AUTUMN 2006

NEWSLETTER OF THE DEPARTMENT OF MATHEMATICS AT THE UNIVERSITY OF WASHINGTON

Mathematics NEWS

$$f(z) = \frac{1}{2\pi i}\int_C \frac{f(\zeta)}{\zeta - z}\,d\zeta$$

CONTENTS

Pictured (front cover):

Upper left: Assistant Professor Isabella Novik – See article page 12.

Middle: Photo from the 2006 Undergraduate Honors Luncheon; (back row from left) Yuan Luo, Alvin Raj, Matt Halpin, Noah Giansiracusa, Owen Biesel, Ting-You Wang, Jerry Pan, Kyle Littlefield (front row from left) Paco Cruz, Praveen Venkataramana, Laura Kelly (Hodgson), Surekha Sydney, Eliana Hechter, Ming Li – See article page 6.

Lower right: Eliana Hechter – See article page 4.

MESSAGE FROM THE CHAIR

For over two thousand years mathematics has been characterized by rigor and infallible reasoning through theorem-proof. This characteristic and its utility in problem-solving have placed the subject at the core of science and engineering.

One indication of the significance of ongoing mathematics research is the multitude of applications that are in development. In the case of our department, faculty are engaged in research that is being applied in computer network security, image recognition, digital representations of three-dimensional objects, and the management of financial portfolios, to name a few examples. Gunther Uhlmann, the inaugural Walker Family Endowed Professor, describes in an article the applications of his research to medical imaging. Another faculty member working in the same research area, John Sylvester, is engaged in a collaboration that focuses on the detection of land mines. In addition to applying existing theory, such projects yield experimental data that will feed into new theorems. Theory motivated by applications will often identify critical properties, or make predictions, which can then guide the experimentalist. Collaboration and interaction are the crucial words.

Mathematicians develop mathematical structures and ideas, and aim to understand relationships between different parts of the mathematical fabric. This quest is guided by a desire for absolute truth and a notion of beauty that is very real to the trained mathematician. It relies on insight researchers sharpen through experience, and is often motivated by fundamental examples. Computers have made it possible to call upon examples that were previously beyond reach. William Stein, who joined our department this year, complements his work in number theory with a project called SAGE: Software for Algebra and Geometry Experimentation, whose purpose is to create a unified open source mathematics package. The students who work on this project are introduced to mathematical ideas and research in an environment that is rare in mathematics, though not dissimilar to that of a scientific lab. An article by Sándor Kovács, the inaugural McKibben and Merner Endowed Professor, describes his research at the crossroads of two of the main branches of mathematics, where polynomials and geometric objects meet.

Vigorous research is fundamental to everything the Department does. It brings excellent faculty members to the Department, who hold the key to our continuing success in research and education—missions that are inextricably linked. We have had the privilege of attracting excellent graduate students and some of the strongest UW undergraduate students into our programs. You will read in the following pages about some of their achievements. It is a pleasure to offer students an environment of research and education in which they can thrive as they acquire the mathematical training that carries them into the future. We are grateful to the Department's alumni and friends for their support of our work.

— SELIM TUNCEL

FEATURED GRADUATE: ELIANA HECHTER

Eliana Hechter: Not "Just" a Rhodes Scholar

UW Mathematics major Eliana Hechter made headlines last year when she was selected as a Rhodes Scholar at the age of 18. While certainly impressive on its own, this prestigious award is also the culmination of a noteworthy undergraduate career.

Four years prior to winning the Rhodes Scholarship, Eliana began her university career at the age of 14. After initially entering through the UW's Early Entrance Program, she studied abroad in Rome and took part in a marine biology research apprenticeship at the Friday Harbor Labs before setting her sights on mathematics as her field of study.

> **"She was very enthusiastic, energetic, and ambitious…"**
> **—Prof. Steffen Rohde**

It was at Friday Harbor that she first caught the math bug. One element of the apprenticeship was an abstract mathematics course taught by Biology Professor Gary Odell, who used mathematical concepts to illustrate real-world occurrences in a way that was fascinating to her. Eliana didn't just take an interest in the subject; she even went so far as to revise the lecture notes in order to make them more accessible to those not as familiar with mathematics. Once the apprenticeship was over, she plunged into mathematics, taking as many courses as possible.

By March of 2004, Eliana's study in mathematics was strong enough to earn her the prestigious Goldwater Scholarship. This scholarship, in honor of Senator Barry Goldwater, is designed to assist outstanding students in the pursuit of a career in mathematics, the natural sciences, and engineering.

Propelled by the Goldwater and continuing to seek out as much in the way of mathematics study as possible, her path would soon lead her to the Research Experience for Undergraduates (REU) program, led by Mathematics Professor Jim Morrow (see article on page 8). After he had met Eliana in his Honors Advanced Calculus class, Prof. Morrow discovered that not only was she taking his course, but a senior-level algebra course as well. Impressed by her outstanding performance in his course and the ease at which she handled both courses simultaneously, he invited her to participate in REU.

Eliana's participation in REU was supported by a Phelps Fellowship, a departmental award made possible by an endowment established in 1999 by Professor Bob Phelps and Elaine Phelps.

Following REU, Eliana began her senior year in autumn of 2005. Still an undergraduate, she nevertheless had progressed to the point where all of her mathematics courses were at the graduate level. Beyond this, she also began to take on more duties, this time as a teaching assistant for the Honors Calculus (Math 134/135/136) sequence.

Eliana Hechter with UW President Mark Emmert and Provost Phyllis Wise at a scholarship recognition reception.

"She was very enthusiastic, energetic, and ambitious, too," Professor Steffen Rohde recalls. "She often encouraged me to challenge the students, for instance with an occasional more difficult homework problem, explaining that she liked those challenges herself when she took that course."

The autumn of 2005 also brought the Rhodes Scholarship's strenuous interview process. Yet even during this, atop her teaching and graduate courses, Eliana elected to cap her exemplary undergraduate career with the writing of her senior thesis. Entitled "Explorations in cohomology" and starting as an exposition of the Quillen stratification theorem, it evolved into an exploration into the theorem and related topics.

> **"I was, and continue to be, impressed by her perseverance..."**
> **—Prof. John Palmieri**

Professor John Palmieri, serving as her thesis advisor, enjoyed working with Eliana. Says Palmieri, "I was, and continue to be, impressed by her perseverance—both mathematically and personally when she's striving for something like the Rhodes— and her maturity and composure."

Looking back at her experiences at the Department of Mathematics, one of the things that impressed her was the accessibility of the faculty: "In the Math Department, I can pretty much knock on any professor's door about a problem I'm working on and he or she will be open to talking. The fact that the door is always open is really special. And the research opportunities here rival any I've ever heard of."

Finally, in June of 2006, Rhodes Scholar Eliana Hechter graduated Magna Cum Laude with a Bachelor of Science in Mathematics, also earning the Dean's Medal in Natural Sciences. The scholarship will fund up to three years at Oxford University. It serves as both a fitting cap to her undergraduate career at the UW, and a launching pad to her graduate future as she pursues her Ph.D. in mathematics. We at the Department wish her all the best in what is sure to be a brilliant journey into the frontiers of knowledge.

