Department of Mathematics and Statistics *Newsletter*

University of Massachusetts Amherst College of Natural Sciences and Mathematics Academic Year 2005 – 2006 Volume 21

DEPARTMENT HEAD'S MESSAGE *by Eduardo Cattani*

As I write these words, I have just finished my first full semester as Department Head, although officially I assumed that role a year ago. After I became Head on June 15, 2005, I left on August 1 to spend a semester as a Fulbright Scholar at the University of Buenos Aires. In my absence, Associate Head George Avrunin was acting Head until I returned on January 15, 2006. George did such a superb job that the only blemish on his performance was his refusal to continue doing it. Bruce Turkington, the previous Department Head, will return to teaching this fall after his much deserved sabbatical leave at the University of Warwick.

Thanks to the incredible work of the administrative staff the transition has been very smooth: Arline Norkin, who directs the staff and supervises the course offerings; Phil Szczepanski, the Business Manager who has made sense of the whole budget process; Kim Stone, the Department Head's assistant; as well as Kathy Boron, Joy McKenzie, Terry Reynolds, Chris Richotte, Carol Ryan, Jean Sauter, Kathie Terry, and the entire Research Computing Facility staff, consisting of Steve Ball, Kevin Cummings, and Ken Pollard, the director. *continued on page 2*

INSIDE THIS ISSUE:

PROFILES

One of our goals in this year's newsletter is to try to increase communications between alumni and the department. With this goal in mind we are instituting a new feature involving profiles of alumni. This year we focus on two alumni in the business world. The first is Andreana Shanley, a Vice President at Blue Cross Blue Shield of Massachusetts. The second is Roy Perdue, cofounder of the computer company, Solutions by Computer. Both Andreana and Roy have discovered that the backgrounds in mathematics they gained at UMass Amherst have been invaluable in their professional careers.

Alumna Andreana Shanley '90: Mathematics as a Tool in Business

Andreana Shanley's favorite mathematics course as a UMass Amherst undergrad was vector calculus. "The 3D thinking needed in multivariable calculus is useful for creative problem-solving," says Shanley. "Today those skills continue to help me in my own analytical work."

Shanley knows a lot about business and how a mathematics degree helps. Today she's a Vice President at Blue Cross Blue Shield of Massachusetts, a position she attained after 13 years of actuarial experience. She brings a diverse set of skills to her position, with expertise ranging from financial modeling to medical economics and cost management.

According to Shanley, being a math person also gives her an advantage you might find surprising: more effective communication.

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Alumnus Roy Purdue '73: Mathematics as Creativity

For Roy Perdue, mathematics isn't about number-crunching or formal manipulation: it's about creativity.

"Creative thinking is trial and error, generating possibilities and trying them out," says Perdue. "Mathematics involves that in an essential way. It's muscle-building for the mind."

Perdue should know. After earning a B.S. in mathematics from UMass Amherst in 1973, he honed his problem-solving skills during 9 years in the computer industry, then returned to the Pioneer Valley in 1982 to cofound a computer company, Solutions by Computer (SBC). Today SBC is the worldwide leader in rental management computerization software, with over 2400 businesses relying on software originally developed by Perdue.

Perdue credits much of his business success to his mathematics background. "There's a craft to writing computer programs. You have to analyze a problem, develop a model," says Perdue. "Mathematical

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Department Head's Message ***continued from page 1***

A landmark event this May 31 was the retirement of Professor Doris Stockton after 52 years of teaching at UMass Amherst. (Amazingly, this wasn't Doris' first job.) Doris was appointed an Instructor in Mathematics by UMass Amherst President Van Meter on January 13, 1954 at an annual salary of $3,720. She has devoted her career to helping students acquire the background necessary for taking calculus and other higher-level classes. Doris has also worked closely with colleagues at the School of Education on issues of math anxiety and remediation. Her family, friends, and colleagues celebrated her contributions with a gathering on May 12, at which State Senator Stan Rosenberg presented Doris with a Joint Resolution from the Massachusetts Legislature recognizing her years of service to the university. We congratulate Doris and wish her very well in her retirement. Lest you be worried that Doris will be at a loss as to what to do, let me tell you that she will be back teaching a Continuing Education class. She is also planning to work on a new edition of one of her textbooks.

As you will read in these pages, this has been a proud year for the department in terms of faculty recognition. Professor William Meeks, the George David Birkhoff Professor of Mathematics, received a 2006-2007 Guggenheim Fellowship. This is a wonderful honor bestowed on fewer than 200 scholars and artists this year. Bill will be on leave next fall semester and will visit his collaborators in the US, Europe, and Latin America.

Professor Farshid Hajir has won a College Outstanding Teacher Award and will be recognized both at Commencement and at next year's College Convocation. As I was preparing Farshid's nomination, I was both inspired and humbled by the effusive comments from students and colleagues about his teaching. A colleague from the School of Education called Farshid a "*great* teacher" in the spirit of William Arthur Ward, and quoted this timeless rubric: "The mediocre teacher tells. The good teacher explains. The superior teacher demonstrates. The great teacher inspires."

Professor Nathaniel Whitaker received the 2005-2006 Distinguished Academic Outreach Award for community education at a ceremony held at the Campus Center on May 8, 2006. This was one of five Distinguished Academic Outreach Awards presented this year by the Vice Provost for University Outreach, Sharon Fross. Nate was honored for his efforts in establishing AIMS (Academic and other Initiatives for Maximum Success), a program to boost the mathematical skills and academic self-confidence of African-American students in the Amherst-Pelham schools.

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Andreana Shanley ***continued from page 1***

"The same creative problem-solving skills help me interact with creative people in business, such as colleagues in marketing and design," she says. "Plus, being a math person gives me a broader range of communication skills. It's easier for me to explain something to a person with a low math comfort level than the other way around."

Recently, Shanley put her communication skills to work in our department. In April she gave an energetic presentation about actuaries that was enthusiastically received by the audience of undergraduates. "There was a good mix of about 50 students, and they were really engaged," says Shanley. "They asked me lots of good questions." She also finds the idea of strengthening contacts with alumni through such presentations to be timely and opportune. "It's a great idea to connect students with career people. Those contacts are an untapped resource."

Shanley grew up in East Boston after immigrating to the United States from Italy. She graduated from UMass Amherst in 1990 as a mathematics major with a minor in computer science. She is a member of the American Academy of Actuaries and a Fellow of the Society of Actuaries. Today she resides in Derry, New Hampshire with her husband and two children.

Roy Purdue ***continued from page 1***

thinking is crucial, much more so than computer science thinking." Perdue believes that math people make better programmers. "Mathematical fluency plays a role in our hiring at SBC, even today."

Today Perdue maintains his ties with the Department of Mathematics and Statistics. He is one of the sponsors of the Henry Jacob Mathematics Competition (see story on page 12), and in the past he has given presentations to undergraduates concerning his work. He feels that it's important to actively promote mathematics. "Most people don't realize how many mathematicians there are in the business world, mainly because *mathematician* doesn't happen to be their official job title," he says. "Mathematics is underappreciated."

