy from instability in geometric
analysis. They have been applied to solv-
ing a number of outstanding conjectures in
algebraic geometry and also opened up a
new avenue of applying algebraic geometric
methods to solvability and regularity prob-
lems of partial differential equations.

Siu discussed how the idea of multi-
plier ideal sheaves arose historically from
two different perspectives, explained their
use in complex analysis and algebraic
geometry, and indicated many open ques-
tions where the use of multiplier ideal
sheaves may yet provide the key ingredi-
ent to solve them.

To see how multiplier ideal sheaves
arose from the perspective of failure of
estimates in partial differential equa-
tions, we look at the regularity question
of the \( \bar{\partial} \)-Neumann problem. Consider
the \( \bar{\partial} \)-equation \( \bar{\partial}u = f \) on a domain \( D \)
in \( \mathbb{C}^n \) for the unknown function \( u \) when
the given functions \( f_1, \ldots, f_n \) satisfying the
compatibility condition \( \delta f_j/\delta z^j = \delta f_i/\delta z^i \).
For the \( \bar{\partial} \)-equation on a weakly pseudo-
convex domain (which is the complex
analog of a weakly convex domain), Joseph
J. Kohn posed the regularity question
of the \( \bar{\partial} \)-Neumann problem which asks
whether \( u \) is smooth up to the bound-
ary when \( f \) is assumed smooth up to the boundary. A sufficient condition for the
regularity is that a certain estimate known
as the subelliptic estimate holds for the
test functions for the weak solution of the
equation. When the subelliptic estimate
is not yet known to hold, we multiply the
test function first by a function known as
a multiplier before doing the estimation
in order to make sure that the estimate
holds for the product. The sheaf of germs
of such multipliers is the multiplier ideal
sheaf. The zero-set and the vanishing order
of the multiplier ideal sheaf identify the
local position and the extent of the failure
of estimates. The multiplier ideal sheaf
corresponds to iteration of many levels of
micro-local analysis. Unlike micro-local
analysis which treats all the directions the
Impressions on the conference Non-linear Phenomena in Mathematical Physics

Dedicated to Cathleen Synge Morawetz on
her 85th birthday

This past September the Fields Institute
was proud to host a conference on non-
linear analysis, Non-linear Phenomena in
Mathematical Physics: Dedicated to Cathleen Synge Morawetz on her 85th birthday. The conference was co-spon-
sored by the Association for Women in
Mathematics (AWM) and, departing
slightly from the structure of most AWM
events, featured both women and men
speakers. In fact, slightly to the embar-
rassment of AWM, men outnumbered
women among the attendees. Making the
best of it, the organizers observed that the
influence of Cathleen Morawetz (former
President of the American Mathematical
Society, winner of the U. S. Presidential
Medal of Science, Fellow of the Royal
Society of Canada) has been so profound
that “we couldn’t keep the men out.”

This scientific meeting focused on the
legacy of Cathleen Morawetz and the impact
that her scientific work on transonic flow
and the non-linear wave equation has had in
recent progress on different aspects of analy-
sis for non-linear wave, kinetic and quantum
transport problems associated to mathemati-
cal physics. These are areas where the ele-
ments of continuum, statistical and stochastic
mechanics, and their interplay, have counter-
parts in the theory of existence, uniqueness
and stability of the associated systems of
equations and geometric constraints.

The conference, with a stellar group
of organizers, including Jim Colliander,
Susan Friedlander, Fern Hunt and Walter
Strauss, some of whom were also speak-
ers, was a central event for the applied
and computational analysis community.
The focus was on Partial Differential
Equations. There were 20 speakers
(including two Abel prize winners, Peter
Lax and Ragu Varadhan), 10 poster pre-
sentations, about 70 junior and senior
participants and, of course, the participa-
tion of Cathleen Synge Morawetz.

It was a happy occasion, not only to
celebrate Morawetz’s paramount con-
tributions to the theory of non-linear
equations in gas dynamics, and their
impact in the current trends of nonlinear

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Conference on **WOMEN IN NUMBERS**

**NOVEMBER 2-7, 2008**

Held at the Banff International Research Station

**Organizers:** Kristin Lauter (Microsoft), Rachel Pries (Colorado State), Renate Scheidler (Calgary).

**The idea for this conference was conceived a few years back by the organizers when they noticed the dearth of prominent female number theorists at a conference they were attending.**

The main goal of this workshop was to increase the representation and visibility of women in number theory, thereby enhancing gender diversity in the field. This was to be done by introducing female graduate students to potential advisers, collaborators, and thesis problems, and, as a more long-term objective, by increasing the participation of women in research activities in number theory and related applications.

Against the snowy backdrop of the Canadian Rockies, from the early morning talks to the late night working sessions, the atmosphere was joyful and warm. About 15 faculty, 16 junior faculty and postdocs, and 10 graduate students participated in the workshop.

The junior participants were divided into eight research groups, and distinguished female number theorists were chosen as group leaders. They selected and prepared projects in advance as well as providing materials and references for background reading to the students ahead of time. At the conference, they gave lectures, and directed the research efforts of their respective groups, mentoring students and younger researchers.

Many group members are currently writing joint research articles based on their research project in WIN.

As a result of this workshop, some of the participants will set up a network by establishing a wiki page for Women in Numbers. This will include information on female number theorists from different categories (active researchers, graduate and post-doctoral students, educators). The web page will link to the web pages of participants when possible, and will include an e-mail mailing list for discussion topics. There will also be a list and links to (male and female) advisers, collaborators, and co-organizers of conferences to try to increase the connectivity and inclusiveness of the community.

The organizers and participants are determined to continue working toward the goals of the workshop. Two of the next steps are publishing a top-quality conference proceedings volume, and organizing future follow-up and spin-off conferences, some of which will include both men and women in particular areas of number theory.

Following the standard process of BIRS workshops, participation in this meeting was by invitation only. Since the primary purpose was to highlight the activities of female researchers and bring together junior and senior female number theorists, only women were invited. The group leaders were chosen from established researchers in Canada, the United States, and South Korea. An open application process advertised for graduate students.

Thanks to our sponsors there were sufficient funds to provide travel support to graduate students, postdocs, unfunded young faculty, and the project leaders.

**Sponsors:** The Fields Institute, PIMS, Microsoft Research, the University of Calgary, and the United States National Security Agency.

*Shabnam Akhtari*
Conference on Infinite Dimensional Dynamical Systems

SEPTEMBER 24 - 28, 2008
Held at York University

Organizers: John Mallet-Paret (Brown), Jianhong Wu (York), Yingfei Yi (Georgia Tech), Huaping Zhu (York)

INFINITE DIMENSIONAL DYNAMICAL SYSTEMS are generated by evolutionary equations describing the evolutions in time of systems whose status must be depicted in infinite dimensional phase spaces. Studying the long-term behaviors of such systems is important in our understanding of their spatiotemporal pattern formation and global continuation, and has been among the major sources of motivation and applications of new development of nonlinear analysis and other mathematical theories. Theories of infinite dimensional dynamical systems have also found an increasing number of important applications in the physical and life sciences.