— MIKE MUNZ

UNDERGRADUATE STUDENT AWARDS

Undergraduate Awards

The annual Mathematics Department luncheon to honor its outstanding undergraduates was held this year on Tuesday, May 30, at the University of Washington Club on campus. A gift from the actuarial firm of Towers-Perrin helped pay for the luncheon and was also used for the second annual Towers-Perrin Award, given to the outstanding graduating Mathematics major with an interest in actuarial science. This year the award had two winners, Laura Hodgson (now Laura Kelly) and Surekha Sydney. Laura is now doing a business internship at Renown Health, a hospital in Reno, Nevada, where she works on Medicare and Medicaid billing. Surekha graduated with three degrees, in mathematics, economics, and Spanish, and is currently interviewing for actuarial jobs in Seattle. Other awards were given to the outstanding graduating seniors in our four tracks of Mathematics major, together with further awards given to continuing or graduating students.

The award for outstanding student in first-year honors calculus was presented to two winners, Praveen Venkataramana and Yuan Luo. Praveen is a second-year student and Yuan is pursuing degrees in ACMS and physics. The award for outstanding student in second-year honors calculus went to Ting-You Wang, who participated in Jim Morrow's REU program last summer and is pursuing degrees in computer engineering and mathematics.

The winner of the Gullicksen Award for outstanding non-senior in Mathematics went to Owen Biesel, who won the outstanding student award in second-year honors calculus last year. He is grading that course this year and partipated in Jim Morrow's REU program during the summer.

Ming Li was awarded a Phelps Fellowship and is pursuing a computer science degree. Kyle Littlefield scored highest among UW students on the Putnam exam.

The outstanding seniors in the Comprehensive major were Noah Giansiracusa and Eliana Hechter. Noah is doing graduate work at Brown University, while Eliana won a Rhodes Scholarship and is now studying topology at St. John's College in Oxford. The award for the Standard major went to Jerry Pan, who is now working at Amazon. In ACMS, the awards went to Francisco Cruz, now a graduate student in applied mathematics at the University of Washington, and Alvin Raj, now a graduate student in computer science at MIT. Finally, the outstanding senior in the Teacher Preparation track was Matthew Halpin, who has returned to teach at his old high school and will later go back to school to earn a teaching credential.

— MONTY MCGOVERN

Mathematics Undergraduate Endowed Scholarship Awarded to Amanda Jane Geddes

Amanda Jane Geddes has been selected to receive the Mathematics Undergraduate Endowed Scholarship this year. Amanda graduated from Evergreen High School in Vancouver, and is now in her freshman year at the UW. Last year's winner, Zachary Sanford, continues to do well here.

The Mathematics Undergraduate Endowed Scholarship is made possible by an endowment established by Byron and Sheila Bishop.

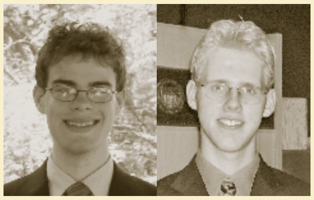
Above: The five recent Goldwater Scholars majoring in Mathematics (from upper left): Noah Giansiracusa, Owen Biesel, Jeff Eaton, Eliana Hechter, and Anna Schneider.

Left: A banner in Red Square celebrating the 2006 Goldwater Scholars. Owen Biesel is a double major in Mathematics and Physics. Jeff Eaton is a triple major in Mathematics, Statistics, and Sociology.

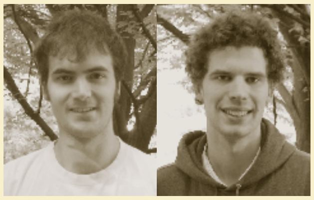
UW Math Majors Win Big Awards

Last year, UW Math majors won several prestigious awards. Eliana Hechter won a Rhodes Scholarship and the Dean's Medal in the Natural Sciences; see page 4 for more about her accomplishments.

Nick Reichert won an Astronaut Foundation Scholarship. There were only 18 of these awarded last year, and Nick was the first Math major from the UW to win (most previous winners were in fields like aeronautics and astronautics, astronomy, or astrophysics). The Astronaut Scholarship Foundation was established by U.S. astronauts, and its goal is to encourage "leadership in science and technology by providing scholarships for college students who exhibit motivation, imagination, and exceptional performance in ... science or engineering."



Owen Biesel and Jeff Eaton won Goldwater Scholarships, out of 32 awarded nationally to mathematics majors last year. As a result the Department was home last year to five UW students who won this prestigious award in the last three years: Owen and Jeff join Anna Schneider (2005), Noah Giansiracusa (2004), and Eliana Hechter (2004) as recent awardees. The Goldwater Scholarship program was established by Congress to commemorate Barry Goldwater, and its purpose is "to provide a continuing source of highly qualified scientists, mathematicians, and engineers by awarding scholarships to college students who intend to pursue careers in these fields."



Wes Essig and Justin Vincent won Math in Moscow Scholarship Awards from the American Mathematical Society, following in the footsteps of Noah Giansiracusa, who won last year. This scholarship helps to fund their participation in the Math in Moscow program, in which they study mathematics at the Independent University of Moscow, an institution specializing in research mathematics.

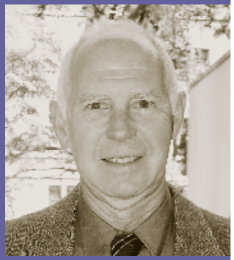
REU Program at the University of Washington

The University of Washington summer REU (Research Experiences for Undergraduates) program, which has been running since 1988, had another successful summer in 2006. The program has established a national reputation and draws outstanding students from all over the United States. In 2006 there were students from the University of Arizona, University of California at San Diego, University of Chicago, Harvard University, Harvey Mudd University, University of Michigan, University of Oregon, Stanford University, Wheaton College, and four University of Washington students. The students in the program are outstanding. In the academic year 2005-6, alumni won a Rhodes Scholarship, an Astronaut Foundation Fellowship, and two Goldwater Scholarships. Another alumnus is a nominee for a Marshall Fellowship (selection takes place in November, 2006). In addition REU alumni make up the bulk of the Department's stellar Mathematical Contest in Modeling Teams. Jim Morrow, the director of the program, was invited to a meeting of REU directors, sponsored by the AMS and NSA, that was held in Chicago in September, 2006. He has also been selected to serve on the MAA committee on undergraduate research.

The program lasts eight weeks. Students do original research on problems related to the inverse problem in electrical networks. In 2006 students found new results on computational accuracy of recovery algorithms, the first example of a 3-1 correspondence from a network to the response matrix, and new theorems on germs of discrete harmonic functions. Some of the students will present their work at the annual meeting of the AMS-MAA which will be held on January 5-9, 2007 in New Orleans. There were four women and nine men in the program, with one of the women supported by a Bob and Elaine Phelps Fellowship. The TAs are alumni of the program and are graduate students (at UCLA, UW, and MIT) and undergrads at UW. A website, http://www.math.washington.edu/~reu, has detailed information about the program, including an archive of students papers going back to 1988. The current program was awarded funding for 2005-07 by the National Science Foundation. In addition it is supported by the VIGRE grant, individual NSF grants, and Department of Mathematics funds.

