Department of Mathematics

The Department of Mathematics seeks to sustain its top ranking in research and teaching by hiring the very best faculty, with special attention to the recruitment of women and candidates from underrepresented minorities, and by continuing to serve the varied educational needs of the department's graduate students, mathematics majors, and all MIT undergraduates.

New Faculty

The Mathematics Department had a very successful year in faculty hires for FY2011. Alexei Borodin is a leading specialist from the California Institute of Technology in the interface between representation theory and probability that is linked to combinatorics, random matrix theory, and integrable systems. He will join the department's faculty as professor in fall 2010. Peter Ozsváth, a major figure in low-dimensional geometric topology from Columbia University, will also join the department in fall 2010. Henry Cohn will be appointed adjunct professor of mathematics. He has been a principal researcher at Microsoft Research New England, working across several fields in discrete mathematics, including computational and analytic number theory, algebraic combinatorics, and theoretical computer science.

Two MIT engineering faculty members are jointly appointed with the Mathematics Department. Martin Bazant, associate professor of chemical engineering, has been jointly appointed on the mathematics faculty since 2008. A specialist in microfluidics and electrochemical systems, he joined the mathematics faculty in 2000 before moving to chemical engineering. In addition to graduate student supervision in applied mathematics, Professor Bazant is the faculty mentor of the MIT teams competing in the International Mathematical Contest in Modeling.

Anette (Peko) Hosoi, associate professor of mechanical engineering, will be jointly appointed in mathematics in fall 2010. She is a specialist in free surface flows, surface tension, and complex fluid dynamics. A MacVicar Faculty Fellow, she first came to MIT as an applied mathematics instructor from 1998–2000.

Clark Barwick, a leading young figure in algebraic topology and homotopy theory, will join the faculty as assistant professor of mathematics. Dr. Barwick received a PhD from the University of Pennsylvania in 2005, and has been a Benjamin Peirce lecturer at Harvard University.

Jacob Fox is a discrete mathematician with broad interests in extremal combinatorics, combinatorial geometry, and probabilistic combinatorics. He will join the faculty as Simons postdoctoral fellow and assistant professor of applied mathematics, with the latter appointment to begin in September 2011. A graduate of MIT, Fox received a PhD from Princeton University in 2010.

Faculty Promotion

Assistant professor Katrin Wehrheim, a leading specialist in analytical foundations of geometry and topology, will be promoted to associate professor.

Retirements

Over the past year, seven of our most distinguished senior faculty members retired. These professors, who joined the MIT mathematics faculty starting in 1956, were dominant in their fields in pure and applied mathematics and were core contributors to the department and to MIT's development as a world-class research and teaching institution. They were teachers and mentors to some two generations of MIT undergraduates, and their graduate student "descendants" number more than 500.

Professor Michael Artin, who joined the MIT mathematics faculty in 1963, was appointed Norbert Wiener professor from 1988–1993. He served as chair of the pure mathematics committee from 1982–1983, and twice as undergraduate chair. He helped weave the fabric of modern algebraic geometry while also working to create the field of noncommutative algebraic geometry. His undergraduate algebra course and textbook have been major features of the MIT mathematics curriculum.

Professor David Benney joined the mathematics faculty in 1960. A fluid dynamicist concentrating on problems in wave stability, he has served as managing editor of *Studies in Applied Mathematics* since 1969. He chaired the applied mathematics committee from 1983–1985 and was department head for two terms, from 1989–1999.

Professor Daniel Kleitman is a discrete mathematician, one of the developers of network analysis. He joined the mathematics faculty in 1966 and served as department head from 1979–1984 and for three terms as chair of the applied mathematics committee. He also served on several institute committees, including the educational policy and discipline committees and the faculty nomination committee.

Professor Arthur Mattuck, an algebraic geometer, joined the mathematics faculty in 1958. He became one of the main lecturers of large calculus and differential equations courses and was instrumental in their further development. He wrote "The Torch or the Firehose," a widely distributed booklet on recitation teaching in many translations. He developed one of MIT's first undergraduate offices in the Mathematics Department and served as undergraduate chairman for many years. He served as department head from 1984–1989.

Institute Professor Isadore Singer is one of the most influential mathematicians of the 20th century. In 2004, he and Michael Atiyah received the Abel Prize for the index theorem, which brought together many branches of mathematics and led to deep interactions with physics. He was appointed Norbert Wiener professor from 1970-1979, the first John D. MacArthur professor in 1983, and institute professor in 1987. He served extensively on national councils and committees, including the National Academy of Sciences (NAS) Committee on Science, Engineering, and Public Policy, 1971–1984; the Council of the NAS, 1981–1984; and the White House Science Council, 1982–1988. In 2005 Singer received the James R. Killian Jr. Faculty Achievement Award.