This conference was designed to bring together researchers working in different areas of the subject to celebrate the past achievements, to discuss recent progress and to stimulate and develop future collaborations. The very successful conference of over 80 participants from all over the world was held at York University, Sept. 24-28, 2008, thanks to generous support by the Fields Institute, PIMS and York University.

The forty-eight invited lectures covered a wide range of topics and addressed both the common features and distinctions in those infinite dimensional dynamical systems generated by parabolic partial differential equations, hyperbolic partial differential equations, solitary equations, lattice differential equations, delay differential equations, and stochastic differential equations.

The conference started with a talk by Barbara Keyfitz discussing the difficulties in conservation laws from the point of view of infinite dimensional dynamical systems. After some discussions about the essential difference between conservational laws and other infinite dimensional systems that behave somewhat like finite-dimensional dynamical systems, Keyfitz reviewed some of her collaborative work, providing critical tools for the understanding of the dynamics of multidimensional systems. Her talk was followed by lectures by Susan Friedlander, Michael Jolly and Genevieve Raugel on Onsager’s conjecture, on the global attractors and on the long-term behaviors of high dimensional Navier-Stokes equations.

Invariant manifolds and their approximations continue to be a major concept and to provide technical tools in the study of infinite dimensional systems, as was clearly illustrated in the conference. Peter Bates presented his work on using invariant manifold theory to reveal the global dynamics of boundary spike states for the generalized Allen-Cahn equation, and Chongchun Zeng described the unstable manifolds and $L^2$-nonlinear instability of the Euler equation. Alexandre N. Carvalho discussed perturbation of attractors, while Yuncheng You talked about the existence of global attractors of cubic autocatalytic reaction-diffusion systems. Through the presentations of Weishi Liu and Ken Palmer, singular perturbation techniques were shown to be effective tools in the investigation of the impact of turning points on global dynamics and homoclinic orbits.

A conference in this subject normally has many talks dedicated to the dynamics of parabolic equations, and this conference was no exception. Peter Polacik talked about parabolic Liouville theorems and their applications; Hiroshi Matano showed how a braid-group method can be used in the blow-up problem in nonlinear heat equations; and James Muldowney described the Bendixson conditions for differential equations in Banach spaces and used them to rule out periodic motions in certain parabolic equations. There were talks about “beyond” classical diffusion. For example, Chris Cosner considered conditional dispersal in ecological models, and Stephen Gourley presented a novel nonlocal reaction-diffusion model for cellular adhesion. Travelling waves and their connections to global dynamics as well as their applications to biological invasion, disease propagation and combustion were the central subject of a number of talks – by Wenzhang Huang, Xing Liang, Xiao-Biao Lin, Stephen Schecter, Wenxian Shen and Xiaoqiang Zhao.

Delay differential equations, another prototype of infinite dimensional dynamical systems, received the attention they deserved in the conference. Stefan Siegmund presented his work on a general qualitative theory for equations with random delay, based on the recent work of Zeng Lian and Kening Lu on generalized multiplicative ergodic theorem of Oseledec’s in Banach spaces. Delay differential equations with state-dependent delay were covered by a few featured talks: Hans-Otto Walther provided a brief account of his recent work on algebraic-delay differential systems in the temporal order of reactions, Roger Nussbaum and Tibor Krisztin presented their results on the global structure of solutions, intro-

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**“Are Cells Dynamically Critical?”**

**OCTOBER 31, 2008**
Stuart Kauffman
Institute for Biocomplexity and Informatics, University of Calgary

“Are Cells Dynamically Critical?”

**ON THE NIGHT OF HALLOWEEN 2008,** Professor Kauffman gave what might be a humbling survey of Theoretical and Mathematical Biology. He opened to the audience a box of questions, concerning the laws of nature and emergent structures in biology, particularly in the areas of evolution and ontogeny.

Professor Kauffman began by offering his conceptual framework and motivation for using Random Boolean Networks (RBN) to model Gene Regulatory Networks (GRN). He refers to GRNs as a system of synchronous “light bulbs” and used the tool of RBNs to describe the stability of these networks. He suggested that many interacting nodes within a network might protect the functionality of organisms from minor environmental perturbations. A useful analogy was made with pixels on a television screen such that if only a few pixels die out, the overall function of the screen is preserved. The stance established in the lecture was that one should have a global perspective, i.e., look at the GRN as a system rather than at its individual parts. Hence Kauffman is an advocate of the study of Systems Biology.

Several prospects worthy of note were introduced. The progress on Yeast Cell dynamics is promising, with respect to giving us insight and tools to study the GRNs of human cells. “Life in test tubes is not too far in the future,” says Professor Kauffman. He emphasized that the thermodynamic wake (a.k.a. energy) cycle of human life and efficiency of GRNs is not far from being understood. This could lead to the creation and understanding of a more general Theoretical Biology.

The usual network configurations for GRNs were modeled as existing “on the edge of chaos.” Hence many networks on one side of the boundary are robust and protected against minor perturbations. Conversely there exist configurations in a chaotic regime where organisms are very sensitive to their environment, and thus not fit to survive or evolve. Kauffman uses Hamming distances on Derrida graphs to classify networks into being chaotic or ordered. Critical networks are those on the boundary between the two. The model elucidates that being on the boundary will optimize robustness of cells to mutations and also optimize the capacity to evolve new cells types and configurations. On the boundary we discover that the Log-Log plot gives us an important slope of -1.5. Also, he gave a summary of other detailed models of critical biological networks and noted that theories of criticality seem to be a prominent theme in biology. This gives a special flavor to his evolutionary theory.

A small and informal forum followed the lecture continuing the conversation between the worlds of mathematics and biology. The discussion concluded with the vision of a bright future for Theoretical Biology and the conviction that Mathematicians will play a ‘critical’ role in the understanding of life.

Richard Cerezo and Irwin Pressman

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**COXETER LECTURE SERIES**
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Swinnerton-Dyer conjecture to more general situations.

First, let $Y = X_1 \times X_2 \times X_3$ be the product of three curves over a number field $k$ and let $\text{CH}^i(Y)$ denote the kernel of the rational map $\text{CH}^i(Y) \to \text{H}^{2i}(Y)$ from the Chow group of codimension-$i$ cycles on $Y$ modulo rational equivalence to cohomology. As a generalization of the Birch and Swinnerton-Dyer conjecture, the Beilinson-Bloch conjecture asserts that the rank of $\text{CH}^i(X)$ is finite, and equals the order of vanishing of the $L$-function $L(s, \text{H}^{2i-1}(Y)(i))$ at $s = i + 1$.

Specializing to $i = 2$, let $X$ be a smooth projective curve over a number field $k$, and fix $e \in X(k)$. There is a Gross-Schoen cycle $\Delta_e \in \text{CH}^2(X)^0$ defined by $\Delta_e = \{(x,x,e) : x \in X\} - \{(x,e,x) : x \in X\} - \{(e,x,x) : x \in X\} + \{(e,e,x) : x \in X\}$.