— JIM MORROW

This spring Jim Morrow was awarded the Distinguished Teaching Award of the Pacific Northwest section of the Mathematical Association of America. Congratulations to Jim!



Last year's REU participants: (from top left) Sam Whittle, Ting-You Wang, Ilya Grigoriev, Rohun Khsirsagar, TA Ryan Card, Ming Li, Rachel Bayless, TA Jennifer French, George Tucker, Nathan Pflueger, TA Peter Mannisto, Sandy Durkin, Zack Begalle, Justin Tittlefritz, and TA Mark Blunk. (Other participants, not pictured, were Tim Banham, TA Owen Biesel, and TA Ernie Esser.)

GRADUATE STUDENT AWARDS

Graduate Awards

Teaching Excellence Award for 2005-2006

Dan Finkel
Anusha Sekar

Academic Excellence Award for 2006-2007

Sean Holman
Andrey Novoseltsev
Zsolt Patakfalvi

New McKibben and Merner Fellow

Sean Holman

McFarlan Fellows for 2006-2007

Ilgar Eroglu
Leo Tzou

New Microsoft Fellows

Joao Gouveia
Zsolt Patakfalvi
Ting Kei Pong

New ARCS Fellow

Katherine Merow

GO-MAP Research Assistantship

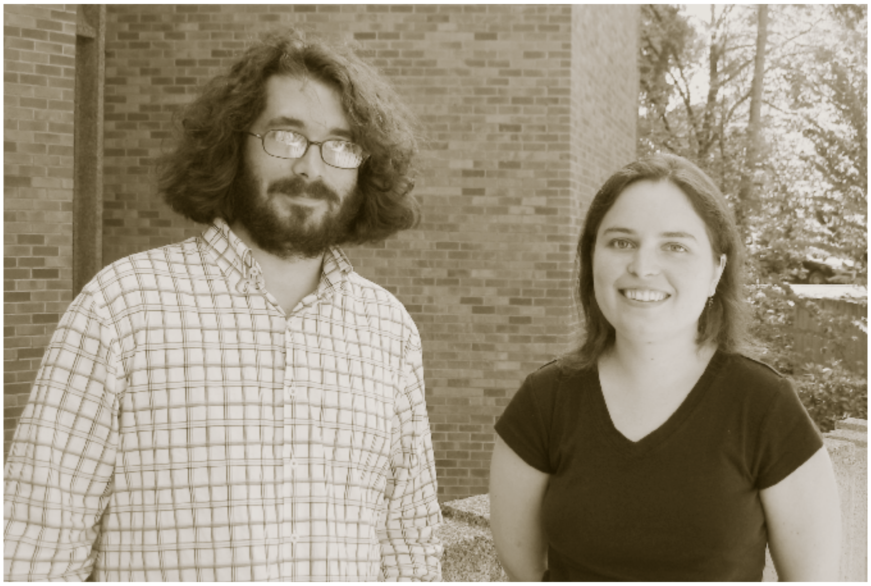
Elisa Celis

VIGRE Fellows (2006-2007)

Matthew Badger
Ryan Card
Walker Carlisle
Michael Decker
Anton Dochtermann
Julia Eaton
Matthew Korson
Jacob Lewis
Kurt Luoto
Micah Warren
Catherine Williams

Top Scholar Awards 2006

Mark Contois
Sarah Gilles
Joao Gouveia
Lee Patrolia
David Sullivan
Ting Zhou



McKibben and Merner Graduate Fellows: Sean Holman (2006) and Ursula Whitcher (2005). This award is made possible by an endowment established by Craig McKibben and Sarah Merner.

SPECIAL PROGRAM NEWS

SAGE: Software for Algebra and Geometry Experimentation

This year the UW Mathematics Department hired William Stein as an associate professor. In January 2005 he started a project called SAGE: Software for Algebra and Geometry Experimentation (http://sage.math.washington.edu), whose purpose is to create unified free open source mathematics software. He is currently using an NSF grant, startup funds, and the UW VIGRE grant to involve many UW students in research on theoretical and computational projects related to SAGE.

J. Neubuser described the crucial importance of free open source mathematics software as follows:

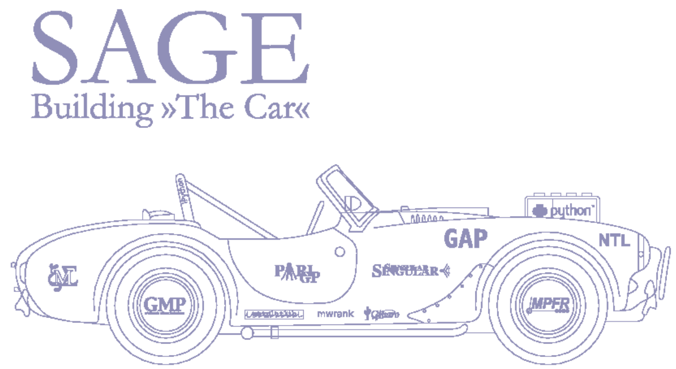
> You can read Sylow's Theorem and its proof in Huppert's book in the library [...] then *you can use Sylow's Theorem* for the rest of your life free of charge, but for many computer algebra systems *license fees have to be paid* regularly [...]. You press buttons and you get answers in the same way as you get the bright pictures from your television set but you cannot control how they were made in either case.
>
> With this situation *two of the most basic rules of conduct in mathematics are violated*: In mathematics *information is passed on free of charge* and *everything is laid open for checking*. Not applying these rules to computer algebra systems that are made for mathematical research [...] means *moving in a most undesirable direction*. Most important: Can we expect somebody to believe a result of a program that he is not allowed to see?
>
> **—J. Neubuser**

William Stein and SAGE

William Stein joined the UW Mathematics Department in 2006 as an associate professor. He received his Ph.D. in 2000 at the University of California, Berkeley, and has since been on the faculty at Harvard and the University of California, San Diego. He does research in number theory and computation, and uses computers heavily in his work.

Both the development model of SAGE and the technology itself is distinguished by a strong emphasis on openness, community, cooperation, and collaboration.

SAGE uses the open source free software GAP, Maxima, Singular, PARI, Macaulay2, Gfan, Python, and other more specialized software, to build an environment for rigorous mathematics computation. SAGE also provides unified interfaces to Mathematica, Maple, MATLAB, Magma, Axiom, and other systems.



SAGE is about building the car, not reinventing the wheel.

The overall goal of SAGE is to create an optimal computational environment for research and education in algebra, geometry, number theory, cryptography, numerical analysis, statistics, and other areas. This involves the creation of software, databases, and web sites. Students at UW have been developing and implementing advanced mathematical algorithms, designing user interfaces, running computations, and giving presentations in seminars and at conferences.