When asked about his favorite professor, Perdue responds without hesitation: "Professor Foulis." He specifically remembers three courses he took under Foulis: statistics, analysis, and tensor analysis. His only regret is that he didn't take more. Today he continues to learn about new mathematics through self-study. His latest project involves linear programming and the simplex method.

Roy Perdue is a native of Massachusetts. He attended high school in Andover, and has lived in several towns including Ware, Rowe, and Boston. Today he makes his home in West Springfield.

PROFESSOR DORIS STOCKTON RETIRES AFTER 52 YEARS

by Brian Emond

After 52 years of teaching in the Department of Mathematics and Statistics, Doris S. Stockton retired at the end of the Spring 2006 semester. A celebration honoring Doris was held in the departmental lounge on Friday, May 12, 2006, at which State Senator Stan Rosenberg presented her with a Joint Resolution from the Massachusetts Legislature recognizing her many accomplishments as well as her dedication to student learning.

Although she published research on partial differential equations in Banach spaces, Doris realized that many incoming students were not prepared for college-level math courses. The need for appropriate materials led her to publish a series of texts entitled *Essential Mathematics* (1972), *Essential Algebra* (1973), and *Essential Algebra with Functions* (1973). The third text was immediately adopted by the Air Force Academy and by Long Beach State in California. She eventually published eight other texts and workbooks.

Massachusetts State Senator Stan Rosenberg (D-Amherst) and Prof. Doris Stockton

Doris's mission has always been to make mathematics accessible and understandable to everyone, not just mathematicians and scientists. In 1960 she conducted innovative research on the use of computer technology in large calculus lecture classes and published her results in *The American Mathematical Monthly*. Doris also produced a video instructional program entitled *Algebra, Analytic Geometry, and Trigonometry* for the College of Engineering at UMass Amherst and was responsible for the establishment of math anxiety workshops held at the beginning of each semester. In the early 1990s, Doris established a program in basic mathematics, the purpose of which was to bridge the gap that incoming students had in their algebra skills. The program utilized in-service high school teachers to teach the course. Not only did the students benefit from their instruction, but also there developed a strong connection between the Department of Mathematics and Statistics and area high schools.

Doris was not always interested in mathematics as a career. In fact, she started out as a major in dramatic arts at the New Jersey College for Women at Rutgers in 1941. However, when her advisor told her that the country was preparing for a long-term war and that there would be a shortage of mathematicians and scientists, she immediately changed her major to mathematics with a minor in physics.

Over the years Doris has received awards such as the University of Massachusetts Amherst College of Mathematics and Natural Sciences Teacher of the Year Award and memberships in Phi Beta Kappa and Sigma Xi.

Doris's dedication and caring has touched many students. At the celebration held on May 12, a letter written by one such student was read aloud to the gathering.

> "Failed classes, academic probation, two steps from giving up and dropping out of college. Add Doris Stockton, and six semesters later I graduated magna cum laude with my B.S. in math, headed to UCLA for graduate study in education. Two years later, I graduated top of my class with my M.Ed., ready to try to make the kind of difference in the lives of my students that Doris had made in my life. So again, she may not know what she did for me or the impact she had on me, but I'm certain that I wouldn't be where I am today had it not been for her help along the way.
>
> "Congratulations, Doris, on your retirement. Although I am happy for you, ... it makes me a little sad to think of all the students who will come through UMass Amherst who won't get the chance to know you as I did."

The members of the Department of Mathematics and Statistics join this letter writer to congratulate you, Doris, for all your devotion and hard work.

Your donations to the Mathematics and Statistics Department support programs that enable interactions like that between Doris and this student, who was an undergraduate Teaching Assistant in our department. You can give using the enclosed gift envelope or via our gift page: www.math.umass.edu/Give/donate.html. Your contributions make a huge difference in the lives of our students.

Department Head's Message *continued from page 2*

As most of you know, rebuilding the faculty has been a priority for both of my predecessors, Don St. Mary and Bruce Turkington. Their success in attracting outstanding young faculty to our department was the envy of the panel of distinguished mathematicians and statisticians who visited us in the spring of 2005 as part of the departmental review known as AQAD. I hope to continue this tradition and will do everything possible to make the department an exciting and supportive environment for research and teaching. Frankly, the start couldn't have been better. Two outstanding mathematicians will be joining us next fall: Qian-Yong Chen (Applied and Computational Mathematics) and Evgueni Tevelev (Algebraic Geometry). Professor Chen is currently an Industrial Postdoctoral Fellow at the Institute for Mathematics and its Applications (IMA), and Professor Tevelev has a postdoctoral position at the University of Texas, Austin. These new appointments will bring the total tenure-track faculty to 38. We are hoping to continue expanding the faculty during the next few years.

Four Visiting Assistant Professors (VAPs) will be departing this year: Georgia Karali, Mikhail Perepelitsa, Ivan Soprunov, and Evgenia Soprunova. Georgia and Mikhail are leaving after a year at UMass Amherst, having accepted tenure-track positions elsewhere. Ivan and Jenia have been with us for four years and are leaving many friends behind. They are moving to Cleveland, where Ivan has accepted a position at Cleveland State University. Three new VAPs will be joining us next year: Ana Maria Castravet (Algebraic Geometry), Jesus Espínola-Rocha (Applied and Computational Mathematics), and Zhigang Han (Differential Geometry and Topology). The VAPs bring a tremendous amount of energy into our research atmosphere while benefiting from the mentoring of first-class researchers and the opportunity of obtaining valuable teaching experience. Catherine Benincasa and Adena Calden, who are receiving their M.S. degrees in Applied Mathematics this spring, will join the department as lecturers in AY 2006–2007. I am delighted to welcome these new colleagues.

Thanks to the efforts of Tom Weston and Bruce Turkington, the department has completely revamped its honors courses and created a new capstone course for Commonwealth College students. Six courses have received honors designation: Math 511, Math 523, Math 532, Math 534, Math 563, and one section of Stat 515. The topic for next year's capstone course will be number theory and will be taught by Michael Bush and Farshid Hajir. Two of the students who will be doing their honors thesis on this topic, Laura Beltis and Emily Braley, have received Sheila R. Flynn Scholarships for Undergraduate Research and will be working with the number theory group this summer.

Anna Liu and Michael Sullivan have led the efforts to reevaluate actuarial courses in the department and on campus. They have worked with other departments to obtain the approval of the Society of Actuaries for VEE courses in Statistics, Finance, and Economics. Plans are underway to begin offering courses to help students prepare the first two actuarial exams through Continuing Education. You can get more information about the undergraduate program in Actuarial Science through the departmental web page at http://www.math.umass.edu.

I am sure that everyone reading this newsletter has noticed and is enjoying the greatly improved presentation. Beyond the cosmetic improvements, we are also working to make the newsletter a vehicle for a dialog between the Department and its alumni. The first steps in this direction are the profiles of Roy Perdue (1973) and Andreana Shanley (1990). In the future we hope to include contributions from many more of you. Please write to us and let us know what you are doing and what things you value about your UMass Amherst experience.

Finally, I want to thank you for your generous contributions to the Department. Alumni help is essential in supporting the kinds of activities that make such a difference to the life of the Department: from the Undergraduate Colloquium to scholarships for summer research and awards to our seniors and to winners of the Henry Jacob Mathematics Competition.