Now assume that $X$ is a Shimura curve, and choose cusp forms $f_1,f_2,f_3$ of weight 2. These define algebra homomorphisms $T \to \mathbb{C}$, where $T$ denotes the Hecke algebra, and $T^3$ acts on $\text{CH}^2(X)^0$ by letting each copy of $T$ act on one factor of $X^3$. This gives a cycle $\Delta_{f_1f_2f_3}$ that is closely related to $\Delta_e$, and after extending it to a cycle in Arakelov theory, its height $\Delta_{f_1f_2f_3}$ is a number which the Gross-Kudla conjecture asserts is related to $L'(2,f_1 \times f_2 \times f_3)$ in much the same way as the Birch and Swinnerton-Dyer conjecture relates the derivative $L'(E,1)$ to the height of a generating rational point when the rank of that elliptic curve equals 1.

As an application of this conjecture, Zhang then showed how a generalization of Grothendieck’s “standard conjectures” due to Gillet and Soulé overlaps with the Riemann hypothesis for $L(s,f_1 \times f_2 \times f_3)$.

As these lectures showed, some of Euler’s ideas have come very far, but still have a long way to go.

Paul Vojta
The Algebra Week kicked off with a day dedicated to the representation theory of finite dimensional algebras. The main speakers were Osamu Iyama (Nagoya), Bernhard Keller (Denis Diderot – Paris VII) and Claus Ringel (Bielefeld). The day opened with a lecture by Iyama on $n$-cluster tilting and $n$-APR tilting. He touched on Auslander’s notion of representation dimension, bringing us up-to-date on the most recent results on the subject. His lecture was followed by Bernhard Keller who spoke on quiver mutation and derived equivalence. A high point of his lecture was the java applet he had created with animated quiver mutations. The final talk of the first day was by Claus Ringel who gave a dynamic presentation on the structure of length categories.

Our two mini-courses aimed at graduate students began on Monday, along with a colloquium talk by Ringel at Carleton. Ringel’s riveting lecture focused on a class of algebras of representation dimension at most 3 called torsion-less finite algebras; these are algebras with only finitely many isomorphism classes of indecomposable modules that embed in projective modules. The mini-course at Carleton was taught by Osamu Iyama. His crisp lectures on Auslander-Reiten theory were a boon to the graduate students attending the talks. He gave both the functorial construction of almost split sequences, as well as the construction via Auslander-Reiten duality. Dlab suggested that Iyama’s notes presented an excellent viewpoint, worthy of being made generally available.

Equally well presented and attended was the mini-course at the University of Ottawa on PI-algebras, given by Vesselin Drensky (Bulgarian Academy of Science, Sofia) from Monday to Thursday. The taped lectures as well as Efim Zelmanov’s fascinating colloquium on *Asymptotic properties of finite groups and finite dimensional algebras* can be viewed at www.fields.utoronto.ca/programs/scientific/08-09/algebraweek/. In his lecture Zelmanov discussed limits of finite groups and finite dimensional algebras and their connections with number theory, low dimensional topology, combinatorics etc. This included, for example, topics such as the Burnside problem, Milnor’s problem on growth of groups, expander graphs and Kazhdan’s property (T), the structure of the Golod-Shafarevich groups, the Fontaine-Mazur conjecture on Galois groups of number fields, the Virtual Positive Betti-Number Conjecture by Thurston and Waldhausen, and his recent work with Petrogradsky and Shestakov on algebras with polynomial growth. It was an amazing view of diverse and fundamental problems, yet all connected by the concept of growth.

The colloquium was part of a 3-day conference (Friday-Sunday) celebrating our colleague Michel Racine on the occasion of his retirement. The topics of the conference were of course those close to Michel’s mathematical interests: nonassociative algebras. We were fortunate that the world’s leading experts in these areas came to Ottawa to take part in this conference. Allison (Victoria) and Faulkner (Virginia) talked on structurable algebras, Loos (Innsbruck) and Petersson (Hagen) on composition algebras, Anquela (Oviedo), McCrimmon (Virginia) and Zelmanov again on Jordan (super) structures, Shestakov (Sao Paulo) on Malcev algebras and Drensky on nilpotent derivations of polynomial algebras, a topic closely related to the Jacobian conjecture (for the record, he did NOT announce a solution of the conjecture) and Hilbert’s 14th problem.

Of course, part of the celebration was a big retirement party, graciously organized by Michel’s friend Henri Wong in his cottage, to which everyone was invited. It was a great party, even if at the end the bus couldn’t make it up a steep hill and all participants had to walk up the hill in the darkness of the night – a humorous event, which will not be easily forgotten.

Erhard Neher
diophantine approximation, and hyperbolic geometry with its close relative, Nevanlinna theory, is quite extensive. A correspondence was originally noted by C. Osgood in 1981 and further developed by P. Vojta starting in 1983. This correspondence proceeds roughly as follows. A non-constant holomorphic curve $f: C \rightarrow X$ in a complex projective variety $X$ corresponds to an infinite set of $k$-rational points on a projective variety $X$ over a number field $k$. One can think of the restriction of $f$ to the disc $|z| < r$ as corresponding to a single rational point. Under this correspondence, the metrical behavior of $f|_F$, the boundary $|z| = r$ can be compared with the metrical behavior of a rational point at archimedean places of the number field, and if $D$ is a divisor on $X$ then the analytic divisor $f^* D$ on $|z| < r$ can be compared with a similarly obtained divisor on $\text{Spec} O_k$, where $O_k$ is the ring of integers of $k$. If one makes this analogy, then Nevanlinna’s characteristic function $T_f(r)$ corresponds to the height of the rational point, and statements of theorems and conjectures in Nevanlinna theory translate over to statements of theorems and conjectures in diophantine approximation. The proofs of the foundational theorems, however, are quite different and at this time cannot be translated.

The analogy has spawned a different proof of the Mordell conjecture, which in turn led to proofs of conjectures of S. Zhang on rational points on closed subvarieties of abelian varieties and on integral points on their open subvarieties, as well as counterparts for semiabelian varieties. This analogy calls to mind a much older analogy in number theory, in which the ring $\mathbb{Z}$ and certain of its extensions are replaced by polynomial rings $\mathbb{F}[t]$ over a field $F$, and certain of its extensions. This leads to finite extensions of the field $F(t)$, which also arise as fields of rational functions on projective curves $B$ over $F$. Projective varieties $X$ over $F(t)$ extend to projective varieties $X$ over $F$ with a flat morphism to the base curve $B$. One can then apply standard methods of algebraic geometry (such as intersection theory) to $X$ to obtain Diophantine results on $X$. This methodology does not immediately carry over to the study of schemes over $\text{Spec} O_k$, however, since the latter is not a complete curve. This limitation is largely overcome by Arakelov theory, which adds structure at archimedean places of $k$ to replace much of what is lost by replacing $B$ with $\text{Spec} O_k$.

Arakelov theory has become a key tool in arithmetic geometry. In addition, complex manifolds and related objects play a key role in the theory – in fact some of its tools (such as secondary Chern classes) were originally developed for Nevanlinna theory.

This thematic program brought together the leading experts in the three areas of arithmetic geometry, hyperbolic geometry, and Arakelov theory. This was a welcome development, since there had not been an extended program in the fields for many years.