Professor Daniel Stroock joined the mathematics faculty in 1984. A leading figure in probability theory and stochastic processes, he was appointed Simons professor of mathematics from 2002–2006. He served on the board of the National Research Council and as chair of various committees of the American Mathematical Society. He chaired the pure mathematics committee from 1995–1997.

Professor Alar Toomre joined the mathematics faculty in 1963. His research concentrated on problems in fluid mechanics and galaxy dynamics. He served on numerous committees at MIT and elsewhere and twice as chair of the applied mathematics committee. A Guggenheim and MacArthur Fellow, Professor Toomre received the Brouwer Award from the American Astronomical Society in 1994.

Administration

Michael Sipser will continue as department head.

David Jerison will continue as chair of the pure mathematics committee and Michel Goemans as chair of the applied mathematics committee. Haynes Miller will continue as chair of the Undergraduate Committee. Bjorn Poonen and Gigliola Staffilani will continue as cochairs of the graduate student committee in pure mathematics, and Peter Shor as chair of the committee in applied mathematics graduate admissions. John Bush and Ju-Lee Kim will cochair the committee of undergraduate advisors.

New Mathematics Academic Services Office

The department has combined the undergraduate mathematics office (UMO) and the graduate student office into the mathematics academic services office. Jeffrey Kinnamon, who served as registrar and systems officer at Harvard University, has joined the department to manage this new service center. His appointment coincides with the retirement of Joanne Jonsson, the department's academic administrator since 1978.

Joanne Jonsson designed the services of UMO with professor Arthur Mattuck and many undergraduate chairs during her tenure. She developed procedures and forms to accommodate both the expanding mathematics curricula that serve all undergraduates and the increasing number of mathematics majors. Under her leadership, UMO became a model service center that has been emulated widely at the Institute. In 2001, the UMO office team received the MIT Excellence Award. Joanne Jonsson also received the 1985 James N. Murphy Award, the 2001 Infinite Mile Award, and the 2003 School of Science Dean's Educational and Student Advising Award.

Faculty Honors and Awards

Professor Tobias Colding will follow professor Richard Stanley as the next Norman Levinson professor of mathematics. Professor Colding, with his collaborator William P. Minicozzi, was awarded the 2010 Veblen Prize in Geometry of the American Mathematical Society (AMS), "for their profound work on minimal surfaces."

Assistant professor Benjamin Brubaker was appointed the Cecil and Ida Green career development assistant professor of mathematics. Brubaker is a number theorist working in analytic number theory and the theory of automorphic forms.

John Bush was elected a fellow of the American Physical Society. He also received a Paris Sciences chair at the École Supérieure de Physique et de Chimie Industrielles.

Michael Artin, Tom Leighton, and Gilbert Strang were selected to be fellows of the Society of Industrial and Applied Mathematics.

Michel Goemans received the Best Paper Award at the 21st Symposium on Discrete Algorithms of the Association of Computing Machinery—Society for Industrial and Applied Mathematics, for a paper jointly with A. Asadpour, A. Madry, S. Oveis Gharan, and A. Saberi.

Paul Seidel received the 2010 AMS Oswald Veblen Prize in Geometry "for his fundamental contributions to symplectic geometry and, in particular, for his development of advanced algebraic methods for computation of symplectic invariants."

Tomasz Mrowka received a Guggenheim Fellowship. (As a matter of record, the Simons chair he currently holds will be renamed the Isadore Singer chair of mathematics.)

Assistant professor Abhinav Kumar received a National Science Foundation CAREER award, and Jonathan Kelner a Sloan research fellowship.

Richard Stanley gave the AMS Colloquium Lectures, and Peter Shor, the AMS Josiah Willard Gibbs Lecture, at the 2010 joint AMS/Mathematical Association of America/ Society for Industrial and Applied Mathematics meeting.

Resource Development

The Department of Mathematics had another good year in reaching out and engaging alumni and friends of the department. We continued to do faculty presentations for alumni, parents, and friends. We arranged for department head Michael Sipser and School of Science dean Marc Kastner to travel to Greenwich, CT, this year, where we held a reception and Michael Sipser gave a talk, "Beyond Computation: The P versus NP problem." We also held a small dinner to thank our donors. We continue to highlight the Department of Mathematics through our School of Science breakfast talks on campus. This year Gigliola Staffilani gave a talk, "From Disorder to Order: How a Mathematician Sees Life and Work." Both talks were good opportunities to share work that our faculty members are doing and to highlight needs of the department. We sent a holiday greetings card this year from the department. We remember all donors to the department and thank them in our publication *Integral*, highlighting donors who have made a particular impact on the department.