RESEARCH PROJECTS BY UNDERGRADUATES

by Peter Norman

During this past summer four undergraduate students worked full time, one on one, with members of our faculty on individual research projects. By giving students the opportunity to discover new mathematics, this activity allowed them to see another side of mathematics that they do not see in class.

- **Garret Cahill worked with Ivan Suprounov on polytopes.**
- **Christine Croll worked with Farshid Hajir on a project involving elliptic curves.**
- **Susan Saw worked with Michael Sullivan on knots.**
- **Elena Zaurova worked with Tom Weston on a different project involving elliptic curves.**

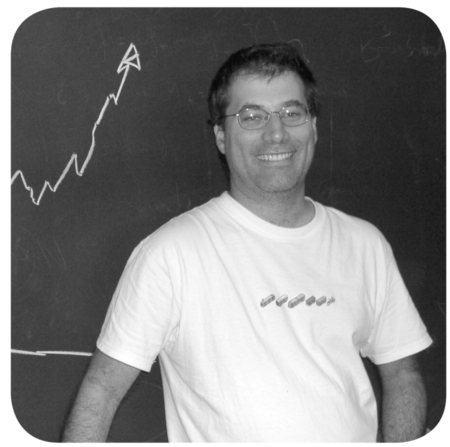
Support for the students came largely from donations by alumni to the department. Additional support also came from the National Science Foundation as supplemental grants to faculty research grants. Faculty involved in these undergraduate research projects are not compensated beyond the pleasure of working with bright, hardworking students.

THE MATH OF FINANCE: HOW MUCH IS YOUR SIGN-UP BONUS WORTH?

by Michael Sullivan

You just graduated from UMass Amherst with a degree in mathematics and statistics. You are flooded with job offers, but only two of them attract your attention. The two potential employers offer the same starting salary and comparable health benefits; however, the sign-up bonus from AB Co. is $4,000 while PDQ Inc. will give you 1000 stock options if you accept their offer. Unfortunately, you skipped Math 441, "The Math of Finance," in your senior year because it conflicted with coed volleyball (1 credit). Fortunately, you see this article the day before you must decide.

What is a stock option? A stock is a fraction of ownership in some company. Its value, or market price, is determined by supply and demand. No one can definitively predict what one PDQ stock will cost in the future, but financial analysts try to model the behavior of stock prices using statistics and probability. For example, any reasonable model should imply that the probability of PDQ stock increasing 800% tomorrow is quite small. A stock option is a contract that allows the holder of the option to buy or sell one stock for a pre-specified price, the "strike price," from the writer of the option. The holder may do this in some pre-specified time interval, or s/he may not "exercise" the option at all and let it "expire." Clearly the holder has an advantage over the writer; thus the holder must compensate by paying some premium to the writer when they enter this agreement. This premium is the price of the option.



PDQ has offered you one of the more basic stock options: a *European call* option on one PDQ stock with strike price $50 expiring in 6 months. Here "call" means that you, as the holder, have the right to *buy* the stock. "European" means you can exercise this option at the expiration date only, and not before. To evaluate your job offers, you must compute the price of the call option on PDQ, multiply it by 1000, and then compare this to AB Co.'s $4000 bonus. Let X denote the price of PDQ stock in 6 months. If , you let the option expire, and the value of the call option will be worth $0. If X > $50, you exercise the call, and resell the stock on the market for $X, making the value of the option $(X–50). More succinctly, the call will be worth, or priced at, $max(X–50, 0) in 6 months.

But since X is an unknown "random variable," this does not solve your problem. How much, exactly, does the option cost today? Let c be today's call price. At this point, some assumptions about the behavior of the stock price need to be made. For simplicity, suppose PDQ stock costs $50 today and, in the next 6 months, will either go up or down by 10%. So X is either $55 or $45. This is an example of a one time-step binomial tree. In this tree model, the call will be worth either $5 or $0 in 6 months.

Consider the following two choices: one PDQ stock, or 2 PDQ calls and $45 in cash. Today, the first choice is worth $50 and the second one is worth $(2c+45). In 6 months, however, the first and second choices are worth the same: if the stock goes up, then it is worth $55, and the two calls and cash are also worth 2*5+45 = $55; if the stock goes down, then it is worth $45, and the two calls and cash are also worth 2*0+45 = $45. One could argue that the $45 cash invested in a bank would earn interest, or that owning the stock might have provided some dividends. But interest and dividends change the outcome only slightly, and so ignore them in this exposition.

A fundamental assumption in finance is that there are no arbitrage opportunities. An arbitrage opportunity is an investment which requires no initial money up-front and is guaranteed to make the investor a profit. If such an opportunity were available, everyone would take it, and market forces would make the opportunity disappear.

No arbitrage implies that the two choices will also be worth the same today: 2c+45 = 50, or c = $2.50. Suppose the market priced the call today at $3 instead of $2.50. Such a discrepancy would provide you with the following arbitrage opportunity: sell 2 calls for $6, borrow $44, use the $50 to buy 1 stock, and wait 6 months. If the future stock price X is $45, you sell the stock for $45 and repay the loan with $44. Your profit is 45–44 = $1. If X = 55, then both calls that you wrote are exercised. You buy a second stock for $55, deliver the two stocks to the call holders for 2*50 = $100, and repay the loan of $44. Your profit is 100–55–44 = $1. You started with nothing, and ended up with $1 regardless of the outcome. Multiplying this trading strategy by 1 million, you might see why such arbitrage opportunities are rare to non-existent.

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PROFESSOR NATHANIEL WHITAKER WINS DISTINGUISHED ACADEMIC OUTREACH AWARD

Nathaniel Whitaker, an associate professor in the Department of Mathematics and Statistics, has won UMass Amherst's prestigious Distinguished Academic Outreach Award for community education. The award honors his contribution to AIMS, a program supporting the success of African-American children and youth in Amherst public schools.

The AIMS program encourages local African-American students through a combination of academic enrichment and personal interaction with positive role models. In the mathematics portion of AIMS, about 20 to 30 students from grades 3 to 10 meet weekly with Whitaker in a UMass Amherst classroom. They hone their skills by completing advanced mathematics workbooks used by children in Singapore.

Throughout his career, Whitaker has been actively involved at all levels in increasing the number of underrepresented minorities in mathematics and science. As a graduate student at Berkeley in the 80s, he organized qualifying exam tutorial sessions for new minority students and helped to create a network among African-American and Hispanic graduate students. More recently, he is a member of the Park City Math Institute (PCMI) Steering Committee. This committee at the Institute for Advanced Study (Princeton) organizes a 3-week summer school in a different area of mathematics each summer. One of Whitaker's tasks is assisting PCMI with minority recruitment.

"It's difficult to increase the number of minorities in math and science at universities," Whitaker says. "The numbers are lower as the level get higher. The greatest potential for impact is at the grade school levels. That's why I'm proud to have laid the foundation from which AIMS has evolved."