One unique aspect of this program was how it interwove the arithmetic and hyperbolic sides of the program. Long-term residents came from both fields: M. McQuillan, P. Vojta, P. Corvaja, C. Gasbarri, and H. Gillet from the arithmetic side; J. Noguchi, Y.-T. Siu, Pit-Mann Wong, S. Lu, and Min Ru from the hyperbolic side. The October workshop on arithmetic geometry and Arakelov theory was matched by the November workshop on hyperbolic geometry; the mini-workshop on $p$-adic dynamics paired with a mini-workshop on complex dynamics; and the Coxeter Lecture Series by S. Zhang emphasized arithmetic, whereas the Distinguished Lecture Series by Y.-T. Siu had more analytic flavour. Courses on Arakelov theory, on Nevanlinna theory and diophantine approximation, and on jet spaces ran throughout the semester.

Among the topics prevalent in the first workshop were recent results using Schmidt’s celebrated Subspace Theorem, on approximation to hyperplanes in projective space, which has been adapted to give results on more general divisors on arbitrary varieties. Other talks concerned work on extending the Lefschetz theorems to Arakelov theory, and an integral-points version of the Brauer-Manin obstruction to the Hasse principle.

One of the interesting aspects of the second workshop was that it reflected the growing interactions with other areas of current interest, such as random polynomials and random matrices. Topics ranged from classical Nevanlinna theory and hyperbolic geometry to the Torelli theorem over finite fields to problems on bounded symmetric domains arising from questions in arithmetic geometry.

Both workshops featured panel discussions on possible future trends in their respective areas, leading in each case to lively discussions on topics such as whether “Griffiths’ conjecture” is true (i.e., whether the Second Main Theorem extends in the same form to higher dimensions).

Dynamical systems, in which one studies behavior of measures or points under iterations of a map from a variety to itself, have been a growing area both in complex analysis and arithmetic geometry. In reflection of this, the program included two instructional mini-workshops to emphasize the importance of this circle of ideas to the main topics of the program. Attendees were able to see directly the parallel methods and results in these mostly separate areas.

Henri Gillet (UIC) was in residence for the semester as Clay Mathematics Institute Senior Scholar.

In his course on Arakelov Theory, he explained how the intersection theory on arithmetic surfaces introduced by Arakelov and Faltings can be generalized to arithmetic varieties $X$ of arbitrary dimension. His treatment featured a number of recent developments, including the use of the Deligne pairing in the case of surfaces, the use of cycle complexes constructed using Milnor K-theory, following Rost, and the use of Burgos’ approach to Green currents using relative real Deligne cohomology. These techniques, together with a judicious use of de Jong’s alterations, make it possible to carry over the Fulton-
MORAVETZ CONFERENCE IMPRESSIONS

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phenomena in mathematical physics, but also to serve as an awareness session of current women’s contribution to mathematics. Of the twenty speakers, seven were women, and many among them showed how their research has been inspired by or carried the legacy of Morawetz’s work.

At a gala banquet, held at the Faculty Club of the University of Toronto, Cathleen Morawetz’s friends and family toasted her achievements as a researcher, colleague, wife and mother, and stateswoman of the world mathematical community. And we saluted Constance Reid, whose letter to AWM President Cathy Kessel suggesting that the time was ripe for such a conference, started the whole affair. Not for the first, and, we hope, not for the last time, Cathleen enjoyed the banquet like the true Irishwoman she is — and showed up bright and early the next morning for the culminating set of talks.

WINDOWS INTO ELEMENTARY MATH

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(MeMcMaster University), explores spherical geometry and is titled Do Parallel Lines Meet?

The fourth Window features Lindi Wahl (UWO) on the topic of growth patterns.

Coming soon is a Window featuring Peter Taylor (Queen’s), on Telescopes and Paraboloids.

In the videos, the mathematicians also talk about their views of mathematics.

For example, Megumi Harada comments that “I love mathematicians. I can say that without any doubt the math students were the most fun to be around, and I think it’s because, as a group, mathematicians love what they do more than many, many other groups of people I know.”

When we asked Megumi Harada to identify her favourite interview clip, she said: I will admit that my favorite is the “I love mathematicians” clip -- so it’s not even about spherical geometry! The feelings about math and mathematicians that I was able to express in the “I love mathematicians” clip are actually very central to how I view the process of being a mathematician, yet is not something I have ever been invited to express on any previous occasion. It was a pleasure to have the occasion to acknowledge, even in this small way, the debt that I owe to all the mathematicians -- college classmates, graduate school friends, professional colleagues, et cetera -- who have supported me all this time.

George Gadainidis

ARITHMETIC HYPERBOLIC GEOMETRY

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MacPherson method of deformation to the normal bundle to the arithmetic situation. This gives a very satisfying and elegant definition of the functorial ring structure on the arithmetic Chow groups $CH^*(X)_{Q}$. Along the way to the proof of this fundamental result, Gillet’s lively and lucid lectures provided a wealth of background material and many valuable insights and explanations.

Yum-Tong Siu was in residence throughout the program as Dean’s Distinguished Visiting Professor at the University of Toronto, and gave a very enlightening and entertaining course on transcendental techniques in complex geometry. One of his themes in the course can be summed up by the following analogy: in both arithmetic geometry and hyperbolic geometry, metrics play a central role; in arithmetic geometry, one tries to concentrate the curvature at points, while in complex geometry, one tries to spread the curvature out over the entire space. Through this analogy, Siu suggested ways to think about the correspondence between the two areas.

In this course, Siu began with the definitions of complex manifolds, line bundles, metrics, connections and curvatures and rapidly progressed to surveying modern uses of multiplier ideal sheaves in complex analysis and algebraic geometry. The course emphasized the historical development, providing the basic understanding of how and in what manner new techniques and theories were developed. In the spirit of the program, his topics ranged from Bombieri’s proof of the Gelfond-Schneider theorem in arithmetic to an effective version of the Fujita conjecture, which is proved using analysis. He ended the course by outlining his proof of finite generation of the canonical ring, exhibiting the power of multiplier ideal sheaves.

Overall, the program was a beehive of activity, with two workshops, four graduate courses (on Arakelov theory, on number theory and Nevanlinna theory, on complex geometry, and on jet spaces), two “mini-workshops” on complex and $p$-adic dynamics, an affiliated weekend workshop held in Montreal, and lecture series by S. Zhang and Y.-T. Siu. Accordingly, it should have a lasting impact on the field.

Paul Vojta
arduously to expand and strengthen those relationships. She has persuaded leading mathematicians to participate in our programmes. She has demonstrated to the universities the value that Fields provides. She has taken our case to political and government leaders. She has been active with the international community of mathematics institutes, helping to co-ordinate their collective activity and programming. The impact of this effort is to be found in a growing external appreciation of Fields, its rising reputation in the world, and the diversity of the participants in its activities.

A successful institute, however, requires more than vision and a network of relationships. There needs to be a strong internal pulse. There has to be a buzz about the place. An institute’s rhythm keys off the approach of its director, and at Fields Barbara has demonstrated constant energy and drive. Many times I have witnessed moments where Barbara says, “That’s it for talk. Now we need a decision and action.” This directness, the hallmark of any successful organization, is especially important to an institute such as Fields, which depends upon short-term and part-time contributions from so many. Barbara knows how to extract and harness that energy.