> I think the SAGE developers were very bold—maybe even audacious—to actually attempt this. And they are doing it in a largely pragmatic way without attempting to incorporate the more formal and theoretical ideas developed by the OpenMath community.
>
> One might have been tempted to predict an early failure to this effort but on the contrary SAGE seems to be growing more rapidly than any other computer algebra research and development effort.
>
> **—Bill Page** (one of the main Axiom developers)

The SAGE Days 2 workshop (http://sage.math.washington.edu/sage/days2) at UW in October was a major success. Over 30 mathematicians, students, and technology workers came from as far as Germany to work intensely on SAGE for five days. UW students participated in the workshop include undergraduates Emily Kirkman, Yi Qiang, Tom Boothby, and Bobby Moretti, and graduate students Josh Kantor, Robert Bradshaw, and Robert Miller.

SAGE development at UW is helping to bring a wide range of mathematicians together, from many areas of pure and applied mathematics. It is also providing long-term research experience for mathematics students, similar to what they might get working in a Biology or Physics lab:

> Students at UW did not have any easy way to get started doing mathematics research (no washing petri dishes, etc.). This is something that I have experienced personally and know that many of my math major friends are frustrated about. SAGE is opening the door to advanced mathematics research to many students that wouldn't have this chance otherwise.
> — **Yi Qiang**, UW undergraduate

Collaboration at the SAGE Days 2 workshop.

If you are interested in SAGE, please drop by the "SAGE Lab," Padelford room C-423. Or come to the SAGE Seminar on Fridays at 4pm in C-401. Also, in the Spring 2007, Stein will be teaching an undergraduate number theory course, and a graduate course on the Birch and Swinnerton-Dyer conjecture, and both will use SAGE extensively.

— WILLIAM STEIN

PIMS 10th Anniversary

The Pacific Institute of Mathematical Sciences (PIMS) was created in 1996 to foster the development of mathematics at all levels in Western Canada. The first five founding Universities were Simon Fraser University, the University of Alberta, the University of British Columbia, the University of Calgary, and the University of Victoria. The Departments of Applied Mathematics, Mathematics, and Statistics at the University of Washington joined PIMS in September 2000, making the UW the sixth PIMS university, and thus opening up a new era of scientific collaboration between the US and Canada.

In the last two years, PIMS has sponsored several successful activities at the UW including the "Graduate Student Warm-Up Workshop for AMS Summer Institute in Algebraic Geometry," the "PIMS-MITACS-VIGRE Summer Graduate School on Inverse Problems," the "International Conference on Stochastic Analysis and its Applications," and the workshop on "Stability and Instability of Nonlinear Waves."

In celebration of its 10th anniversary, PIMS has launched a program of distinguished lectures across all of its sites. Speakers at the UW include Kari Astala, Peter Bickel, Lee Kadanoff, Carlos Kenig, Gary Lawler, Peter Lax, Elliot Lieb, Klaus Schmidt, Richard Schoen, Stephen Smale, Peter Winkler, Bin Yu, and Jim Zidex; these mathematicians come from all over the world: from Helsinki to Vienna, from Berkeley to New York. For details of the lectures at the UW, see the web page http://www.math.washington.edu/Seminars/PIMS10th.php.

— GUNTHER UHLMANN

Novik Wins Sloan Fellowship

Isabella Novik has been awarded an Alfred P. Sloan Research Fellowship for 2006-2008. Currently an Assistant Professor, Novik has been with the Department since 2001, having previously served as a Morrey Assistant Professor at UC Berkeley. She received her award-winning Ph.D. in 1999 from Hebrew University in Israel under the supervision of Gil Kalai.

Novik does research in combinatorics, and is one of the editors-in-chief of the Journal of Algebraic Combinatorics. The field of combinatorics has been a strength of the UW Mathematics Department for years, since the arrival of Victor Klee in 1953 and Branko Grünbaum in 1966. Klee and Grünbaum have since retired, but with Novik, Sara Billey, and Rekha Thomas, combinatorics at the UW continues to thrive.

Mathematical historians may find it interesting to note that Novik is Branko Grünbaum's mathematical great grand-daughter: Her Ph.D. advisor Gil Kalai was advised by Micha Perles, who in turn was advised by Grünbaum!

Richard Hamilton, Columbia University Professor of Mathematics and 2006-2007 Milliman Lecturer

Milliman Lecturers Linked to Fields Medals

The Fields Medal is often viewed as the highest honor that a mathematician can achieve, the mathematician's version of a Nobel Prize. At the International Congress of Mathematicians in August, the Fields Medals were awarded to Andrei Okounkov, Grigory Perelman, Terence Tao, and Wendelin Werner. Two of this year's medalists have connections with the Milliman Lecture Series at the UW Department of Mathematics: this year's Milliman lecturer is Richard Hamilton (pictured, left), and some of his work played a central role in Perelman's solution of the Poincaré conjecture. The following year, Terence Tao will be visiting as the 2007-2008 Milliman lecturer.

For more information about the Milliman Lecture series, see http://www.math.washington.edu/Seminars/milliman.php.

From the President: We Did the Math

"Mathematics is the door and key to the sciences."

That assertion, which sounds so contemporary, is in fact more than 700 years old. It was made by a 13th-century scholar, natural scientist, and Franciscan monk named Roger Bacon. (What he really wrote, of course, was *Et harum scientiarum porta et clavis est Mathematica*.) Bacon, an extraordinary man, foresaw steam engines, flying machines and telescopes, and he knew, even before the invention of calculus, that mathematics would be central to human progress and enlightenment.

Fast forward to the early 1990s. That was when the UW math department decided that too many of its students were finding the mathematical door locked and the key lost. For those students, mathematics was serving, not as an entry to science and engineering, but as a roadblock. So the faculty embarked on a broad program of reform and innovation.

First came creation of the Mathematics Study Center, where students could gather for informal tutoring and communal problem-solving. Then, over a period of years, came careful restructuring of the pre-calculus and calculus sequences. Class size was dramatically reduced (the faculty voted itself an increased teaching load to help make this possible). Professors developed new texts and teaching methods. They created a new (highly popular) course in mathematical reasoning, a new calculus sequence for the life sciences, a new set of courses for senior math majors, and, in collaboration with three other departments, a whole new degree program: Applied and Computational Mathematical Sciences (ACMS).

Meanwhile, the department worked equally hard on bringing mathematics to a broader community. The Math 100 sequence has for years been the "door and key" for students who enter the UW with weak math preparation; it continues to put these students, many of them disadvantaged, on the road to success in many fields, including science and engineering. The department strengthened and deepened its courses for aspiring K–12 math teachers. Several imaginative new programs, funded by competitive national grants, send UW math students out to work and learn in local schools. Once a year, Math Day brings swarms of young people to campus to see for themselves all the "cool" fields to which math today is the "door and key." And for advanced high-school students, the Summer Institute for Mathematics is an exciting introduction to the beauty and power of higher mathematics.