Five Distinguished Academic Outreach Awards were given this year to recognize faculty and professional staff who excel in the outreach component of the campus's mission. Nominations for the awards were solicited from school and college deans. A subcommittee of the Outreach Council selected the recipients on the basis of the scholarly nature of the work involved, its impact on the individuals served, and how the work reflects the integration of teaching, research, and outreach. Winners received a commemorative plaque and the sum of $3,000 and were recognized both at Commencement and at a special award ceremony held on May 8, 2006.

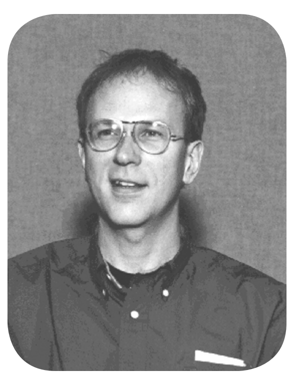
RESULTS OF THE 2005 PUTNAM EXAM
by Haskell Cohen

The UMass Amherst team consisting of Thomas W. Folz-Donahue, Edward D Hanson, and Patrick Dragon finished in 61st place out of 395 teams from U.S. and Canadian colleges and universities. The team was led by Hanson, who got a score of 31. This placed him in the top 6% of the more than 3500 students who took the test.

PROFESSOR WILLIAM MEEKS IS AWARDED GUGGENHEIM FELLOWSHIP

William Meeks, who is the George David Birkoff Professor of Mathematics at the University of Massachusetts Amherst, was recently awarded a Guggenheim Fellowship for the fall semester of 2006. Professor Meeks was one of 187 out of approximately 3,000 applicants to receive this year's prestigious award from the John Simon Guggenheim Memorial Foundation. The foundation offers fellowships to further the development of scholars and artists by assisting them to engage in research in any field of knowledge and creation in any of the arts, under the freest possible conditions and irrespective of race, color, or creed. These fellowships are a great honor not only to those who receive them, but also to the universities whose professors receive them.

Professor Meeks plans to use his fellowship during the 7-month period July 2006 – February 2007, devoting his time and energy to his research project on minimal surfaces. He will spend much of that period at the University of Granada in Granada, Spain and will also travel to the University of Nice in Nice, France, to IMPA in Rio de Janeiro, Brazil, to Rice University in Houston, to the University of Pennsylvania in Philadelphia, and to Harvard University. The purpose of many of these trips is to carry out joint research with collaborators at these other locations.



Professor Meeks is a world-renowned expert in his field of research, which includes low dimensional topology and the global properties of minimal surfaces in three dimensional spaces. The title of his research project is "The Global Structure of Complete Embedded Minimal Surfaces in Three-Manifolds."

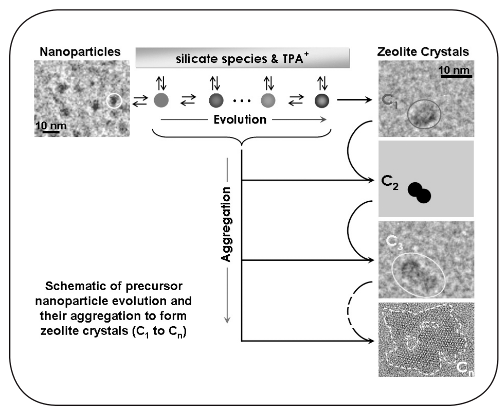
FROM MULTISCALE MODELING TO TAILOR-MADE ADVANCED MATERIALS

Problems having diverse scientific, technological, and environmental relevance are intrinsically "multiscale." In essence, this means that information at very small spatial and temporal scales — for instance, properties and motions of atoms or molecules — can profoundly impact intermediate and large-scale behavior, such as the permeability of a membrane or the viscosity of a fluid. Multiscale problems arise in numerous applications, which include developing novel materials, understanding fundamental biological mechanisms, and predicting the weather and climatological trends.

An example of a real-life multiscale problem is the formation of zeolite membranes. Zeolites are a technologically important class of porous, sieve-like minerals that are used extensively in filters, separation membranes, and other related devices. For example, by separating targeted chemicals, they allow the extraction of chemical components out of petroleum and its by-products on an industrial scale. One of the primary challenges for researchers in this field is to tailor zeolites for specific applications by controlling the structure, size, and shape of the zeolite crystals. However, because researchers have lacked a clear understanding of the nucleation and growth processes that control the formation of zeolites at, respectively, small and intermediate scales, creating new types of zeolites still relies mainly on sophisticated methods of trial and error.

In an effort to improve the understanding of these mechanisms, Markos Katsoulakis of the Department of Mathematics and Statistics joined efforts with Tim Drews and Michael Tsapatsis of the Department of Chemical Engineering at the University of Minnesota. Their first goal was to develop qualitative mathematical models that capture initial stages of zeolite formation, combining careful multiscale modeling with preliminary experimental evidence and extensive numerical simulations. These new models can describe aggregative crystal growth starting from evolving "primary nanoparticles"; these are particles having the size of several nanometers (billionths of a meter) with composition and structure different from that of the final crystal. This initial work was reported in the *Journal of Physical Chemistry* in 2005.

The new feature of their models is the inclusion of a crystal-growth mechanism involving the addition of nanoparticles to the crystals after a certain stage of evolution. Motivated by early promising qualitative predictions of this model, Tsapatsis and his colleagues in the Departments of Chemistry and Chemical Engineering at the University of Minnesota spent more than a year monitoring the growth of zeolites in a laboratory setting, where they used state-of-the-art microscopy to closely study the crystal growth, observing changes on the scale of single nanometers. Consistent with the predictions of the mathematical model proposed by Drews, Katsoulakis, and Tsapatsis, the study carried out by Tspapatsis and his colleagues showed that the zeolites form in a step-by-step, hierarchical fashion with silicon-oxygen nanoparticles forming first. Those particles then aggregate into larger, more complex structures, incorporating other atoms and molecules while still leaving substantial pores and tunnels. See the figure for a comparison of the mathematical model and the experimental observations.



Schematic of precursor nanoparticle evolution and their aggregation to form zeolite crystals (C_1 to C_n)

Based on these experimental findings, a more realistic class of mathematical models was then developed that describes the entire nucleation and growth process and demonstrates agreement with the experiments. The related research was reported in *Nature Materials* in May 2006. Ultimately, Katsoulakis and Tsapatsis hope to further develop and validate even more detailed quantitative mathematical models as a crucial step towards the dual goal of understanding the underlying physical mechanisms and developing an inexpensive tool for predicting and tailoring properties of zeolites. The array of models under consideration extends from stochastic models for nanoparticle evolution and aggregation that allow a refined, small-scale description of the physical process, to models based on partial differential equation that, in turn, can provide an understanding of the dependence of scaling laws on material properties at much larger scales.

From a practical perspective, one of the primary drawbacks of laboratory-made zeolites is that typically they are only in the form of microcrystal powders. It is hoped that the new experimental and modeling insights provided by the work of Katsoulakis and Tsapatsis will allow for making much larger structures, even layers and thin films. These scales would be suitable for technological applications in sensors, optoelectronics, and micro-reactors as well as in replacing energy-inefficient separation methods such as distillation with membrane-based separations. On the other hand, using current technology to make zeolite membranes at such large scales — typically on the order of hundreds or even thousands of square meters — can cost more than $1,000 per square meter. It is conceivable that the detailed knowledge now being obtained both at the mechanistic and at the modeling levels could allow researchers to design film-formation processes that could cost as low as a tenth of that amount.