Academics coming to work and participate at Fields have always remarked on the cheerfulness of the place. That goodwill and the atmosphere present at 222 College Street flows from our staff. Barbara recognized the asset Fields has in its staff, and has helped develop and guide its members as they have learned to deal with the increased workload of the Institute, without in any way impairing its reputation as a good place to be.

Bringing to life a vision, working with the Institute’s clients, the endless expenditure of energy, and the constant urging of staff combine to suggest an environment characterized by pressure with exhaustion building steadily as the day progresses. Fields is a busy place to be, a place where many balls are up in the air at all times. The pressure could be intimidating, perhaps discouraging, but never for Barbara. She can always see the humour in a situation, whether it is an idea we have eventually concluded is leading nowhere, or a relationship that is turning unnecessarily difficult. Barbara’s ability to laugh smoothes the ride over the bumps.

When Barbara accepted our offer to become Fields’ Director in 2004, she was uncertain as to whether she was going to like the role of a senior, full-time academic administrator. At the end of this year Barbara will join the faculty of Ohio State University in Columbus, where her husband Marty has become Director of the Mathematical Biosciences Institute. I hope Barbara has enjoyed her experience at Fields, and the visible signals suggest she has. I know that Fields will benefit from Barbara’s continued involvement on our Board and on our Scientific Advisory Panel. I also suspect Marty will find her a very wise counsellor with respect to his Institute.

John Gardner

same way, the multiplier ideal sheaf technique distinguishes certain directions and jet directions.

The second perspective of the multiplier ideal sheaves is related to the notion of stability. When a differential equation is solved by using the continuity method or by using an evolution equation such as the heat equation, the most crucial part of the problem is the convergence of the limit or the closedness question. In order to get the convergence of some subsequence in the norm under consideration, according to the technique of Ascoli-Arzelà, we try to get a uniform bound in some stronger norm. For example, in order to get the $L^2$ convergence for some subsequence, we can use a uniform bound of the $L^2$ norm for derivatives up to the first order. The $L^2$ norm for first-order derivatives scales differently from the $L^2$ norm without derivatives. To use ever smaller coordinate charts with varying scaling to normalize the stronger norm, such as the $L^2$ norm for derivative up to the first order, is the same as estimating the stronger norm after inserting a multiplier to account for the varying scaling. In the limit the base manifold jumps to a new structure defined by the multiplier ideal sheaf and becomes unstable. In this perspective the multiplier ideal sheaf is known as the destabilizing subsheaf. The work of Alan Nadel on the problem of the existence of Kähler-Einstein metrics on Fano manifolds and the work of Donaldson and Uhlenbeck-Yau on the relation between Hermitian-Einstein metrics for vector bundles and their stability are used as examples to illustrate this perspective of the multiplier ideal sheaves.

The technique of multiplier ideal sheaves has been applied to obtain effective results in algebraic geometry, such as the Fujita conjecture, the effective Matsusaka’s big theorem, and the effective Nullstellensatz. Both the Fujita conjecture and the effective Matsusaka big theorem are effective versions of Kodaira’s embedding theorem, which states that for a positive line bundle $L$ on a compact complex algebraic manifold $X$, global holomorphic sections of $mL$ over $X$ can distinguish points and give local coordinates when $m$ is noneffectively sufficiently large. The Fujita conjecture states that when the complex dimension of $X$ is $n$, at every point $P$ of $X$ there is a global holomorphic section of $mL + K_X$ which is nonzero at $P$ for $m \geq n + 1$. Moreover, global holomorphic sections of $mL + K_X$ over $X$ can distinguish points and give local coordinates for $m \geq n + 2$. The effective Matsusaka big theorem gives an explicit bound $m_0$ depending on the Chern numbers $L^n$ and $L^{n+1}K_X$ such that global holomorphic sections of $mL$ over $X$ can distinguish points and give local coordinates for $m \geq m_0$. The effective Nullstellensatz is the effective version of the Hilbert Nullstellensatz. For the other direction the method of multiplier ideal sheaves makes it possible to apply algebraic geometric methods to...
ous mini-symposia and contributed talks that comprised the bulk of the 4 day conference. The sessions spanned a broad range of topics in mathematical biology, although cancer remained a major theme of each. Seven other plenary speakers, T. Secomb (Arizona), H. Levine (San Diego), M. Knothe-Tate (Case Western), N. Komarova (Irvine), Y. Zhou (China), M. Lewis (Alberta) and M. Golubitsky (MBI) gave distinct perspectives on their particular areas of research in mathematical biology.

SMB2008 elided smoothly into the CMM/VICBC 4th workshop/summer school “Current Challenges in Oncology: Through the mathematical looking glass” which ran from August 2-6. This was based on the exemplary hands-on workshops pioneered by VICBC over the previous three years. This workshop brought the Vanderbilt efforts to a new level. We were fortunate in managing to assemble an excellent collection of faculty (thanks to the tireless efforts of Dr. Lourdes Estrada, VICBC) as well as over 70 graduate students and postdocs. The students were divided into four groups, each under the mentorship of several faculty (mathematical, biological and clinical) and were actively engaged in current problems of interest to basic scientists and clinicians in oncology. The Fields Institute was a constant hive of activity over this period, with many participants working through the night in a contagiously enthusiastic and stimulating atmosphere. This was fortified by the ever-flowing supply of coffee and tea from the Fields Institute (the staple of every successful mathematical institute!) The workshop was a resounding success by all accounts, and extremely successful in exposing and engaging a new generation of researchers to a new paradigm of biomedical research. Ultimately, the aim is to generate a critical mass of young researchers, well-versed in both mathematics and oncology to whom the torch will be passed. Energized by the workshop, many of the participants remained for the Coxeter lectures.

CMM and Fields were delighted to welcome Martin Nowak of Harvard University to deliver the Coxeter lectures. He presented three highly engaging and accessible talks in a style perfectly suited to the mixed audience of biomedical and mathematical scientists. Nowak covered three directions in his research (in which he has made seminal contributions): the evolutionary dynamics of cancer, discrete models of evolution, and the evolution of co-operation. Nowak expounded masterfully on evolutionary dynamics, the mathematical study and description of evolution. Why is this an important field? Nowak commented that the renowned geneticist T. Dobzhansky had once stated that “nothing in biology makes sense except in the light of evolution.” It is Nowak’s contention that ideas in evolutionary biology are crying out for a mathematical description, since evolutionary biology is based on very simple and very precise fundamental principles – namely, selection and mutation. A mathematical description of these simple concepts has contributed to more precision and a deeper understanding in evolutionary biology. Clearly one of the major applications of the mathematical models developed, is in the study of cancer progression.

“the aim is to generate a critical mass of young researchers, well-versed in both mathematics and oncology to whom the torch will be passed”

In summary, the workshops/conference and the thematic program as a whole provided a focused, stimulating (if demanding) two month period where many collaborations were forged and new research directions set. In many respects, it exceeded our expectations and represents the “coming of age” of CMM. It is also the dawning of a new era of collaborative, inclusive interdisciplinary research and we look forward to future collaborations with VICBC and OICR and indeed with other mathematical bioscience institutes and centres. In his “Opus Majus,” Roger Bacon comments that “The strongest arguments prove nothing so long as conclusions are not verified by experience…. Experimental science is the queen of all sciences and the goal of all speculation.” On reflection, the program very successfully brought together the experimental sciences (cancer biology, clinical oncology) and the mathematical sciences to move the field forward under a new paradigm and under the new banner of “integrative mathematical oncology.”