The department's hard work has paid off. Some key indicators: Since 1999, three professors of mathematics—David Collingwood, Ron Irving and Jim Morrow—have won Distinguished Teaching Awards. Since 2002, the number of math majors has doubled and it's still growing. In the last four years, five teams of UW math students have been named Outstanding Winners in the international Mathematical Contest in Modeling (this year, just 13 of the 828 teams competing won that distinction). A recent outside review found the department's K–12 outreach program unique among research universities. And this past June, the department received a Brotman Award for Instructional Excellence.

There is much national anxiety these days about the number and quality of American students in mathematics, science and engineering, as well there should be. The United States is falling far behind other nations in producing the next generation of scientists and engineers. At the UW we are trying to do something about this crisis. The outstanding performance of the UW math department, on a broad range of measures, should be a source of great pride for all of us. With 15,000 student enrollments every year, the department contributes hugely to the University's educational mission and, ultimately, to the strength of the state and the nation. Somewhere, Roger Bacon is smiling.

– MARK A. EMMERT, '75, PRESIDENT

This article originally appeared in the September 2005 edition of Columns, the University of Washington Alumni Magazine.

Last year, thanks to two very generous donations, two new professorships were endowed: the Craig McKibben and Sarah Merner Endowed Professorship in Mathematics, and the Walker Family Endowed Professorship in Mathematics. Inaugural four-year appointments to these positions have now been made: Sándor Kovács is the McKibben and Merner Endowed Professor, and Gunther Uhlmann is the Walker Family Endowed Professor. These two mathematicians describe some of their work on the following pages...

MCKIBBEN AND MERNER ENDOWED PROFESSORSHIP

Sándor Kovács
Craig McKibben and Sarah Merner Endowed Professor

Sándor Kovács is a Professor in the Department of Mathematics. He joined the UW faculty in 2000 after holding faculty positions at the University of Chicago and the Massachusetts Institute of Technology. At the University of Washington he has directed 4 Ph.D. theses and is currently working with 8 graduate students. Since 2002 he has served as the Academic Director of the Summer Institute for Mathematics at the University of Washington (SIMUW), a summer program for high school students interested in mathematics.

Kovács earned his B.S. degree at Eötvös University in Budapest, Hungary in 1990 and his Ph.D. at the University of Utah in 1995.

Kovács's area of expertise is higher dimensional complex algebraic geometry, in particular moduli and classification problems. "Higher" in this context means dimension three or more. Here "three" is actually a bit more than it may sound at first. Complex algebraic geometry considers objects defined by polynomials in several variables with complex numbers as coefficients. Recall that complex numbers are real numbers extended with the imaginary unit i, the square root of -1. The field of complex numbers is usually represented by a plane, that is, a two-dimensional object over the (good old) real numbers. As a result, an object that is 3-dimensional over the complex numbers is "really" 6-dimensional according to our more traditional concept of dimension. A "complex curve" is actually a surface and a "complex surface" is actually four dimensional.

The ultimate goal of algebraic geometry is to classify all algebraically defined geometric objects. It is expected that such a classification will not produce a finite list, or even a countable one. The desired list will actually be nothing like a list. In fact, it is expected that the classification will produce some geometric objects whose points parametrize our objects, thereby these objects will themselves become the "lists." However, this is actually more useful than having a simple list, because the geometric properties of these parameter spaces, called "moduli spaces," contain a lot of information on how the different objects can be transformed into one another.

Moduli spaces of curves were constructed by David Mumford in the 1960s. At the time it was expected that surfaces wouldn't have to wait long to get their own moduli spaces. It turns out, however, that the case of surfaces presents many more difficulties than originally expected and accordingly the moduli theory of surfaces is still in its infancy today.

Kovács's main research interests revolve around the moduli theory of surfaces and higher dimensional varieties. In a joint work with Brendan Hassett he solved a long standing technical issue regarding the construction of moduli spaces in general.

An important characteristic of higher dimensional algebraic geometry is the inescapable fact that one must work with singular varieties, that is, objects containing points whose neighborhoods are significantly different from the neighborhoods of other points. For instance on a sphere, any point looks locally the same as any other point. This is, however, not true for example on a cone. The neighborhood of the vertex is nothing like the neighborhood of any other point.

> "These results...lead to new and more interesting and important questions waiting to be answered."

Working with higher dimensional objects forces the necessity of understanding singularities. Kovács and some of his students has worked on various singularity questions, such as giving new characterizations of known singularity classes and establishing relationships between different classes.

Another area of Kovács's research builds both on moduli theory and working with singularities. At the 1962 International Congress of Mathematicians Igor Shafarevich made a powerful conjecture that still drives important research today. The original conjecture, roughly speaking, predicted that there are only finitely many families of curves with some numerical invariants fixed parametrized by a fixed curve. This was proved in the geometric case by Yurij Arakelov and Aleksey Parshin in the late 60s and early 70s and in the number field case by Gerd Faltings in the early 80s.

After a decade of dormancy, the geometric case of the conjecture regained interest through the (independent) work of Luca Migliorini and Kovács. These works ignited a flurry of new results in the area. The last 10 years saw far reaching generalizations of the original conjecture. Eckart Viehweg with various collaborators, most notably with Kang Zuo, and Kovács first working alone and recently joining forces with Stefan Kebekus and Max Lieblich produced better and better results. Today our knowledge is on a different scale than it was even after Arakelov's groundbreaking result. The current results handle families of objects of arbitrary dimension over an arbitrary dimensional base. Not surprisingly the problem evolved into several sub-problems and these are usually phrased in terms of moduli spaces. The best known results at this time in various aspects of the problem are due to the working duos of Viehweg and Zuo, Kebekus and Kovács, and Kovács and Lieblich.

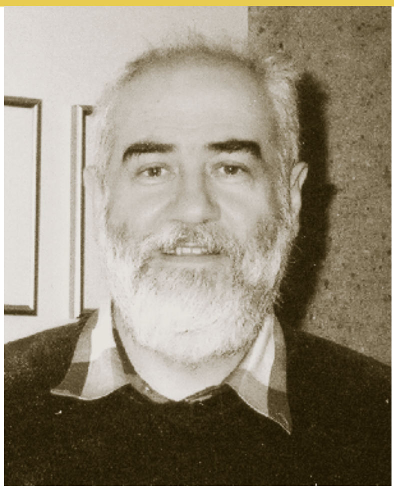
These results, as often in mathematics, do not signal the end of the road, but instead lead to new and more interesting and important questions waiting to be answered. Kovács is currently working on these questions collaborating with several mathematicians from around the world, including Princeton University, Rice University, the Universities of Georgia, Pennsylvania, Texas and Utah in the United States, Université Joseph Fourier in France, Universität zu Köln in Germany and Instituto Nacional de Matemática Pura e Aplicada in Brazil. He is also involved in a long-term project that aims at collecting the scattered pieces of the construction of moduli spaces of surfaces and fill in the gaps where necessary. This, once completed, will be a major and important accomplishment.