Simons Lecture Series

The 2010 Simons lectures were given by two lecturers: Andrei Okounkov, professor of mathematics at Princeton University, and Peter Winkler, the Albert Bradley Third Century professor in the sciences at Dartmouth College. Professor Okounkov, a Fields Medalist, spoke on topics in a series entitled "Applied Noncommutative Geometry." Professor Winkler, renowned in discrete mathematics and theoretical computer science, presented a series of talks entitled "Forceless Physics and the Combinatorial Arsenal."

Women in Mathematics

The department has begun a website, MIT Women in Mathematics, http://math.mit.edu/wim/,to feature biographies and vignettes of, and quotations from, women postdoctoral students, graduate students, and mathematicians in other MIT departments. The site also lists awards, statistics, and historical data, highlighting events, seminars, and relevant links.

Diversity Efforts

The Mathematics Department has had some success in enrolling women students and in hiring women scholars, but it has had little or no success in identifying and hiring members of underrepresented minorities (URM). A major difference at the hiring level is that few URM candidates appear in the initial pool. With MIT's URM population now at 23 percent of total enrollment, there may be more opportunity to recruit students to major in math.

Last April, the department invited William Yslas Vélez to speak on diversity in the mathematical sciences. He is distinguished professor of mathematics at the University of Arizona and former president of the Society for Advancing Hispanics/Chicanos and Native Americans in Science. His talk, "The Mathematical Enterprise: A Minority Perspective," addressed a number of perspectives experienced by undergraduates that are often not perceived by recruiters and educators. The department has invited him to be Dr. Martin Luther King Jr. professor in spring 2011, when he will primarily concentrate on helping the department increase the URM population in mathematics at MIT.

The department has implemented a number of additional avenues to reach out to URM students, potential graduate students, and scholars as we seek to address the challenges put forth by the report of MIT's Initiative on Faculty Race and Diversity:

- Working with the Admissions Office to contact URM applicants who are considering MIT
- Supporting and interacting with on-campus URM groups, such as the National Society for Black Engineers and the Society of Hispanic Professional Engineers
- Developing a department website for URM students, as is currently under way for MIT women in mathematics
- Encouraging and supporting gatherings for URM students, and arranging URM speakers at department seminars

Education

Graduate Students

There were 114 graduate students in mathematics in 2009–2010, all in the PhD program. During 2009–2010, a total of 22 students received a doctoral degree; two received a master's degree.

The 2010 doctoral candidates are highly distinguished. Five of them were National Science Foundation graduate fellowship recipients; two had been awarded Department of Defense National Defense Science and Engineering Graduate fellowships (NDSEG/DOD); one had been selected as a joint Hertz and NDSEG/DOD fellow. Two of the doctoral students had been selected as recipients of competitive institute fellowships: one had held a Martin Family fellowship from the MIT Energy Initiative and one had been awarded the Collamore-Rogers fellowship through the office of the dean for graduate education.

All of the 22 have secured employment for the coming year: 17 will have postdoctoral positions in either mathematics or related departments at Brown University, Harvard University, MIT, Northwestern University, Princeton University, Rutgers University, Stanford University, Tsinghua University (China), the University of Chicago, the University of Denmark, the University of Illinois, the University of Michigan, and the University of Minnesota. One will work at an educational nonprofit organization, two will work at Oracle, and the remaining two are entering careers in engineering and finance.

There will be 22 new graduate students in our doctoral program in 2010–2011, including three women. We continue the policy of offering all first-year students fellowship support; as usual, many incoming students come with support from external sources.

Awards

Craig Desjardins and David Jordan received the Housman Graduate Student Teaching Award for their exceptional skill in and dedication to undergraduate teaching.

Roman Travkin was awarded the Charles W. and Jennifer C. Johnson Prize for an outstanding research paper accepted in a major journal. Travkin was also selected for an Albert Memorial Fellowship by the dean of graduate education.

Majors

During 2010, more than 330 students listed mathematics as their major, making this the largest undergraduate program in the School of Science. Seventy-six students graduated with a first degree in mathematics and 51 finished with a second degree in the department. Thirteen of our seniors are continuing in graduate school in mathematics, and 42 are continuing in other disciplines.