Siv Sivaloganathan
Global attractivity of solutions of differential equations, both retarded or neutral types, with infinite delay and monotonicity were discussed in the talks by Carmen Núñez and Rafael Obaya. Yuming Chen gave a rather complete description of the global attractor of a delayed differential system with monotone feedback, and Bernhard Lani-Wayda showed, for a scalar equation, how disk-like global attractors change when the nonlinearity changes to non-monotone shapes.

Two other speakers, Sue Ann Campbell and Connell McCluskey, added further to the strong Canadian representation in the subject area: Campbell considered a model for regenerative chatter in a drilling process and some perturbation techniques to obtain the delayed induced Canards, and McCluskey illustrated how the classical Lyapunov functional method coupled with some local analysis can yield the global asymptotic stability of a disease model with distributed delay. The interface between spatial diffusion and time delay were addressed by the talks of Sérgio Oliva and Xingfu Zou.

Horst Thieme’s talk concerned the classical but difficult issue of differentiability of convolution operators in solving an abstract linear inhomogeneous evolution equation, where the linear part gives rise to an integrated semigroup. Semilinear equations involving integrated semigroups and a non-densely defined Cauchy problem were then discussed in back-to-back presentations by Pierre Magal and Shigui Ruan, focusing on the center manifold theorem and applications to structured population models.

Martin Golubitsky talked about feed-forward networks near Hopf bifurcation and illustrated how the theoretical work finds applications to auditory receptor cells on the basilar membrane in the cochlea. Pattern formation due to the interaction of symmetric coupling and feedback was addressed by Yuan Yuan, and the realization of critical eigenvalues for linear delay-differential equations with multiple delays and with a certain symmetry was discussed by Pietro-Luciano Buono.

There were a couple of talks about data and databases, by and for nonlinear dynamical systems: Arno Berger spoke about “Digits and dynamics: from finite data to infinite dimensions” while Konstantin Mischaikow discussed “Building a database for global dynamics of parameterized nonlinear systems.”

The conference concluded with a talk by Walter Craig that provided an authoritative update of some remarkable progress on infinite dimensional Hamiltonian systems. Hamiltonian systems were also discussed by Yingfei Yi.

This conference was dedicated to Professor George Sell of the University of Minnesota on the occasion of his 70th birthday. Sell was honored by an invitation to deliver a public lecture “An evolution in evolutionary equations”. His lecture and the reception following the lecture were sponsored by Mathematics for Information Technology and Complex Systems (MITACS). Sell described some of the historical developments of the theory of infinite dimensional dynamical systems during the last 50 years, with particular focus on the theory of the dynamics of solutions of partial differential equations, and specially on the applications of the theory of the Navier-Stokes equations in fluid flows. A number of colleagues from Minnesota delivered their best wishes to Sell, along with their lectures, including: Marta Lewicka on “Derivation of shell theories from 3d nonlinear elasticity” and Arnd Scheel, about “How robust are Liesegang patterns?”.

A special feature presentation was jointly given by John Mallet-Paret and Gerry Sell consisting of some personal anecdotes of Sell’s mathematics and life, providing an excellent view of the evolution of evolution equations and the dynamics of the study of dynamical systems by a legendary figure with infinite energy.

Jianhong Wu

Distinguished Lecture

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regularity problems in partial differential equations as illustrated by the algorithm which Kohn introduces to generate multipliers for the regularity question of the $\sigma$-Neumann problem. In his algorithm new multipliers can be constructed by applying some process of differentiation to known multipliers so that, under some geometric condition involving a uniform bound for the order contact between the boundary of the domain and local complex-analytic curves, the subelliptic estimate can be shown to hold by generating the constant function 1 as a multiplier from the algorithm. The relation between the estimate and the geometric condition of the boundary comes from the idea that the directions of failure of estimates given by the multiplier ideal sheaves cannot be integrable in the sense of Frobenius.

Finally, it should be mentioned that the techniques of multiplier ideal sheaves are central to Siu’s recent work on the deformational invariance of the plurigenera and the finite generation of the pluricanonical ring.

Siu’s beautifully constructed lectures gave a very nice overview of how the techniques of multiplier ideal sheaves provide a unifying framework in which to understand many problems which arise in analysis and geometry, and how the structure of the sheaf inherits structure coming from the original situation. The multiplier ideal sheaf effectively captures the geometry of the degeneracies/singularities and even encodes the microlocal nature of the problem.

John Bland
The first method also led to concluding that the series
\[ 1 + 0 + (-1) + 1 + 0 + (-1) + ... = \frac{2}{3} \]
as we will later see since the partial sums are 1, 1, 0, 1, 0, ...

Gillet then returned to the general question of how to sum a series \( a_0 + a_1 + \cdots + a_n + \cdots \) which is possibly divergent according to the modern point of view. There are some reasonable conditions to require:

1. If the series converges, its sum should be \( \sum a_n \) in the usual sense.

2. If \( a_0 + a_1 + \cdots + a_n + \cdots \) and \( b_0 + b_1 + \cdots + b_n + \cdots \) are summable in the new sense, then so is \((a_0 + b_0) + (a_1 + b_1) + \cdots = (a_0 + a_1 + \cdots) + (b_0 + b_1 + \cdots)\).

3. \( a_0 + (a_1 + \cdots + a_n + \cdots) = a_0 + a_1 + \cdots + a_n + \cdots \)

One possible approach if a series has an infinite sum in the usual sense, is to subtract \( \infty \) from it in some consistent way to obtain a finite sum. This is similar to the "renormalization" process in physics.

Gillet then discussed two other approaches: Abel and Cesàro summability. The series \( a_0 + a_1 + \cdots + a_n + \cdots \) is Abel summable if, first of all \( a_0 + a_1x+ \cdots + a_nx^n + \cdots \) converges for \( |x| < 1 \), and secondly the limit of \( a_0 + a_1x + \cdots + a_nx^n + \cdots \) exists as \( x \) approaches 1 from the left. And then of course its sum is defined to be this limit. The series is Cesàro summable if the sequence \((s_0 + s_1 + \cdots + s_n) / (n + 1)\) of averages of the partial sums of the series converges, and then again the sum is defined to be the limit.