SOLUTION TO LAST YEAR'S CHALLENGE PROBLEM

Last year's problem was taken from the Putnam Exam and was the following:

"Basketball star Shanille O'Keal's team statistician keeps track of the number S(N) of successful free throws she has made in her first N attempts of the season. Early in the season, S(N) was less than 80% of N, but by the end of the season, S(N) was more than 80% of N. Was there necessarily a moment in between when S(N) was exactly 80% of N?"

We received solutions from Kody Law, Mark Leeper, Ethan Lewis '88, Jay Markot '68, David Melega '79, Robert J. Reed '63, Mark Ruegg '81, and Walter Sizer '72. Here is Jay Markot's solution, slightly edited.

"Yes, for at least one moment Shanille was an 80% free throw shooter. Assume that there was no such moment. Then there was a transition such that $S(N)/N < 4/5$ and $S(N+1)/(N+1) > 4/5$. Since $S(N)+1$ must equal $S(N+1)$, it follows that $[S(N)+1]/(N+1) > 4/5$. Thus $5S(N) < 4N$ and $5S(N)+5 > 4N+4$. Combining, we get $5S(N) < 4N < 5S(N)+1$. But this is impossible since there is no integer between $5S(N)$ and $5S(N)+1$. The contradiction proves that for at least one moment Shanille was an 80% free throw shooter."

Jay Markot goes on to give values of N and S(N) for which one more successful free throws will make $S(N+1)/(N+1) = 4/5$. Several other solvers suggested generalizations of the problem.

APPLIED MATH MASTER'S DEGREE PROGRAM: MODELING GOOGLE AND HUMAN RUNNING

by Nathaniel Whitaker

The Master's Degree Program in Applied Mathematics prepares students to work in an industrial setting after graduation. Students participating in the program take courses both outside and inside the department. However, the most important part of the program is the group project or projects, of which this year there were two. The first was the modeling of the Google search engine and the second the modeling of human running.

The students involved in these projects were Catherine Benincasa, Adena Calden, Emily Hanlon, Matthew Kindzerske, Eddery Lam, Kody Law, John Rhoades, Ishani Roy, Michael Satz, and Eric Valentine. It was my pleasure to direct these students in their projects.

The Google project will be described first. Ever since the internet became popular in 1990s, there has been a revolutionary improvement in data collection and research. Instead of spending many hours in the library, today people can sit comfortably in front of a computer, log onto the internet, open an internet browser, and type the keywords they are interested in. Within seconds, the computer generates a list of websites associated with the related keywords. People can click on those websites and gather the information they are looking for. Clearly, the internet greatly accelerates the process of gathering information.

There are many search engines on the internet, such as Yahoo, Google, and Netscape. This year, the students in the Applied Math Master's Degree Program analyzed the ranking system used by the Google search engine. Every time people type keywords in Google, it provides a list of websites with related information. In particular, the websites that Google consider the most important or the most closely related appear at the top of the list whereas the least important or the least related appear at the end of the list. These observations give rise to two questions. How does Google measure the importance of the website? What method does Google use to create its ranking system?

The two main factors in Google's calculation is the page-rank factor and non-page-rank factors. Due to the limitation of the data set and lack of information on the non-page-rank factors, we decided to focus on the calculation of page rank. The calculation of page rank proceeds as follows. After people type keywords in Google, it prepares a list of websites associated with those keywords. Each website then receives a score. Websites with more connections to other websites receive higher scores while websites with fewer connections receive lower scores. By applying the power method in numerical analysis, the students were able to simulate the page-rank processing of a network. They wrote a program, called a webcrawler, that crawls the internet site by site to determine how sites are interconnected. This created a network of 60,000 sites containing the Department of Mathematics and Statistics and its connected sites. The students then applied the page-rank algorithm to this network. In contrast to the network of 60,000 sites created by the students in this project, the actual internet contains over 3.5 billion sites. A small network of websites and their interconnectivity is shown in Figure 1.

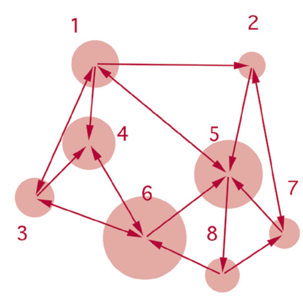


Figure 1

NEW CHALLENGE PROBLEM

by Haskell Cohen

This problem is taken from this year's Henry Jacob Mathematical Competition.

"For which rational numbers q is $3q^3 + 10q^2 + 3q$ an integer?"

As usual, send your solutions to

Professor Emeritus Haskell Cohen, Problem Editor
Department of Mathematics and Statistics
University of Massachusetts Amherst
Amherst, MA 01003-9305

or send email to haskell@math.umass.edu

The students in the Applied Math Master's Degree Program also applied the same algorithm to other topics such as developing a ranking system of US airports that would help determine which airports are the most important according to the numbers of passengers. Once again using the power method and applying it to an actual data set obtained from Bureau of Transportation, the students concluded that Dallas/Fort Worth International Airport is the most important airport in the US. Certainly, it is possible to adapt this algorithm to other applications involving ranking, such as determining the most important countries in international trade.

The second group project this year focused on running, which is as common as walking in the human species. We do not usually think about the mechanics of the running process and usually undertake it unconsciously. Although running seems to be a simple activity, it is more complicated than most people think. Running is, in fact, a series of one-legged bouncing impacts. In the field of biomechanics this is called a spring-loaded inverted pendulum (SLIP) model or as it is commonly referred to, a monopedal hopper (see Figure 2). This year, we chose to model the monopedal hopper and use it to simulate running or hopping.

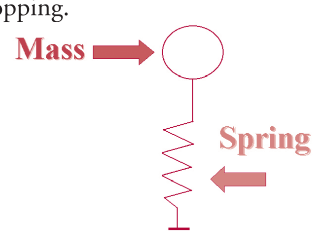


Figure 2

Among the benefits to be gained from studying the monopedal hopper is the insight into understanding locomotion in creatures with two, four, and even six legs. The six-legged cockroach is one of the most stable runners in nature, and researchers are using its body type to create robots that are extremely stable on rough terrain. The SLIP model also applies to human locomotion. Further understanding into how the human body behaves during the running process has helped and will continue to help in developing better prosthetics, in discovering better treatments for biomechanical ailments such as arthritis, and in producing better athletic equipment just to name a few. In Figure 3, one observes a human running and as well as the motion of the monopedal hopper. The similarities are amazing.

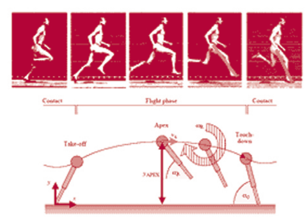


Figure 3

Undertaking this project involved input from many academic areas. We first had to understand the *physiology* of the leg as well as the *mechanics* of how the leg moves and interacts with various forces during running. As we learned, the running process can be broken down into two phases. The stance phase is the period of time when the foot is still in contact with the ground, and the flight phase is the period of time when the foot and the body are in the air. Each phase is governed by a different set of equations derived from Newton's laws of motion. The stance phase is described by three second-order differential equations while the flight phase is described by the equations for common projectile motion found in physics. The students solved the coupled differential equations for the two phases numerically in order to simulate running.