The MIT team placed first in the William Lowell Putnam Mathematical Competition, the third time the team has placed first since 2000. The winning team consisted of seniors

Qingchun Ren, Bohua Zhan, and Yufei Zhao. Two of these team members, Qingchun Ren and Yufei Zhao, were among the five highest-ranking individuals and were named Putnam Fellows. Once again, MIT students dominated the competition, in which 4,036 students participated: following the Putnam Fellows, six MIT students ranked in the next group, and 20 received honorable mention, among 56 honorees. Students benefited from excellent coaching by professors Richard Stanley and Kiran Kedlaya.

The Jon A. Bucsela Prize in Mathematics, given in recognition of distinguished scholastic achievement, professional promise, and enthusiasm for mathematics, was awarded to senior Yufei Zhao. Yufei was also awarded the Gates Cambridge Scholarship for an outstanding student outside the UK to study at the University of Cambridge.

Senior Charmaine Sia was a cowinner of the Alice T. Schafer Prize for excellence in mathematics by an undergraduate woman in mathematics, given by the Association for Women in Mathematics. Charmaine also received the Association of MIT Alumnae Senior Academic Award.

Senior Maria Monks received a Hertz Fellowship, and senior Vinayak Muralidhar was given a Marshall Scholarship for graduate study in the United Kingdom.

Junior David Greenberg won the 2010 Laya and Jerome B. Wiesner Award in the Arts at MIT.

Undergraduate and High School Summer Research Program

In summer 2009 the department hosted its 13th Summer Program in Undergraduate Research, a six-week program of full-time research experience for MIT undergraduates, who are individually paired with a department graduate student as mentor. The program culminates in written papers and lectures to a jury of senior faculty who select the winning team(s) for the Hartley Rogers Jr. Family Prize, established in 2001. In 2009, ten MIT undergraduates were mentored by seven graduate students.

The faculty selected three winning teams: senior Asilata Bapat and mentor David Jordan, senior Gabriel Bujokas and mentor Qian Lin, and sophomore Shaunak Kishore and mentor Hoda Bidkhori.

Summer 2009 was also the 17th year of the Mathematics Department's participation in the Research Science Institute program (RSI) for gifted high school students. Twelve students carried out mathematics projects in RSI. Several went on to great success in the Intel Science Talent Search (STS) and Siemens Competition in Math, Science and Technology with their RSI projects. Lynnelle Ye (mentored by Tirasan Khandhawit and supervised by Tanya Khovanova) placed second in the Siemens Competition 2009, winning $50,000, and fourth in the Intel STS 2010, winning an additional $40,000. Akhil Mathew, in a project suggested by Pavel Etingof, placed third in the Intel STS 2010, winning $50,000. Three other RSI students were among the 24 Siemens regional finalists in the individual category: Tian-yi Damien Jiang (mentored by Yan Zhang), Arjun Puranik (mentored by Martina Balagovic), and Dennis Tseng (mentored by Nan Li).

Research Highlights

John Bush continues his work on surface tension. Following up the work of Yves Couder, who identified both wave–particle duality and probabilistic behavior of bouncing droplets, Bush and his group are developing a broader theoretical framework, such as attempting to rationalize the probabilistic behavior of droplets in terms of chaos theory. Bush also studies microfluidics, recently concentrating on drinking strategies in nature for modeling the efficient handling of small volumes of fluid.

Bonnie Berger and her group collaborate closely with biologists to implement newly designed algorithms for the control and interpretation of large data sets. They work on problems in protein folding, network inference, genomics, and disease classification. Recently, they were the first to combine structure-based predictions of protein–protein interactions with functional data, developing combined experimental and computational techniques for inferring complex signaling networks from large-scale microarray data and from cellular imaging data. This work was recently featured in *GenomeWeb Scan*.

Daniel Freedman recently undertook the study of on-shell amplitudes in supersymmetric gauge theories and supergravity, based on recent developments in the field. He completed six papers with Henriette Elvang and Michael Kiermaier of the MIT Physics Department. He is also working on an advanced technical monograph on supergravity, with Belgian physicist Antoine van Proeyen. The book is under contract with Cambridge University Press, exploring problems that may be confirmed by experiments at the large hadron collider at CERN.

Michel Goemans recently developed solutions to two longstanding problems in the area of approximation algorithms for hard optimization problems. The first was an approximation algorithm for the asymmetric traveling salesman problem, with a sublogarithmic performance guarantee (work done with A. Asadpour, A. Madry, S. Oveis Gharan, and A. Saberi). This is the first major improvement in solutions to this classic problem in more than 30 years. The second is the first approximation algorithm for degree-bounded spanning trees, which relaxes the degree bounds by an additive constant of two and provides a cost that is better than optimal.