Kovács was awarded the Rényi Kató Prize by the Bolyai János Mathematical Society in 1990, a Centennial Research Fellowship by the American Mathematical Society for 1998-2000, a CAREER Research Award by the National Science Foundation for 2001-2006 and a Research Fellowship by the Alfred P. Sloan Foundation for 2002-2006. His research has been continuously supported by the National Science Foundation through individual grants since 1996.

Walker Family Endowed Professor Gunther Uhlmann discusses his research on the following pages...

ENDOWED PROFESSORSHIPS

WALKER FAMILY ENDOWED PROFESSORSHIP



Gunther Uhlmann
Walker Family Endowed Professor

Inside-Out: Inverse Problems

In Inverse Problems one attempts to determine the internal properties of a medium by making observations outside the medium. In order to do this we measure the response of the medium probed with different kinds of waves, including X-rays, sound waves, electromagnetic waves, etc. I have done fundamental research in the mathematics of several inverse problems arising in different applications including medical imaging, seismic exploration, quantum scattering, non-destructive evaluation, and many others. My research has also given new insight into the question that has fascinated people for millennia as to whether one can make objects invisible to light and, more generally, to electromagnetic waves.

Mathematics of Tomography

A familiar inverse problem arising in medical imaging is *Computed Tomography*. In this imaging method the attenuation in intensity of an X-ray beam is measured, and the information from many X-rays from different sources is assembled and analyzed on a computer. Mathematically it is a problem of recovering a function from the set of its line integrals (or the set of its plane integrals). The mathematician Radon found in the early part of the 20th century a formula to recover a function from this information. The application to diagnostic radiology did not happen until the late 60s with the aid of the increasing calculating power of the computer. In 1970 the first computer tomograph that could be used in clinical work was developed by G. N. Hounsfield. He and A. M. Cormack, who independently proposed some of the algorithms, were jointly awarded the 1979 Nobel prize in medicine. Other familiar medical imaging techniques using X-rays to probe the medium are Positron Emission Tomography (PET) and Single Positron Emission Computed Tomography (SPECT). Magnetic Resonance Imaging (MRI) makes an image of tissue by measuring the body's response to strong magnetic fields. Ultrasound uses sound waves to make images of the body.

Mammography is undoubtedly a useful tool for early detection of breast cancer. Another new imaging technique called *Electrical Impedance Tomography* (EIT) has been proposed as a complementary medical imaging technique to mammography to improve on the rate of detecting breast cancer at an early stage. EIT works by applying tiny electrical currents through electrodes placed on the skin, measuring the corresponding voltage response, and then deducing the distribution of electrical conductivity and permittivity inside the body. (Roughly speaking, conductivity measures how easily charge moves through a medium, while permittivity measures the capacity of a medium to store electrical energy.) Since different parts of the body have different electrical properties, the computed distributions provide an image of the body's tissues and fluids. Since the conductivity of a breast tumor is much higher than that of the surrounding normal tissue, this technique could prove to be useful for early breast cancer detection.

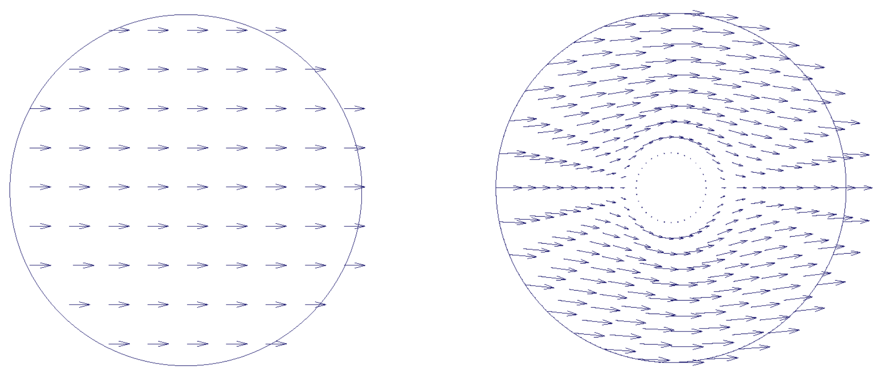
Some of my colleagues and I have shown that, under some circumstances, it is indeed possible to solve the EIT problem, that is to determine the electrical conductivity inside a medium by making voltage and current measurements at the boundary (see e.g. [LU, SU]). This theoretical work has lead to algorithms that are being tried now for early breast cancer detection. David Isaacson and his group at RPI are actively involved in this medical imaging application (see http://www.rpi.edu/~isaacd).

Mathematics of Invisibility

The subject of invisibility has fascinated people for thousands of years and is the subject of many books, films, and television shows, ranging from H.G. Wells' *The Invisible Man* to J.K. Rowling's Harry Potter. There has also recently been considerable interest in the scientific community in the possibility of making objects "invisible," seemingly realizing the science fiction dreams. In particular there were two recent articles in *Science* (Pendry, et al, [PSS] and Leonhardt [L]) which discussed theoretical "cloaking" devices. These would shield an enclosed object from detection by electromagnetic (EM) waves. In principle, such devices could be constructed using "metamaterials," a catchall phrase coined about six years ago, which refers to composites which have physical properties, especially those having to do with the propagation of EM radiation, very different from their constituent materials.

The prescriptions for cloaking devices made of such materials described by Pendry, et al, turn out to be special cases of mathematical constructions of anisotropic conductivities (these depend on direction as well as position) that were given earlier in 2003 [GLU 1, GLU 2] for dimensions three and higher, using very similar methods. The anisotropic conductivities in these counterexamples are quite pathological – they exhibit perfect insulation in some directions and (in some cases) perfect conduction in others. In particular they don't satisfy the requirements of [LU] or [SU].

The space endowed with the conductivities constructed in [GLU 1, GLU 2] appear as vacuum in all external measurements, i.e., the inside of the ball is hidden inside a "cloak of invisibility." We draw the resulting current distribution of this example:



Picture of the currents for the homogeneous case (vacuum) and for the new conductivities that was constructed in [GLU 1, GLU 2]. An observer located outside the region cannot distinguish between the two.

In the figure we see that the current "bends" around the object being cloaked and then leaves as if a homogeneous object were there, without noticing the cloaked object.

In the future I plan to work on transferring the enormous theoretical progress that has been made in the mathematics of Inverse Problems into the practical applications. This will require a joint interdisciplinary effort with the researchers doing the concrete applications.

References

[GLU 1] A. Greenleaf, M. Lassas and G. Uhlmann, *Math. Res. Lett.* 10 (2003), no. 5-6, 685–693.

[GLU 2] A. Greenleaf, M. Lassas and G. Uhlmann, *Phys. Measure.* special issue, Proc. of Mummy Range Workshop on EIT, 24 (2003), 413-419.

[GLU 3] A. Greenleaf, M. Lassas and G. Uhlmann, *Comm. Pure Appl. Math.* 56 (2003), no. 3, 328–352.

[L] U. Leonhardt, *Science* 312 (2006), 1777–1780.

[LU] M. Lassas and G. Uhlmann, *Annales Scientifiques de l'Ecole Normale Superieure* 34 (2001), 771–787.

