

Department of Mathematics

The Department of Mathematics at MIT seeks to improve upon its top ranking in both research and teaching by aggressively hiring the very best faculty, with special attention to the recruitment of top women and underrepresented minority candidates, and by continuing to serve the broad and varied educational needs of its graduate students, the mathematics majors, and all undergraduates of the Institute.

New Faculty, Promotions, and Departures

The department had another exceptional year in outside faculty hires for FY2010. Peter Ozsváth, a major figure in low-dimensional geometric topology, will join the department's faculty as professor of mathematics from Columbia University in fall 2010. Laurent Demanet, a leading young researcher in mathematical computing and applied analysis, will join the faculty as assistant professor of applied mathematics. Dr. Demanet received a PhD from the California Institute of Technology and has been Szegö assistant professor at Stanford University.

Associate professor Kiran Kedlaya, a number theorist, received tenure. Associate professor Denis Auroux, a world leader in symplectic geometry, was promoted to full professor. Associate professor John Bush was also promoted to full professor; he is a leading experimental and theoretical fluid dynamicist. Assistant professor Steven Johnson, a numerical computationalist and analyst, was promoted to associate professor.

Associate professor Lars Hesselholt joined the faculty at Nagoya University's Graduate School of Mathematics in January. Associate professor Jacob Lurie will join the faculty at Harvard University. Both are algebraic topologists.

Kenneth M. Hoffman

Professor emeritus Kenneth M. Hoffman, head of the Mathematics Department from 1971 to 1979 and member of the mathematics faculty for more than 40 years, died at the age of 77. Hoffman's area of research was in functional analysis. Along with Richard Arens and Isadore Singer, he made fundamental contributions to complex and abstract analysis. Some of these appeared in a joint paper with Singer, answering many of the questions on commutative Banach algebras raised by I. M. Gelfand. As department head, Professor Hoffman oversaw crucial faculty appointments and developed the undergraduate faculty chair position. Relocating to Washington, DC, in 1980, Professor Hoffman worked on projects to raise understanding of the central role of mathematics in science. Among other leadership positions, he served as executive director of the Committee on Resources for the Mathematical Sciences of the National Research Council (1981–1984). The panel's 1984 report, *The David Report*, highlighted the imbalance between research support for the mathematical sciences and related disciplines in science and engineering. From 1984 to 1989, Professor Hoffman headed the Office of Governmental and Public Affairs of the Joint Policy Board for Mathematics, which successfully worked to implement the recommendations of *The David Report*. For his extensive service and leadership, Professor Hoffman was selected as the inaugural recipient of two national service awards in mathematics: the Public Service Award of the Joint Policy Board for Mathematics in

1986, and the Award for Distinguished Public Service of the American Mathematical Society (AMS) in 1990. The AMS citation read in part, “Through his efforts, the awareness of the importance of mathematics and the support of mathematical research has been significantly heightened in the general public, among makers of science policy in the government, and among university administrators.”

Retirements

Professor Hartley Rogers, a mathematical logician and one of the main developers of recursion theory, retired from MIT after 52 years of service. Throughout the 1960s and 1970s, Professor Rogers served extensively in the senior administration; he served as chair of the faculty from 1971 to 1973 and as associate provost from 1974 to 1980.

Administration

Michael Sipser will continue as department head for a second five-year term.

David Jerison will succeed Tomasz Mrowka as chair of the Pure Mathematics Committee. Bjorn Poonen will follow David Jerison as co-chair of the Graduate Student Committee, serving with Gigliola Staffilani. Ju-Lee Kim joins John Bush as co-chair of the Committee of Undergraduate Advisors.

The other faculty committee chairs will remain as follows: Michel Goemans, chair of the Applied Math Committee and Haynes Miller, chair of the Undergraduate Committee.

Faculty Honors and Awards

Department Chairs

George Lusztig will be appointed Edward A. Abdun-Nur professor of mathematics, following his tenure as Norbert Wiener professor.

James McKernan will follow George Lusztig as the next Norbert Wiener professor of mathematics. Professor McKernan, with his collaborator Christopher Hacon, was also awarded the 2009 Frank Nelson Cole Prize in algebra by the AMS, for having “transformed the study of the minimal model program in higher dimensions.”

Bjorn Poonen will be the inaugural Claude Shannon professor of mathematics, thanks to a gift of John and Cynthia Reed. Professor Poonen joined the mathematics faculty in 2008.