Extensions of this project could involve teaching our monopedal hopper to move up an incline and to hop along a slippery surface or could incorporate different damping forces from the ones that were used. This project proved to be interesting and mathematically challenging. We all gained valuable skills and experiences from working on it this year.

HEATHER HARRINGTON TO STUDY MATHEMATICAL BIOLOGY AT IMPERIAL COLLEGE LONDON

Heather A. Harrington is a graduating senior majoring in applied mathematics. Throughout her mathematics career at UMass Amherst, she has worked closely with Professors Panayotis Kevrekidis and Nathanial Whitaker, both of whom have been instrumental in introducing her to research and to mathematical biology. Heather was recently awarded the prestigious 2006 Deputy Rector's Award, a three-year Overseas Research Scholarship to study at Imperial College London. In October, Heather will join the mathematics department there as a research student, where she will study under the supervision of Dr. Jaroslav Stark. Hoping to complete the intensive Ph.D. program in three years, she plans to continue pursuing her undergraduate dream of integrating mathematics, biology, and medicine. Her current interest is systems biology; specifically, modeling the activation of T cell receptors.

During her four years at UMass Amherst, Heather has been the recipient of numerous awards, including in 2005 the Goldwater Scholarship and in 2006 a Senior Leadership Award, a 21st Century Leaders Award, and a Women in Massachusetts Public Higher Education Achievement Award, which recognizes Heather for her leadership and contributions to the UMass Amherst community and for her academic achievements. During the summer of 2006, Heather will be one of fifteen students nationwide selected to participate in Enhancing Diversity in Graduate Education, a mathematics program held at New College of Florida for women entering graduate school. Heather also rows on the UMass lightweight team and hopes to continue rowing throughout her graduate studies.

NEW FACE IN THE DEPARTMENT

Weimin Chen joined the Department of Mathematics and Statistics in Fall 2005 as an Assistant Professor. He received his Ph.D. in 1998 from Michigan State University, where he worked under the direction of Professor Selman Akbulut. From 1998 to 2000 he was a Van Vleck Assistant Professor at the University of Wisconsin, Madison. During AY 2000–2001 Weimin was a James Simons Instructor at SUNY, Stony Brook, and he spent the following year as a member of the Institute for Advanced Study in Princeton. Weimin was an Assistant Professor at Tulane University during the period 2002–2005.

It is a surprising fact that questions about topology are often easier to answer in high dimensions than in lower dimensions. In particular the three-dimensional and four-dimensional cases are among the hardest. Weimin's work, supported by the National Science Foundation, is devoted to the elucidation of these questions, particularly in the topology of smooth four-dimensional manifolds. He has also done extensive work on the topology of orbifolds, a generalization of manifolds of great interest in mathematical physics. His work with Yongbin Ruan on orbifolds has become a classic after only four years. Weimin joins the department's excellent group in geometry and topology, and we are delighted to welcome him as a colleague.

The Math of Finance ***continued from page 5***

You now know which job to take. Because PDQ's calls are worth \$2.50 each, PDQ's incentive is worth \$2500 compared to AB Co.'s \$4,000 cash.

Extend the one-step binomial tree model to an n-step model with shrinking time increments. As n goes to infinity, the central limit theorem implies that the stock price dynamics converge to an Ito process. In 1973, two economists, F. Black and M. Scholes, derived the formula for the European call option price in this limiting Ito process. Now known as the Black-Scholes formula, their result revolutionized the theory of math finance. Scholes and R. Merton, who extended their results, won the 1997 Nobel Prize in Economics; Black had previously passed away. Their formula also revolutionized the marketplace. Options have always been useful to reduce unwanted investment risk, but they had previously been hard to price. In 1973, the first options market opened. Today, the options market is worth \$7 trillion, and the theory of pricing options is an active area of research.

One final remark: *we did not need to know the probability of PDQ stock increasing or decreasing to compute the price of its call.* For an explanation of this seemingly counter-intuitive fact, or to learn about the more refined model mentioned in the preceding paragraph, you may want to revisit LGRT for the next Math 441 class.

PROFESSOR FARSHID HAJIR WINS OUTSTANDING TEACHING AWARD

by Murray Eisenberg

"Awesome," "great," "fabulous," "amazing." Those are the words undergraduates use again and again in end-of-semester evaluations to describe Farshid Hajir. It's no wonder then that Hajir won awards for his teaching even while he was still a graduate student at MIT. And now he has received special recognition for his teaching at UMass Amherst, too, as a recipient of this year's College of Natural Sciences and Mathematics Outstanding Teaching Award.

The award, announced March 15, carries a cash stipend and public recognition at the Convocation of the College of Natural Sciences and Mathematics (NSM) this fall, where a citation will be read and a plaque will be presented to Hajir. Similar to honors bestowed by each school and college at UMass Amherst, the NSM award is an annual one for which recipients are nominated by their departments and selected by a college-wide faculty committee. In congratulating Hajir on his selection, Professor Arnold Rosenberg, chair of the NSM Awards Committee and a member of the Department of Computer Science, noted that the nomination portrayed Hajir as a "caring, diligent, and innovative teacher — a true role model for your peers."

Hajir came to UMass Amherst in 2002 after holding faculty positions at the University of North Carolina and California State University, San Marcos, and postdoctoral positions at Cal Tech and UCLA. During his four years here, he has taught undergraduate and graduate students at all levels, from mathematics for elementary school teachers and freshman calculus for students in social, biological, and management sciences to an advanced graduate course on algebraic number theory, his own research specialty.

Asked why students are so responsive to him, Hajir replies, "I don't think of myself as someone who understands things quickly, so I try to put myself into the position of somebody who has never seen the concept before. I ask students questions as if I were asking them of myself."

Hajir first realized that he liked teaching during his senior year at Princeton University, where he tutored in the dorm; word soon got around as to how well he explained things. Today, nearly twenty years later, he still thoroughly enjoys teaching, so much so that each class goes by very quickly for him. He admits, "I get a big kick out of all of those students being there to listen to what I have to say!"

When he reads evaluations by his students, Hajir says, "I like the fact that they like my goofy sense of humor." He explains also that he tries "to arrange that unexpected things happen" in his classroom, and he suspects that students will remember the extremes he goes to — standing on the desk, for example — in order to get them to remember things.

In view of his considerable teaching experience elsewhere, it is interesting to hear Hajir's take on how students at UMass Amherst differ from those he taught before: "I have to twist their arms to get them to come to office hours." He suspects that there may be a different student culture here, perhaps even a different perception as to how much the professor cares." There is no doubt that Hajir cares deeply, as he goes out of his way to persuade, coax, and cajole students to visit him in his office. Students express gratitude for the extraordinary extent to which he makes himself available for outside help and for how effective that help is.