[PSS] J. Pendry, D. Schurig and D. Smith, *Science* 312 (2006), 1780–1782.

[SU] J. Sylvester and G. Uhlmann, *Annals of Math* 125 (1987), 153–169.

MATHEMATICS OUTREACH

Outreach Programs

The Department's outreach efforts for this year were to a large extent a matter of carrying forward last year's plans and projects. One, however, has blossomed forth from being a work in prospect to being a work in progress, and a very exciting one at that, so we shall start there.

The project in question, which goes by the name of PD3, is the brainchild of Prof. James King in our department. I think it is collaborative in every possible sense of the word. For a start, it is funded by an NSF Math Science Partnership grant in conjunction with the Park City Math Institute, which works in conjunction with the Institute for Advanced Study. Locally, Jim set up collaboration with Prof. Ilana Horn in the College of Education and the two of them arranged for a partnership between the UW and three high schools in the Seattle school system. Throw in some graduate students working with them at all levels and you have, as I said, something approaching maximal collaboration. The project focuses on how the teachers do their mathematics teaching, with an intensive summer institute in Park City, Utah, and school-year follow-up in a huge variety of forms. At the core of the project is the effort to help all the math teachers at each school function as (yes!) a collaborative team.

The tradition of building a big geometrical object at the Northwest Mathematics Interaction Summer Program for math teachers continued in 2006 with polyhedra made from dowels and whiffle balls.

Three other outreach efforts that didn't turn up in last year's newsletter are the Washington Math Case Study project, TEAM-OP (Teaching for the Environment: Active Mathematics on the Olympic Peninsula) and Project TIME (Transitions in Mathematics Education). The first is a collaboration with WSU and Eastern, working on materials for professional development at the often-neglected middle school level. The second is a collaboration with the College of Forestry, working on professional development for some of the often-neglected rural districts. And the third is working on the very challenging issue of the transition from high school to college mathematics. That one is actually based at Green River Community College, but we get to claim some credit, not merely for being collaborators, but the fact that it originated in part from connections at WaToToM (Washington Teachers of Teachers of Mathematics), which our department sponsors. A more major part of its origin is the Transition Math Project, in which we have been taking part.

I've really only scratched the surface, but space is running out, so I'll resort to a list, with the understanding that anyone who wants to know anything more about any of them should get in touch with us forthwith. For instance, there's SIMUW (Summer Institute in Mathematics at UW), which, thanks to a generous donor, lets us bring 24 very bright high school students to live on campus for six weeks and immerse themselves in learning mathematics both from a variety of mathematicians and from each other. Last spring we did our 16th annual Math Day for high school students throughout the state and now we're head heading into #17. Math Fairs in the elementary schools are going strong, supported by the Department and the GK-12 Project (another collaboration – this one with Applied Math and University Child Development School) which takes UW graduate students and UCDS teachers into some high-needs elementary schools to be a resource to teachers trying new kinds of teaching. The Northwest Math Interaction summer institute continues to attract teachers from all over the state, and our 497 courses continue to have topics and schedules such as to make them accessible to in-service teachers.

And on top of that, we are very much open to other people's ideas of ways we might reach out. Got any to suggest?

— GINGER WARFIELD

UNDERGRADUATE NEWS

The Undergraduate Program

Undergraduate education in mathematics is healthy and growing at UW. We are now in the sixth year since our major revision of the first two quarters of calculus (Math 124/5), and we have made adjustments to the third quarter of calculus (Math 126) to make the transition from Math 125 to Math 126 smoother. To enrich the experience of our undergraduate majors, whose number has more than doubled during the past five years, we started an undergraduate topics course, Math 480. Two sections were taught in Spring 2006, each on a different topic. We have scheduled four sections of Math 480 for Spring 2007, offering the following courses: The Theory of Knots, Numerical Solutions of PDEs, Introduction to Number Theory, and Introduction to Dynamics.

Our undergraduate degree programs in mathematics have grown in the last several years. We had over 150 students graduate last year with bachelor's degrees in our programs. At the end of last year, just before graduation, we had over 330 Math majors. In Autumn 2006, we already have almost 300 majors. (The number of majors usually grows throughout the academic year.) In addition, our joint program in Applied and Computational Mathematical Sciences (ACMS, joint with Applied Math, Computer Science, and Statistics) continues to offer a variety of tracks, allowing students to study both mathematics and another discipline together in the major. There were 100 ACMS majors at the end of last academic year. The Math Club is doing well in its second year since returning last year. Undergraduate research in mathematics is growing. This is an active time for undergraduate education in mathematics at UW.

— KEN BUBE

Mathematics education in action: Undergraduate students, aided by graduate and undergraduate tutors, come together to work on mathematics in the supportive atmosphere of the Math Study Center. Hundreds of students, regardless of major, use the Math Study Center on a regular basis each quarter.

FACULTY NEWS

Transitions

This year, the department made five new faculty appointments.

Trevor Arnold (Acting Assistant Professor), Ph.D. University of Michigan, 2006. Professor Arnold studies number theory and algebraic geometry.

Emmanouil Milakis (Acting Assistant Professor, not pictured), Ph.D. University of Crete, 2006. Professor Milakis studies PDEs, free boundary problems, nonlinear analysis, mass transportation, and geometric measure theory.

Ioana Dumitriu (Assistant Professor), Ph.D. M.I.T., 2003. Professor Dumitriu studies numerical analysis, random matrices, computing, and algorithmic game theory.

Paul Hacking (Assistant Professor), Ph.D. University of Cambridge, 2001. Professor Hacking studies algebraic geometry.

William Stein (Associate Professor), Ph.D. UC Berkeley, 2000. Professor Stein studies number theory and computation. He arrived in Spring 2006.

Sándor Kovács and **Dan Pollack** were promoted from Associate Professor to Professor.

Jennifer Taggart was promoted from Lecturer to Senior Lecturer.

Professor **Bob Moore** retired; he joined the department in 1968.

Visitors

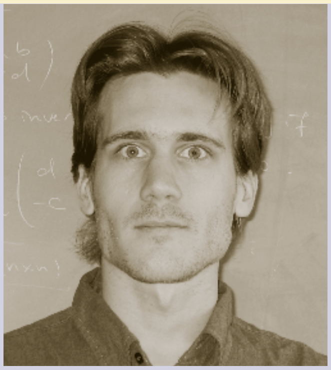
Each year, the UW Department of Mathematics welcomes many visitors. These visitors, who come for varying periods of time, teach classes and participate in our seminars and research. They make significant contributions to the life of the department. These visitors come from all over the world, and this attests to the international nature of mathematics and to the department's attractiveness as a center of mathematical research and teaching. Many visitors come for only a few days or a week, but some stay for a quarter or more. Here is a list of this year's long-term visitors:

Tusheng Zhang (Autumn), visiting from the University of Manchester. Professor Zhang studies stochastic analysis **and Dirichlet forms.**

Sergey Bezuglyi (Winter), visiting from the Institute for Low Temperature Physics. Professor Bezuglyi studies ergodic theory and topological dynamics.