Faculty Awards

Michel Goemans was elected fellow of the Association for Computing Machinery.

Steven Johnson was selected by a department faculty committee to be the next recipient of the Edmund F. Kelly Research Award.

Scott Sheffield was awarded a Presidential Early Career Award for Scientists and Engineers by the National Science Foundation (NSF).

Michael Sipser was elected fellow of the American Academy of Arts and Sciences.

Gilbert Strang was made a member of the National Academy of Sciences.

Assistant professors Benjamin Brubaker, Jonathan Kelner, and Katrin Wehrheim each received an NSF Faculty Early Career Development Award.

Incoming assistant professor Laurent Demanet was selected by the School of Science for the NEC Corporation Fund for Research in Computers and Communications.

Honorary Conferences

Two senior faculty members were honored at conferences during the year.

A conference in honor of Richard Melrose's 60th birthday, *From Wave Propagation to K-theory*, was held at Stanford University, October 25–26, 2008. MIT also hosted its own 60th birthday conference for Richard Melrose, *Singularities@MIT*, on April 4, 2009.

MIT and Harvard hosted a two-day conference, *Perspectives in Mathematics and Physics*, celebrating Institute Professor Isadore Singer's 85th birthday. President Susan Hockfield opened the conference, remarking that Professor Singer represented "the very best of the Institute" as both scholar and teacher. Sir Michael Atiyah was the first speaker, followed by 14 other major figures in mathematics and theoretical physics. Professor Atiyah shared with Singer the 2004 Abel Prize for their work on the index theorem.

Resource Development

The Department of Mathematics had another good year reaching out and engaging alumni and friends of the department. There were two faculty presentations organized specifically for alumni this past year; John Bush gave a presentation titled "Walking on Water" at the MIT Faculty Club and department head Michael Sipser spoke to alumni in Northern California on "Beyond Computation: The P versus NP problem." These breakfast talks bring alumni together to hear what faculty members are doing and to highlight the needs of the department. We have recently been able to engage more donors to support our Research Science Institute and the Summer Program in Undergraduate Research. These two programs are important in deepening the understanding of mathematics and exposing high school students, undergraduates, and graduate students to research. We had many loyal donors who helped us during a time when we needed to make cutbacks. A recent gift from one donor helped us with faculty recruitment. We continue to steward all donors to the department and thank them in our publication *Integral*, often highlighting donors who have made a particular impact to the department.

Department History

In January, the Mathematics Department published its first-ever collection of historical accounts, *Recountings: Conversations with MIT Mathematicians*. The release has generated enthusiastic response and praise. Editor Joel Segel culled through thousands of emails and hours of taped interviews of 13 senior mathematicians whose personal reminiscences and professional perspectives recount a critical growth period in the department's history.

Simons Lecture Series

The 2009 Simons Lectures were given by Étienne Ghys, a senior researcher at the Centre National de la Recherche Scientifique-École Normale Supérieure de Lyon, and Robert Schapire, professor of computer science at Princeton University. Professor Ghys is renowned for his study of four-dimensional objects in three-dimensional space. He spoke on asymptotic invariants for flows, right-handed vector fields, and the Rademacher function in a series entitled “Dynamics in Dimension 3.” Professor Schapire lectured on the AdaBoost algorithm he introduced with Yoav Freund in a series of lectures titled, *The Boosting Approach to Machine Learning: Foundations, Perspectives and Applications*.

Women in Mathematics Lecture Series

Following up on the conference in spring 2008, *Women in Mathematics: A Celebration*, the Mathematics Department initiated the Women in Mathematics Lecture Series in spring 2009. Organized by CLE Moore instructor Mia Minnes, professor Gigliola Staffilani, and assistant professor Katrin Wehrheim, the series featured 10 lectures by visiting women faculty and researchers in industry. Open to all students at the advanced undergraduate level, the lectures covered a considerable variety of research topics and real-world applications, such as “mathematics and voting.” Professor Sara Billey, formerly on the MIT faculty and currently at the University of Washington, spoke on how to transition from a class-oriented test-taking-machine to a full-fledged mathematician.