In many academic fields, Hajir notes, faculty often teach within a fairly narrow area of expertise but are able to keep their teaching fresh by constantly updating material as knowledge advances. At the undergraduate level in mathematics, by contrast, the material is more or less "standard." That is why, he explains, mathematicians are lucky in being able to teach a variety of courses. "One thing that I really enjoy," Hajir says, "is to teach a variety of courses; that keeps me excited about teaching."

Work in the classroom is but one piece of Hajir's involvement with teaching. He has mentored students through summer Research Experience for Undergraduates programs, has supervised both undergraduate and

continued on page 13

GRADUATE PROGRAM NOTES

by Ivan Mirkovic

Jacob Gagnon presented an algorithm to rank "invisible" web sites at the meeting of the Mathematical Association of America held June 17–18, 2005 at Bates College in Maine. His computer graphic designs were accepted for presentation at the Information Visualization Conference to be held July 5–7, 2006 in London, England and at the Computer Graphics, Imaging, and Visualization Conference to be held July 25–28, 2006 in Sydney, Australia. Jacob's joint paper entitled "Stability of Solutions to the Discrete Nonlinear Schrödinger Equation in Multiple Dimensions" was presented at the meeting of the Mathematical Association of America held November 18–19, 2005 at the University of New Hampshire.

Laura Hall-Seelig was nominated for the University Teaching Award. **Mairead Greene** and **Hiro Oh** were both nominated for the University of Massachusetts Amherst Graduate Student Fellowships.

This year, the paper of **So Okada** entitled "Stability Manifold of P1" was published in the prestigious *Journal of Algebraic Geometry*. He also obtained a one-year position at the Max Planck Institute for Mathematics in Bonn.

In September 2005 **Ang Gao** received the M.S. degree in statistics and **Stacy Carrier** the M.S. degree in mathematics. In February 2006 **Mei Cheng Chan** received the M.S. degree in statistics, and **Molly Fenn** and **Corey Irving** received the M.S. degrees in mathematics.

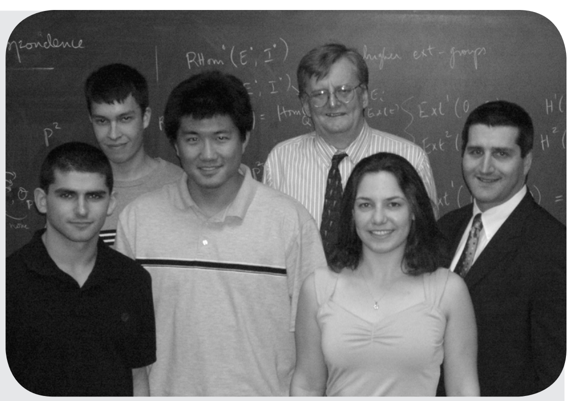
The following students are expected to receive their M.S. degree in May 2006: **Andrew Hearin** and **Omer Kucuksakali** in mathematics; **Tao Feng**, **Pallavi Gupta**, **Davit Khachatryan**, **Simon Keller**, and **Yongjoon Shin** in statistics; **Catherine Benincasa**, **Adena Calden**, **Eddery Lam**, **Ishani Roy**, and **Michael Satz** in applied mathematics.

Marius Costeniuc received his Ph.D. in September 2005. After spending the academic year 2005–2006 as a postdoctoral fellow at the Max Planck Institute in Leipzig, Germany, in the fall he will enter the Master of Advanced Studies Program in Finance. This program is run jointly by the University of Zurich and ETH-Zurich.

After defending his Ph.D. dissertation in August 2005, **Dmitrios Tsagkarogiannis** visited the Institute for Advanced Studies of the Czech Republic and then assumed a two-year postdoctoral fellowship position at the Max Planck Institute in Leipzig, Germany.

HU WINS HENRY JACOB MATHEMATICS COMPETITION

Shaohan Hu, a sophomore majoring in mathematics and computer science, won first prize in this year's Henry Jacob Mathematics Competition. The $1,400 cash award was presented to Hu by the sponsors of the competition, Roy Purdue '75 (Solutions by Computer) and James Francis '90 (Northern Trust Global Investments).



The winners and sponsors of the Henry Jacob Mathematics Competition. From left, Michael Kranin, Alexander McAvoy, Shaohan Hu, Roy Perdue, Hilary Scheintaub, and James Francis.

Other winners were Michael Kranin (second prize, $1,000) and Hilary Scheintaub (third prize, $600). Alexander McAvoy received honorable mention.

The awards were presented at a departmental dinner held at the University Club on April 27, 2006. Prof. Farshid Hajir gave a short and lively presentation on the changing face of mathematical collaboration, and the role it plays in current mathematics research. Also in attendance were Professors Eduardo Cattani, Haskell Cohen, Paul Gunnells, and Eleanor Killam, as well as Gretchen Jacob, the wife of the late Professor Henry Jacob, and several family members of the winners.

Support the Henry Jacob Mathematics Competition

The Henry Jacob Mathematics Competition carries on a tradition begun by its namesake, who had a longtime interest in promoting mathematics among undergraduates. The competition plays a vital role in recognizing and encouraging mathematical talent at UMass Amherst. Many students taking the exam go on to pursue a closer relationship with the department, for instance through undergraduate research projects and honors theses.

Today, the mathematics competition seeks your help. Your contributions to the competition help to kindle interest in mathematics among undergraduates, bring new students into the Department, and raise the visibility of the undergraduate mathematics program at UMass Amherst. For information about how to give, go to www.math.umass.edu/Give/donate.html

"YOU CAN'T ALWAYS GET WHAT YOU WANT": MEASUREMENT ERROR IN STATISTICS

Noisy data is a fact of life for many scientists. Examples include an ecologist who uses a sampling method to estimate the number of deer in a park or a public-health researcher who uses a combination of surveys and physiological measures to estimate the amount of calories that a person burned in the previous week. Using noisy data such as these in statistical analyses leads to the problem of measurement error, for which two questions emerge: What are the consequences of naively ignoring the noise or the measurement error in the measured quantities? If the measurement error causes problems with the statistical analysis, then how can they be fixed? For example, it is well known that measurement errors can create biases; the best known example is that in many cases the effect of an exposure variable on the occurrence of a disease is underestimated when the exposure is mismeasured.

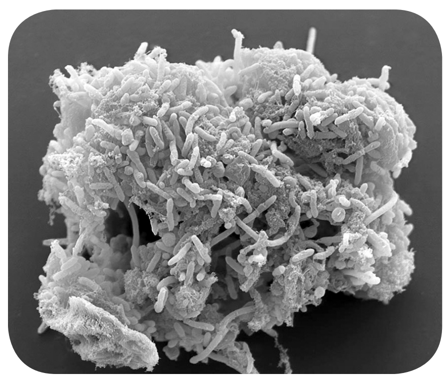
Problems involving measurement error have been a primary area of interest for two statisticians in the department, Professor John Buonaccorsi and Assistant Professor John Staudenmayer. They are nearing the completion of a three-year grant from the National Science Foundation that examines the problem of measurement error in time series, with particular emphasis upon population dynamics. An important problem in ecology is to model the behavior of animal populations over time and to estimate probabilities about the population at future times, including the probability of extinction. Animal abundances must be estimated, often through some complicated sampling method, which then leads to measurement error. The research of Professors Buonaccorsi and Staudenmeyer both provides an assessment of the quality of analyses that have ignored the measurement errors and gives techniques to correct for these errors.