Kiran Kedlaya recently completed the semistable reduction theorem in p-adic cohomology, thus paving the way for a full theory of coefficients in p-adic cohomology. He carried over some of these ideas to the classification of formal flat meromorphic connections, resolving a conjecture of C. Sabbah. This may have some applications in complex analytic geometry. He also established a new upper bound on the asymptotic complexity of factoring polynomials over finite fields (jointly with C. Umans of the California Institute of Technology). This may lead to a practical algorithm.

George Lusztig recently clarified the foundations of the theory of Chevalley groups over integers in terms of the theory of canonical bases—a major result, recently published in the *Journal of the American Mathematical Society*.

Ruben Rosales studies a number of areas of fluid dynamics, among them:

- Boundary conditions for Navier-Stokes solvers, which do a very poor job of implementing the no-slip boundary conditions at non-planar boundaries
- Stratified flows: issues of stability and wave breaking,related to the transport of energy by waves, believed to play a role in the "pumping" of the upper atmosphere (trade winds, e.g.)
- Modeling traffic flow: developing models for analysis and theory, to improve flow prediction and contribute to design strategies

Peter Shor works mainly on quantum information theory and quantum complexity theory. He has shown that adding a feedback channel or a two-way side classical channel can increase the capacity of a quantum channel, something that is not true for classical channels. He has been looking at quantum codes that are adapted to specific channels—in particular, the amplitude damping channel—and he has shown that there are quantum codes that are better for this channel than general-purpose quantum codes. Finally, in the past year, he and his team have been looking at quantum cryptographic schemes for unforgeable quantum states.

Gigliola Staffilani is working on several different areas with different collaborators. The most important results obtained thus far concerns weak turbulence theory. Given a wave phenomena of dispersive type, one would like to understand if and how the energy of the wave moves from low to high frequencies by remaining constant during evolution. There were no mathematical theorems describing these phenomena before the paper, "Weakly turbulent solutions for the cubic defocusing nonlinear Schrödinger equation," jointly with J. Colliander, M. Keel, G. H. Takaoka and T. Tao, accepted in *Inventiones Mathematicae*. A second project concerns the study of the water wave problem, studying the highly nonlinear question of existence, uniqueness, and relative properties of surface waves above a body of water. The approach she and colleagues used is different from the classical one; they use more microlocal and Fourier analysis. The resulting paper, "Strichartz estimates for the water-wave problem with surface tension," written jointly with former CLE Moore instructors Hans Christianson and Vera Hur, will appear in *Communications in Partial Differential Equations.*

Richard Stanley, in a paper written with W.Y.C. Chen, E.Y.P. Deng, R.R.X. Du and C.H.F. Yan, introduced new techniques to the theory of matchings that led to solutions of previously intractable problems. The paper received an award as one of the top 100 Chinese science papers of 2007, and its results have been successfully applied to mathematical biology. Stanley has also obtained many new results on a widely studied class of permutations called ``alternating permutations.'' Many of these results use representation theory, which has never been applied in such a way before. In a paper with R.R.X. Du, Stanley showed how identities in Hecke algebras can be used to analyze certain random walks. For his work, Professor Stanley was invited to give colloquium lectures at the January 2010 meeting of AMS.

Lie Wang's main research interests are the analysis of high-dimensional/functional data. The data can be roughly divided into two separate areas, nonparametric function estimation and high dimensional sparse signal recovery. In the nonparametric function estimation area, he proposed a new difference-based estimate and derived the minimax

rate of convergence for the variance function estimation. He also proposed a wavelet thresholding procedure, which is nearly optimally adaptive to the smoothness of both the mean and variance functions. In the high dimensional sparse signal recovery area, Professor Wang developed a powerful tool called "Shifting Inequality." With this inequality he achieved the current strongest results with the weakest conditions.

Katrin Wehrheim's research focuses on fundamental questions in the realm of symplectic topology and its interaction with gauge theory, complex geometry, and low-dimensional topology. In the symplectic category, e.g., Lagrangian correspondences are viewed as morphisms between manifolds that are not necessarily symplectomorphic, but their geometric composition is generically singular. Wehrheim's work with Christopher Woodward resolves this problem and realizes Lagrangian correspondences as composable functors on refined Donaldson-Fukaya categories associated to symplectic manifolds (their objects are generalized Lagrangians and morphisms are Floer homology classes). This provides a general framework for studying questions relating the symplectic category to others, e.g., categories of sheaves involved in mirror symmetry, or cobordism categories involved in topological quantum field theories. Moreover, their general framework provides a crucial functorial tool in mirror symmetry that has already been applied successfully.

Michael Sipser
Department Head
Professor of Applied Mathematics

More information about the Mathematics Department can be found at http://math.mit.edu/.