Education

Graduate Students

There were a total of 115 graduate students in mathematics, all in the PhD program. Last year 19 students received a doctoral degree and one received a master’s degree. There will be 19 new graduate students (three women) in 2009–2010. We continue the policy, put in place last year, of supporting all first-year students on fellowships. This coming year these students will be supported from a variety of sources, including a Samsung Scholarship, two National Sciences and Engineering Research Council Fellowships, a Hertz Fellowship, an NSF Fellowship, a National Defense Science and Engineering Graduate (NDSEG) Fellowship, and an Ida M. Green Fellowship.

The 2009 doctoral candidates are highly distinguished. This group has already seen some 36 papers published and 31 more submitted. They have contributed 20 papers to conference publications and presented papers at some 42 conferences and 43 non-MIT seminars. Eight of them held NSF Graduate Research Fellowships, two held NDSEG Fellowships, and one held a Martin Family Fellowship from the MIT Energy Initiative.

Professor Gigliola Staffilani, co-chair of the graduate program, was also a member of the Task Force for Education. The task force emphasizes that graduate programs, as a measure of their overall quality, should monitor and work closely with upcoming graduates to obtain appointments in competing research and educational institutions. Accordingly, the 2009 graduates include two who received NSF Postdoctoral Fellowships, both to be taken at Stanford. Eleven graduates were hired into postdoctoral

positions at the California Institute of Technology, Cambridge University, l'École Polytechnique Fédérale de Lausanne, the Korean Advanced Institute of Science and Technology, l'Institut de mathématiques de Jussieu, the Mathematical Sciences Research Institute at Berkeley, the Max Planck Society, Tsinghua University, the University of Chicago, and the University of California at Irvine. One doctoral graduate will continue research at Facebook and five others are moving into careers in finance.

Awards

Chris Evans, Chris Kottke, Michael Manapat, and Angelica Osorno received the Housman Graduate Student Teaching Award for their exceptional skill and dedication to undergraduate teaching.

Yanki Lekili was awarded the Charles W. and Jennifer C. Johnson Prize for an outstanding research paper accepted in a major journal by a graduate student in mathematics.

Majors

During AY2009, there were 316 undergraduates majoring in mathematics, 274 in Course 18 Mathematics and 42 in Course 18-C Mathematics/Computer Science. SB degrees, including double majors, were awarded to 105 students—91 in Course 18 and 14 in Course 18-C.

MIT mathematics majors continue to dominate the field in the William Lowell Putnam Mathematics Competition. The MIT mathematics team, composed of juniors Qingchun Ren and Yufei Zhao and senior Xuancheng Shao, finished third in the 2008 competition. Participants included more than 3,600 undergraduates from 545 institutions across the United States and Canada. Two MIT undergraduates, sophomore Bohua Zhan and junior Yufei Zhao, were among the five highest ranking individuals and were named Putnam Fellows. Another five MIT students ranked in the next 30, and 16 were given honorable mention among 54 honorees. This exceptional performance was due to the coaching of professors Hartley Rogers and Richard Stanley and associate professor Kiran Kedlaya. Professor Rogers, who retired in January, is credited for having reinvigorated MIT's effort to successfully compete in the Putnam Competition. Under his direction, the MIT team has ranked among the top five schools in 14 of the last 17 years.

The Jon A. Bucsela Prize in Mathematics, given in recognition of distinguished scholastic achievement, professional promise, and enthusiasm for mathematics, was awarded to seniors Hansheng Diao and Ruitian Lang.

The Alice T. Schafer Prize, given for excellence in mathematics to an undergraduate woman by the Association for Women in Mathematics, was awarded to junior Maria Monks, with honorable mention given to senior Doris Dobi.

Maria Monks also received the Barry M. Goldwater Scholarship, given to students who exhibit outstanding potential with intention to pursue a career in mathematics, the natural sciences, or engineering disciplines.

Senior Alan Deckelbaum was one of only 10 students nationwide to receive a 2009 Fannie and John Hertz Foundation Fellowship.

Two of our seniors were selected for NSF graduate fellowships to continue their study of mathematics: Boris Alexeev at Princeton University and Doris Dobi at the University of California at Berkeley.

Senior Raluca Ada Popa won the 2009 Outstanding Female Undergraduate Award from the Computing Research Association. She has co-written five conference papers.