A second area of application is the measurement of physical activity, a project in which they are collaborating with Professor Patty Freedson of the Department of Kinesiology at UMass Amherst on a new, five-year, approximately $1 million grant from the National Institutes of Health. Their collaborative research will have two parts. The first part focuses on accelerometers, which are fancy pedometers that can be worn during daily activities. They will devise methods to convert the sea of data produced by accelerometers into estimates of aspects of physical activity such as the fraction of time a person exercises at a certain intensity during a week. In the second part of their research, they will model the measurement error in the resulting estimates and develop method to reduce its effects. The grant will include funding for research assistantships for students in the Department of Mathematics and Statistics.

STATISTICAL APPLICATIONS IN GENOMICS

Geobacter is a microbe that can conduct electricity from organic waste matter and help clean up contaminated environments. The first *Geobacter* species named *Geobacter metallireducens* was discovered by University of Massachusetts Amherst Professor of Microbiology Derek R. Lovley in the Potomac River in 1987 near Washington, D.C. In a manner that is similar to how humans use oxygen, this microbe gathers energy by using iron oxides, which are comparable to rust. *Geobacter metallireducens* and other Geobacter species are the focus of a five-year, $21.8 million grant that was awarded to Derek R. Lovley by the U. S. Department of Energy.

Lovely and a team of colleagues are studying *Geobacter* in order to optimize the practical applications of this microbe, including bioremediation and energy harvesting. Collaborators at the University of Massachusetts Amherst include Assistant Professor Erin Conlon, a Co-PI, and Assistant Professor Anna Liu, both of whom are statisticians in the Mathematics and Statistics Department. Professor Conlon is working with both gene expression information and DNA sequence data in *Geobacter sulfurreducens*. By integrating this data, she and associates are identifying patterns in DNA sequence that control the expression of genes in different environmental conditions. Professor Liu and associates are also analyzing gene expression data in order to identify which genes are activated and deactivated in various experimental designs. The goal of this research is to provide information that can be used in a computer model to predict the activity of *Geobacter* under various settings. In addition to the University of Massachusetts Amherst group, the team of investigators also includes associates at Argonne National Laboratory, University of California-San Diego, Genomatica of San Diego, The Institute for Genomic Research, University of Indiana, and University of Tennessee. More information regarding the project can be found at http://www.geobacter.org.



A geobacter microbe, magnified 3600 times

Professor Hajir ***continued from page 11***
graduate students in Independent Study courses, and is directing the dissertation of a Ph.D. student. Especially notable is his involvement with the "What Is …?" Graduate Seminar (TWIGS), which he created four years ago and has continued to guide and frequently speak in since then. In TWIGS, faculty members informally introduce a variety of topics at a level aimed at beginning graduate students; further details concerning TWIGS are contained in an article by Farshid appearing in last year's newsletter. Farshid has also been collaborating with mathematics education groups in the School of Education in a number of ways, which include advising prospective teachers and advising School of Education search committees on new faculty appointments.

All of us in the Department of Mathematics and Statistics congratulate Farshid Hajir upon his designation as the College of Natural Sciences and Mathematics Outstanding Teacher.

STABILITY OF THE QUANTUM HARMONIC OSCILLATOR

by Wei-Min Wang

The invention of quantum mechanics and the development of spectral theory are two important, related achievements in 20th century physics and mathematics. The equation that describes the motion of a quantum mechanical system is called the Schrödinger equation. Consisting of a kinetic energy term and a potential energy term, the Schrödinger equation is an example of a partial differential equation because it involves derivatives with respect to both the time variable and the spatial variable. An important quantum mechanical system is the quantum harmonic oscillator, which is described by a Schrödinger equation having a potential energy that is quadratic in the spatial variable.

Besides being an important system in its own right, the quantum mechanical oscillator plays a central role in physics because it arises naturally as an approximation to more complicated systems. In fact, when one studies a class of quantum mechanical systems close to equilibrium, under appropriate conditions one can make a quadratic approximation to the potential function, obtaining the Schrödinger equation for the quantum harmonic oscillator. It also plays a central role in spectral theory because it is an integrable system and so is exactly solvable.

The eigenfuctions of the quantum harmonic oscillator are the Hermite functions. They are constructed from the Hermite polynomials, which are the orthogonal polynomials with respect to a Gaussian measure. The Hermite functions are obtained by multiplying these polynomials with the corresponding Gaussian density. Determining the eigenfunctions of quantum mechanical systems such as the quantum harmonic oscillator involves sophisticated mathematics that is an aspect of spectral theory. Historically the theory developed as an infinite dimensional generalization of the study of matrices, which arise in a number of courses in the undergraduate mathematics curriculum.

Another insight that spectral theory gives into the behavior of the quantum harmonic oscillator is that the solutions of the corresponding Schrödinger equation are periodic in time and so have bounded orbits. A consequence is that an initially localized particle remains localized for all future times. Thus, if it is near the origin at time 0, then for all future times it will remain near the origin.

One of the topics of my research is the stability of the quantum harmonic oscillator under small perturbations. When the perturbations are independent of time, one can study stability using conventional spectral theory. However in numerous situations the perturbations are time-dependent or nonlinear, two cases in which conventional spectral theory can no longer be used. Another natural mathematical question to ask is how one can analyze the perturbed system when it loses the property of integrability that the original quantum harmonic oscillator has.

The study of the stability of the quantum harmonic oscillator under time-dependent or nonlinear perturbations is the subject of a sophisticated theory known as KAM theory for partial differential equations, which applies not only to the Schrödinger equations but also to a class of other partial differential equations. KAM theory for partial differential equations is a newly emerging field that uses operator methods from spectral theory and also adapts a number of ideas arising in the study of dynamical systems. In my research I have proved that the one-dimensional quantum harmonic oscillator is stable under a wide class of perturbations that cannot be studied by conventional techniques. Mathematically this stability result is a KAM-type of theorem that was not known before using the purely dynamical systems approach. The stability result also has a number of important applications, including the physics of confining charged particles at low temperatures and more recently Bose-Einstein condensation.

Bose-Einstein condensation in gases is a new form of matter at the coldest temperatures in the universe. Honored with the Nobel Prize in Physics in 2001, Bose-Einstein condensation is now the object of intensive and ever growing theoretical and experimental study. Reasons for the excitement about this topic are its relevance to areas such as superconductivity and superfluidity—the subject of the Nobel Prize in Physics in 2003—and its potential applicability to numerous areas including quantum computation and atom lasers. It is hoped that the new insights into Bose-Einstein condensation provided by my work will help scientists gain even deeper insight into this new form of matter that is at the forefront of research today.

THE FOLLOWING ALUMNI AND FRIENDS HAVE MADE CONTRIBUTIONS

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YOU ARE IMPORTANT TO US!

We want to hear about how your experience with our Department affected your life. There are also many opportunities for alumni and friends to become involved with the Department, from giving to the Department to giving a presentation to our students about your career and how the Department is important to you. Please contact us, share your news with us, and let us know what you're doing! Send any correspondence to:

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