Both of these methods satisfy the properties 1., 2. and 3. above and furthermore if a series is Cesàro summable, it is Abel summable (with the same sum). For example the series \( 1 + 0 + (-1) + 1 + 0 + (-1) + ... \) considered earlier is easily seen to have Cesàro (and Abel) sum \( \frac{2}{3} \) since the averages of the partial sums are
\[ 1, 1, \frac{2}{3}, \frac{3}{4}, \frac{4}{5}, \frac{2}{3}, \frac{5}{7}, ... \]

One can think of a more general approach similar to Abel summation, namely: find a function involving \( a_0, a_1, \ldots, a_n, \ldots \) and then define the sum \( a_0 + a_1 + \cdots + a_n + \cdots \) to be given by some particular value of the function. For example one can use the Riemann zeta function to evaluate \( 1 + 2^k + 3^k + \cdots \) (a nonnegative integer) in this way: the zeta function is defined to be
\[ \zeta(s) = 1 + 1/2^s + 1/3^s + \cdots \]
and is easily seen to be convergent for \( s > 1 \) — or \( \text{Re } s > 1 \) if one considers \( s \) as a complex variable — as one must for this method to be applied. In fact \( \zeta(s) \) is then an analytic function for \( \text{Re } s > 1 \), and can be analytically continued to a meromorphic function in the complex plane, holomorphic everywhere except for a pole at \( s = 1 \). If this is done, one can define \( 1 + 2^k + 3^k + \cdots \) (for \( k \geq 1 \)) to be \( \zeta(-k) \), which is known to be \( -B_1 + 1/(k + 1) \) where \( B_k \) is the \( k \)th Bernoulli number defined by
\[ x/(e^x - 1) = \sum_{n=0}^{\infty} B_n x^n/n! \]

Thus
\[ 1 + 2 + 3 + \cdots = \zeta(-1) = -B_1/2 = -\frac{1}{12}, \]
and
\[ 1 + 1 + 1 + \cdots = \zeta(0) = -B_1 = -\frac{1}{2}, \]
a result known to Euler — which he worked out in a manner similar to this example, in spite of the fact that the Riemann zeta function had not yet been defined!

At this point, Gillet returned to the problem in the title, a definition (or determination?) of \( \infty \). He first introduced the “alternating” version of the zeta function:
\[ L(s) = 1 - 1/2^s + 1/3^s - 1/4^s + \cdots \]
and then applied the “Euler transformation”, giving
\[ L(s) = \frac{1}{2s}(1 + (1 - 1/2^s) - (1/2^s - 1/3^s) + (1/3^s - 1/4^s) - \cdots \]
which implies that
\[ L(0) = \frac{1}{2}. \]
(One can show that \( L(s) \) actually converges for \( s > -1 \). Simple algebraic manipulation shows that \( \zeta(s) - L(s) = 2^{1-s} \zeta(s) \) so
\[ \zeta(s) = \frac{1}{1 - 2^{-s}} L(s), \]
and then a little freshman calculus that the derivative

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 DIRECTOR’S MESSAGE
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Directors allows this institutional memory to be transferred from one directorate team to the following one. The Board of Directors also plays an important role in this regard. There are, of course, transcription errors in this copying of memory, but this is probably just as desirable as it is in the evolution of biological systems. And, of course, it would be a major oversight to forget that a critically important source of stability in the dynamical system that is the Institute is the permanent staff, who are crucial to the successful running of all scientific programs, as well as the maintenance of the Institute and its finances.

However, this discussion of the stability of the Institute is not intended to leave the impression that changes are impossible, or even difficult. As I admitted at the outset, though, the hard part is in determining which changes are desirable; and knowing how to solve problems about leaking cisterns is of no help at all in answering that question.

CLAY SENIOR SCHOLAR LECTURE
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\[ \zeta'(0) = -\frac{(2 \log 2)}{2 - \Lambda'(0)} = -\log \]

and, since the derivative of \(1/n^s\) at \(s = 0\) is \(-\log n\),

\[ \Lambda'(0) = \frac{1}{2} (\log 2 - (-\log 2 + \log 3) + (-\log 3 + \log 4) + \ldots) \]

\[ = \frac{1}{2} (\log 2 + \log (2/3) + \log (4/3) + \log (4/5) + \log (6/5) + \ldots) \]

\[ = \frac{1}{2} \log \left(1 + \frac{2}{3} + \frac{2}{3} + \frac{4}{5} + \frac{4}{5} + \ldots\right) \]

\[ = \frac{1}{2} \log \frac{\pi}{2} \]

since \[\frac{\pi}{2} = \frac{2}{3} + \frac{2}{3} + \frac{4}{5} + \frac{4}{5} + \ldots\]

by the “classical” Wallis product for \(\frac{\pi}{2}\).

But

\[ \zeta'(s) = \sum_{n=1}^{\infty} (-\log n)/n^s, \]

so formally

\[ \zeta'(0) = \sum_{n=1}^{\infty} (-\log n) = -\log (\infty!) = -\log \left(\frac{\pi}{2}\right), \]

and therefore

\[ \log (\infty!) = \log \sqrt{2\pi}, \]

so

\[ \infty! = \exp(\log \sqrt{2\pi}) = \sqrt{2\pi}. \]

QED!!

Carl Riehm

GENERAL SCIENTIFIC ACTIVITIES
continued from page 20

MAY 11-21, 2009
Summer School in Applied Probability
Carleton University

MAY 21-23, 2009
Extremal Graph Theory Workshop
University of Waterloo

MAY 22-23, 2009
Discrete Mathematics Days 2009
University of Ottawa

MAY 25-28, 2009
2nd Canadian Discrete and Algorithmic
Mathematics Conference (CanaDAM)
CRM, Montréal, Quebec

MAY 27-28, 2009 - 3:30 P.M.
Distinguished Lecture Series in Statistical
Science
David Spiegelhalter, Winton Professor of
the Public Understanding of Risk,
Centre for Mathematical Sciences,
Cambridge

MAY 27-28, 2009
A Symposium and Workshop in Honour
of James C. Fu
University of Manitoba

MAY 27-31, 2009
Workshop on Geometry Related to the
Langlands Programme
University of Ottawa

MAY 29-30, 2009
Appalachian Set Theory Workshop

JUNE 1-5, 2009
Coclques and Colourings
University of Waterloo

JUNE 15-27, 2009
Summer School on Geometric
Representation Theory and Extended
Affine Lie Algebras
University of Ottawa

JUNE 22-26, 2009
OCCAM-Fields-MITACS Workshop
University of Toronto

JUNE 27-JULY 29, 2009
Mini Conference in Number Theory
Carleton University

JUNE 28-JULY 3, 2009
Conference in Geometric Representation
Theory and Extended Affine Lie Algebras
University of Ottawa
Call for Proposals, Nominations, and Applications

For detailed information on making proposals or nominations, please see the website: www.fields.utoronto.ca/proposals

General Scientific Activities
Proposals for short scientific events in the mathematical sciences should be submitted by October 15, February 15 or June 15 of each year, with a lead time of at least one year recommended. Activities supported include workshops, conferences, seminars, and summer schools. If you are considering a proposal, we recommend that you contact the Director, or Deputy Director (proposals@fields.utoronto.ca). Also see www.fieldsinstitute.ca/proposals/other_activity.html

Thematic Programs
Letters of intent and proposals for semester long programs at the Fields Institute are considered in the spring and fall each year, and should be submitted by March 15 or August 31. Organizers are advised that a lead time of several years is required, and are encouraged to submit a letter of intent prior to preparing a complete proposal. The Fields Institute has started a new series of two-month-long summer thematic programs focussing on interdisciplinary themes. Proposals for the summer of 2010 are now being considered. Organizers should consult the directorate about their projects in advance to help structure their proposal.