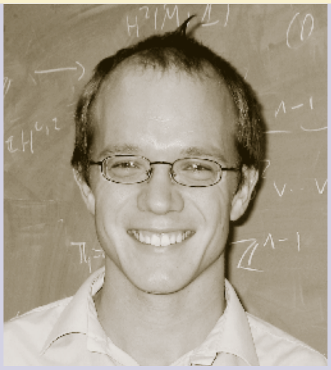
Vladimir Sharafutdinov (Winter), visiting from the Sobolev Institute of Mathematics. Professor Sharafutdinov studies differential geometry and topology.

Nguyen H.V. Hung (Spring), visiting from Vietnam National University. Professor Hung studies algebraic topology.



Trevor Arnold

Ioana Dumitriu



Paul Hacking

William Stein

Ronald Pyke, 1931 2005

Ronald (Ron) Pyke was associated with the Department of Mathematics at the University of Washington from 1953 to 2005, except for a few short periods. He was first a graduate student, then a member of the faculty, and finally a Professor Emeritus.

Ron Pyke passed away on October 22, 2005, as a consequence of amyotrophic lateral sclerosis. He was 73. Ron was born on November 24, 1931, in Hamilton, Ontario, and graduated from Westdale High School in Hamilton in 1949. He married Gladys Mary Davey on December 19, 1953, in Hamilton.

Ron graduated with honors from McMaster University in 1953 and then moved to the University of Washington. He completed an MSc in Mathematical Statistics in 1955 and a Ph.D. in Mathematics in 1956 under Bill Birnbaum on the topic "On one-sided distribution free statistics."

Immediately following his Ph.D., Ron moved to Stanford for two years, followed by another two at Columbia. In 1960 he returned to Seattle, where, except for sabbaticals at Cambridge (64/65), Imperial College (70/71) and the Technion (88), he settled permanently. Ron retired from the University of Washington in 1998.

In his early professional years, Ron made a number of important contributions to topics as diverse as statistical hypothesis testing (mainly centering around Kolmogorov-Smirnov and other goodness of fit statistics), Markov renewal and branching processes, empirical processes, fluctuation theory and two-armed bandits, to give but an abbreviated list. A significant majority of the papers were published in the Annals of Mathematical Statistics, and even briefly running through his early papers one sees any Search Committee's dream candidate in terms of their breadth and quality.

When Ron first arrived at the University of Washington there was no independent Statistics department, and activity in Statistics was concentrated in Mathematics. In 1965 a 'Biomathematics Group' interdisciplinary program was set up, in which Ron was heavily involved. Ron also worked tirelessly towards the establishment of an independent Department of Statistics, which was finally established in 1979, and is now one of the leading departments in the US, with over 25 faculty members. Although Ron originally joined the infant department, he shortly thereafter returned to Mathematics.

In 1973 Ron published his first paper on the Brownian sheet (also coining the name that then stuck to this remarkable process). While Ron's interest in the Brownian sheet grew out of his work on Kolmogorov-Smirnov type statistics, from the 1970's onwards he was concerned more with its amazing local sample path properties. Retirement did not stop Ron from working, and his last paper, written with long-time friend and colleague Willem van Zwet, appeared in the Annals of Probability in 2004.

Over the years Ron supervised 15 Ph.D. students, many of whom are now well known names in statistics and probability.

Ron began what was to be a lifelong commitment to the Institute of Mathematical Statistics by taking an active leadership role. In 1963, at the age of 32, Ron chaired his first Institute of Mathematical Statistics committee, the Program Committee. In the Institute of Mathematical Statistics, Ron was probably best known as a previous President (1986/7) and as the editor of the fledgling Annals of Probability in the first four years of its existence, from 1972 to 1975.

As one would expect from a scholar of his calibre, Ron was a Fellow of the American Statistical Association and Institute of Mathematical Statistics, an Elected Member of the International Statistical Institute, and had a long list of invited addresses and other honors. He served as the Institute of Mathematical Statistics President in 1986/7, and also as International Statistical Institute Vice President from 1989 to 1991.

(Based on the obituary by Robert Adler, published in the Bulletin of the IMS, January 2006; adapted by Krzysztof Burdzy)

MATHEMATICS DEGREES

Recent Degree Recipients

The following students completed their doctorates in Mathematics during the academic year 2005-2006:

Kirk Blazek. His advisor was Ken Bube, and his thesis title was "The One-Dimensional Inverse Problem of Reflection Seismology on a Viscoacoustic Medium." Kirk is now a Pfeiffer-VIGRE Postdoc Instructor at Rice University.

Davis Doherty. His advisor was Sándor Kovács, and his thesis title was "On Singularities of Generic Projection Hypersurfaces." Davis is now an instructor at Seattle University.

Bela Frigyik. His advisor was Gunther Uhlmann, and his thesis title was "Injectivity and Stability of Generalized X-Ray Transforms on Curves." Bela is now a Research Assistant Professor of Mathematics at Purdue University.

Hai Jin. His advisor was Ken Bube, and his thesis title was "The Inverse Problem of Fiber Bragg Gratings."

Keir Lockridge. His advisor was Ethan Devinatz, and his thesis title was "The Generating Hypothesis in General Stable Homotopy Categories." Keir is now a visiting assistant professor at Wesleyan University.

Edwin O'Shea. His advisor was Rekha Thomas, and his thesis title was "Toric Algebra and the Weak Perfect Graph Theorem." Edwin is now a Visiting Assistant Professor of Mathematics at the University of Kentucky.

Pablo Shmerkin. His advisor was Boris Solomyak, and his thesis title was "The structure of overlapping self-affine sets." Pablo is a postdoc at the University of Jyväskylä.

Zachary Treisman. His advisor was Sándor Kovács, and his thesis title was "Arc spaces and rational curves." Zach is a postdoc at the Tata Insitute for Fundamental Research.

Sona Zaveri. Her advisor was Chris Burdzy, and her thesis title was "The Second Eigenfunction of the Neumann Laplacian on Thin Regions." Sona is an instructor at the University of Wisconsin.

Below is a list of those who finished their work at the UW with a Master's degree in Mathematics, with each student's advisor listed in parentheses:

Chiahui Cheng (Arms)

Alexander Papazoglou (Babson)

Sidney Butler (Toro)

Michael Cecil (Babson)

Gary Howell (Greenbaum)

Kristofer Reed (Burdzy)

Bachelor's Degrees

158 Bachelor's degrees were awarded during the 2005-2006 academic year: 108 in Mathematics and 50 in ACMS.

OUR DONORS

The following is a list of our friends who have contributed to the Department between September 1, 2004, and October 18, 2006. Should you notice an error or omission in this list, please draw it to our attention by a telephone call or e-mail message to Mike Munz (206-543-1151 or munz@math.washington.edu).

INDIVIDUALS

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Dr. Corin Ross Anderson
Mr. and Mrs. Andrew Anschell
Dr. and Mrs. Loren N. Argabright
Prof. Judith M. Arms & Mr. Stan Sorscher
Prof. Michael Artin
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