Undergraduate and High School Summer Research Programs

In summer 2008, the department hosted its 12th Summer Program in Undergraduate Research (SPUR), 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. This summer, 10 MIT undergraduates participated with five mathematics graduate-student mentors and one outside visitor mentor. The faculty selected five winning teams. Two tied for first place: junior Aleksandr Arkhipov and mentor Zuoqin Wang, and senior Sungyoon Kim and mentor Hoda Bidkhori; three tied for second place: junior Wesley Brown and mentor Hoda Bidkhori, senior Yuncheng Lin and mentor Julia Wolf, and junior Cordelia Link and mentor Julia Wolf.

Summer 2008 was the 16th year of the department's participation in the Research Science Institute (RSI) program for gifted high school students. Twelve mathematics graduate students served as mentors for 23 high school seniors for a five-week period. Several students presented their projects in the Siemens-Westinghouse and/or Intel Science Talent Search (STS) competitions with remarkable success. Eric Larson placed first in the Intel STS competition, winning \$100,000, and second in the Siemens-Westinghouse competition, winning another \$50,000. Noah Arbesfeld placed sixth in the Intel STS competition, winning \$25,000. Both Eric and Noah's projects were suggested by professor Pavel Etingof and by Etingof's advisee, David Jordan, who also served as their mentor. Max Rabinovich and Adam Sealfon were among 40 Intel finalists, winning \$5,000 each. Two other students were among the 300 Intel semifinalists winning \$1,000 each.

The SPUR director and RSI supervisor was professor David Jerison. With the assistance of the School of Science development office, he applied for and received partial support from the Lord Foundation for the 2008 SPUR and RSI programs. That grant was renewed for 2009 but cannot continue beyond two years.

Undergraduate Education

Service Teaching

We continue to involve new faculty in teaching; for example, Bjorn Poonen will teach 18.02 Calculus in the fall. We are under threat of losing Denis Auroux, our most popular lecturer, to the University of California at Berkeley, where he will be on leave next year.

We won a grant from the d'Arbeloff Fund for Excellence to examine and renew our basic subjects, and that work is currently under way.

Teacher Training

The Department of Mathematics continues the microteaching workshop for graduate teaching assistants and incoming instructors. Assistant professor Mark Behrens will take over for Denis Auroux as director of this program.

Graduate students and undergraduate recitation instructors must first observe an ongoing recitation and teach a portion of one class. Their mentor then discusses their performance and the student feedback received. The instructors must then participate in a six-hour microteaching workshop followed by a videotaping of one of their recitations earlier in the semester. We have moved to a system in which the course lecturers view and comment on some of these videos. Over the past two terms we have significantly increased support for recitation leaders by assigning one recitation leader, usually a postdoc, the task of mentoring those who are experiencing difficulties in their classes. This has worked very well and we plan to continue this model.

Curriculum Renewal

We continue to launch new subjects to challenge the large and very talented group of undergraduate majors. Last fall Pavel Etingof taught 18.712 Introduction to Representation Theory and received a very enthusiastic response. This fall we will introduce two more high-level undergraduate algebra courses. Michael Artin will teach 18.721 Introduction to Algebraic Geometry and Bjorn Poonen will teach the charter class for 18.782 Introduction to Arithmetic Geometry. At a less advanced level, Richard Melrose taught 18.102 Introduction to Functional Analysis last year to very good reviews.

Next year, John Bush will conduct a review of the applied mathematics offerings and Richard Melrose will study the theoretical mathematics option.

Advising

Ju-Lee Kim will be joining John Bush as co-chair of the Committee on Undergraduate Advisors.

We have redesigned the undergraduate study website to make it easier for students to understand relationships between courses. We have strengthened advising of our majors in a number of ways.

- We now provide faculty advisors for second majors as well as first majors.
- We require midterm meetings of advisor and advisee.
- We host a start-of-the-year meeting of advisors.
- We have produced a trifold brochure for advisors, modeled on the brochure produced by the Department of Biology.

Research Highlights

Benjamin Brubaker is continuing to explore connections between automorphic forms and combinatorial representation theory. Data from automorphic forms (namely, their Fourier coefficients) can be used to produce L-functions, which are at the heart of many open questions in modern number theory. With his collaborators, principally Daniel Bump at Stanford University and Solomon Friedberg at Boston College, they are looking for novel ways to represent these Fourier coefficients of automorphic forms. In one very recent approach, they are using models for “square ice” from statistical mechanics (a model for arrangements of ions in water) to prove number theoretic properties of L-functions.