Call for Participation: Hong Kong Study Group
Fields is in a partnership to organize the 2009 Hong Kong Workshop on Industrial Applications with the LBJ Center at the City University of Hong Kong. The tentative date for the workshop is Dec 7-11, 2009. Fields will provide support up to $2,000 towards travel expenses for two academic participants while local expenses (accommodation and food) will be covered by the LBJ Center. This 5-day workshop will follow the same format as the Oxford Study Group. Participants will be working on problems coming from non-academic sources. It is an excellent opportunity for young faculty, postdocs and graduate students to learn modeling and problem solving skills. Interested applicants should email their CVs to programs@fields.utoronto.ca by March 31, 2009.

Fields Research Immersion Fellowship
This program supports individuals with high potential to re-enter an active research career after an interruption for family responsibilities. To qualify, candidates must have been in a postdoctoral or faculty position at the time their active research career was interrupted. The duration of the career interruption should be at least one year and no more than eight years. Examples of qualifying interruptions include a complete or partial hiatus from research activities for child rearing; an incapacitating illness or injury of the candidate, spouse, partner, or a member of the immediate family; or relocation to accommodate a spouse, partner, or other close family member. The RIF will participate fully in the thematic program, in the expectation that this will allow her or him to enhance her or his research capabilities and to establish or re-establish a career as a productive, competitive researcher. The award is to be held at the Fields Institute, but there are no restrictions on the nationality or country of employment of the re-entry candidate.

For programs in a given program year (which runs July to June) the closing date will be August 31 of the year before. A later application deadline, February 28, 2009, is set for the programs in 2009-2010. Applications should be sent by email to the Director. Late applications will be considered if the position has not yet been filled.

More details can be found at: www.fields.utoronto.ca/proposals/research_immersion.html

CRM–Fields–PIMS Prize
Nominations are invited for this joint prize in recognition of exceptional achievement in the mathematical sciences. The candidate’s research should have been conducted primarily in Canada or in affiliation with a Canadian university.

Please send nominations to: director@pims.math.ca

Nominations for the CRM-Fields-PIMS Prize should reach PIMS by November 1, 2009.

Distinguished Lecture Series in Statistical Science (DLSS)
Nominations are being solicited for the eighth Fields Institute Distinguished Lecture Series in Statistical Science, to be given in 2010. The awardee will be an internationally prominent statistical scientist, who will give two lectures (one general, one specialized) at the Fields Institute.

Nominations for the DLSS should reach the Institute by October 1, 2009, although late applications may be considered. DLSS nominations should be sent to Nancy Reid c/o Fields Institute or directly to reid@utstat.utoronto.ca
JANUARY – AUGUST 2009

Thematic Programs

THEMATIC PROGRAM ON O-MINIMAL STRUCTURES AND REAL ANALYTIC GEOMETRY

JANUARY-JUNE 2009
Organizers: David Marker (Chicago), Chris Miller (Ohio State), Jean-Philippe Rolin (Bourgogne), Patrick Speissegger (McMaster), Carol Wood (Wesleyan)

JANUARY 12 - 16, 2009
Winter School in o-minimal Geometry

MAY 25-29, 2009 (TENTATIVE DATES)
Distinguished Lecture Series: Jean-Christophe Yoccoz, Collège de France

JUNE 22 - 26, 2009
Workshop on Finiteness Problems in Dynamical Systems

THEMATIC PROGRAM ON THE MATHEMATICS IN QUANTUM INFORMATION

JULY-AUGUST 2009
Organizers: David Kribs, Chair (Guelph), Raymond Laflamme (Waterloo), Kevin Resch (Waterloo), Mary Beth Ruskai (Tufts)

JULY 6-10, 2009
Workshop on Operator Structures in Quantum Information

JULY 26-31, 2009
Workshop on Quantum Marginals and Density Matrices

AUGUST 10-14, 2009
Mathematics in Experimental Quantum Information Processing Workshop
Institute for Quantum Computing, Waterloo

AUGUST 17-21, 2009
Canadian Quantum Information Summer School

AUGUST 2009
Canadian Quantum Information Student Conference
Institute for Quantum Computing, Waterloo

General Scientific Activities

MARCH 1, 2009 - 3:00 P.M.
Royal Canadian Institute Sunday Lectures
Florin Diacu, University of Victoria
Macleod Auditorium, Medical Sciences Building, 1 King’s College Circle
Co-sponsored by the Fields Institute

MARCH 31, 2009
Public Lecture: Maya Bar-Hillel

APRIL 20-22, 2009
Workshop on Computational Methods for Hyperbolic Problems
University of Waterloo

APRIL 29-MAY 1, 2009
Third Annual Meeting of the Prairie Network for Research in Mathematical Sciences and Student Workshop
University of Saskatchewan

MAY 1-3, 2009
Workshop on Smooth Structures in Logic, Category Theory and Physics
University of Ottawa

MAY 3-5, 2009
Nonparametric Statistics Conference
Carleton University

MAY 8-10, 2009
Conference on Connections in Geometry and Physics
Perimeter Institute

MAY 11-13, 2009
The 4th Workshop on Theory of Quantum Computation, Communication, and Cryptography (TQC 2009)
Institute for Quantum Computing, University of Waterloo

MAY 15-17, 2009
Workshop on Discrete and Computational Geometry
Carleton University

MAY 11-15, 2009
Fields Cryptography Retrospective Meeting

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DIRECTOR'S MESSAGE: Rates of Change

Calculating change and using it to gain insights into the problems with which they are grappling is how many mathematicians spend their working hours. Hand an even moderately capable student an improbably shaped cistern, with water gushing in from one end and brine leaking out the other, and you are likely to get a good prediction for the future salinity of the contents. But how should we go about gauging the changes that take place at a mathematics institute? An even more difficult problem, and surely one which is not well posed, is that of determining whether any particular change is going to be good or bad for mathematics.

I am, of course, thinking about these questions because I am writing this editorial on the cusp of significant changes at the Fields Institute. After four years as Director, Barbara Keyfitz will be returning to a more conventional academic appointment (but certainly not to a conventional academic career) at Ohio State. The changes that have taken place during her time at the Institute have been varied, and many of them profound. One change that may not be as well known as it should be is the establishment of an effective diversity policy. Scanning the Fields web site for the guidelines on mentoring on policies that did not exist when Barbara took over. A much better change that may not be as well known as it should be is the establishment of an effective diversity policy. Scanning the Fields web site for the guidelines on policies that did not exist when Barbara took over. 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have even greater impact on mathematics in Canada.

However, change is not always predictable, to say nothing of controllable, and the new director, Ed Bierstone, will likely face a less hospitable financial climate when he takes over in July 2009. While the Institute’s current funding is in place for five years, it is not yet clear how the economic upheaval being experienced by all sectors of society will alter the activities of the Institute.

As I have already mentioned, I find myself at the cusp of these changes and I expect to be riding this cusp as the Acting Director of Fields for the six months between the end of Barbara’s term in December and the start of Ed’s. (Does one ride a cusp? I think not, but the correct metaphor seems too gruesome to contemplate.) Along for the ride will be Matthias Neufang, who will leave his position as Associate Dean of Graduate Studies at Carleton to take on the posi-

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