Richard Dudley is currently working on two research texts, one of them a second edition of his *Uniform Central Limit Theorems*.

Sigurdur Helgason has recently completed his book *Integral Geometry and Radon Transforms*, to be published by Springer Verlag. At the end of 2008, AMS published the second edition of his text *Geometric Analysis on Symmetric Spaces*. AMS is also publishing a *Selecta* volume as a collection of Professor Helgason’s papers on geometric analysis.

Victor Kac has been working in several interrelated directions, including the theory of Poisson vertex algebras with applications to integrable systems. In particular, Kac (jointly with Alberto De Sole, Aliaa Barakat, and M. Minoru Wakimoto) discovered a new hierarchy of soliton-type equations. They also explicitly constructed the variational complex, a problem that goes back to Euler and Lagrange. Kac also worked on the classification of rational vertex W-algebras, a problem from conformal field theory (jointly with M. Minoru Wakimoto, Alexander Elashvili, and Ernest Vinberg). In addition, he worked on a master classification: a unified approach to classification of algebras and their structure theory based on the theory of linearly compact Lie algebras (jointly with Nicoletta Cantarini). Finally Kac participated in a study of complete reducibility of representations, important for conformal field theory (jointly with Maria Gorelik).

Steven Kleiman has worked on four projects over the last year. He collaborated with Renato Martins on the canonical model of an arbitrary singular algebraic curve. They published their first paper in *Geometriae Dedicata* in 2009 and are continuing work on a second paper. Kleinman completed a paper with Ragni Piene. They used the functor of infinitely near points to study the locus $H(D)$ in the Hilbert scheme of a smooth irreducible complex surface, parametrizing the complete ideals with Enriques diagram D ; notably, they proved that $H(D)$ is irreducible and smooth. Kleinman also continued work with MIT Undergraduate Research Opportunities Program student Antoni Rangachev on the Whitney equisingularity theory of a family of arbitrary isolated complex analytic singularities. They were joined by Bernd Ulrich of Purdue University and Javid Validashti of the University of Kansas, who recently proposed using their new notion of epsilon multiplicity. This proposal appears to have led to a breakthrough: the constancy of the multiplicity of the Jacobian module across a family appears to imply the equisingularity of the total space. Also, Kleinman wrote a historical report on the theory of the Picard scheme for inclusion in a three-volume biography of Alexander Grothendieck, the great 20th-century mathematician.

Abhinav Kumar has been collaborating with Henry Cohn of Microsoft Research New England on problems involving lattices, sphere packing, and energy minimization. Some of their work has connections and potential applications to physics, nanotechnology, and molecular self-assembly. Kumar is also working on the arithmetic of K3 surfaces and applying it to the computation of Hilbert modular surfaces.

Tom Leighton continues his research in the area of algorithms, networks, and combinatorial optimization. His student Ankur Moitra was awarded the 2009 Martin Memorial Master's Thesis Award by the Department of Electrical Engineering and Computer Science.

Bjorn Poonen has been researching various topics in algebraic geometry and arithmetic geometry hoping to prove that certain problems in algebraic geometry are undecidable. One success was obtained in 2009: the problem of deciding whether a given variety has an automorphism mapping a given point into a given subvariety is undecidable. He also continued to investigate the extent to which cohomological obstructions determine whether a variety has a rational point. Jointly with Davesh Maulik and Claire Voisin, Poonen studied the variation of the Néron-Severi group in a family of varieties.

Paul Seidel continued to work on mirror symmetry and symplectic geometry. In mirror symmetry, Seidel produced a proof of Kontsevich's mirror conjecture for the genus two surfaces, following a suggestion of physicists Kentaro Hori and Cumrun Vafa. In symplectic geometry, Seidel and collaborators constructed new nonstandard symplectic structures on a large class of manifolds.

Gilbert Strang is currently working on two topics: the change in eigenvalues of the Laplacian when a curved region is approximated by a polygon (with Pavel Grinfeld), and on understanding the space of triangles to find the probability that a random triangle is acute (with Alan Edelman).

David Vogan has been working with former CLE Moore instructor Jeffrey Adams, Marc van Leeuwen, and former graduate students Peter Trapa and Wai Ling Yee on an algorithm to find all the irreducible unitary representations of a reductive Lie group. This has been one of the central problems in representation theory since the 1930s. They have a complete algorithm and many parts of a proof that it is the right algorithm.

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