

## 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 FY2009. Bjorn Poonen, a major figure in number theory, will join the Department's faculty as professor of mathematics from the University of California, Berkeley. Scott Sheffield, a leading young researcher in probability theory and related topics in mathematical physics and game theory, also joins the faculty as professor from the Courant Institute of Mathematical Sciences, New York University. Lie Wang will be appointed as assistant professor. He is a mathematical statistician with a doctorate from the Wharton School of the University of Pennsylvania.

### Resignations

Associate professor Martin Bazant in physical applied mathematics will join the faculty at Stanford University's Institute for Computational and Mathematical Engineering as associate professor.

Three of our junior faculty resigned from MIT this year. Associate professor Igor Pak in discrete mathematics accepted appointment as associate professor at the University of Minnesota, Twin Cities. Associate professor Dmitry Panchenko will join the faculty at Texas A&M as associate professor; he is an applied probability theorist and mathematical statistician. Assistant professor Eric Lauga, a fluid dynamicist, has accepted appointment as assistant professor at the University of California, San Diego, Department of Mechanical and Aerospace Engineering.

### Administration

Michael Sipser will continue as department head.

Michel Goemans will succeed Alar Toomre as chair of the Applied Mathematics Committee, and John Bush will follow Michel Goemans as chair of advisors.

The other faculty committee chairs will remain as follows:

David Jerison and Gigliola Staffilani—Cochairs of the Graduate Student Committee

Haynes Miller—Chair of the Undergraduate Committee

Tomasz Mrowka—Chair of the Pure Mathematics Committee

## Faculty Honors and Awards

### Department Chairs

Associate professor Kiran Kedlaya was selected for the Cecil and Ida Green Career Development Professorship for outstanding contributions in education and research in number theory. Professor Kedlaya also received a Presidential Early Career Award for Scientists and Engineers from the National Science Foundation.

Assistant professor Jonathan Kelner, a theoretical computer scientist, was selected for the Kokusai Denshin Denwa Career Development Professorship for his research in communication and technology.

### Faculty Awards

Tobias Colding was elected to the American Academy of Arts and Sciences.

Thomson Leighton was elected to the National Academy of Sciences.

George Lusztig was honored with the 2008 Steele Prize for Lifetime Achievement, presented by the American Mathematical Society, for having “entirely reshaped representation theory, and in the process, changed much of mathematics.”

James McKernan received a Clay Research Award from the Clay Mathematics Institute for his work on birational geometry of algebraic varieties in dimensions greater than three.

Peter Shor shared the prize of the Institute for Operations Research and Management Sciences with coauthors for his work on the paper “On the Sum-of-Squares Algorithm for Pin Packing,” published in the *Journal of the ACM*.

Gilbert Strang was awarded the 2007 Peter Henrici Prize for “original contributions to applied mathematics and scientific computing, given every four years by the Eidgenössische Technische Hochschule Zürich and the Society for Industrial and Applied Mathematics.

Three of our junior faculty were selected by the School of Science for the following support:

Mark Behrens—NEC Corporation Fund for Research in Computers and Communications

Kiran Kedlaya—NEC Corporation Fund for Research in Computers and Communications

Steven Johnson—James H. Ferry Jr. Fund for Innovation in Research Education

## Honorary Conferences

Three senior faculty were honored at international conferences during the year.

A conference in honor of Victor Kac's 65th birthday, *Symmetries in Mathematics and Physics*, was held at the Palazzone della Scuola Normale Superiore, Cortona, Italy, June 22–28, 2008.

On the occasion of Bertram Kostant's 80th birthday, the conference *Lie Theory and Geometry: The Mathematical Legacy of Bertram Kostant* was hosted by the Pacific Institute for the Mathematical Sciences, Vancouver, British Columbia, Canada, May 19–24, 2008.

Haynes Miller's 60th birthday was honored in June with the workshop and conference, *Homotopical Group Theory and Topological Algebraic Geometry*, held over a two-week period at the University of Copenhagen and the Max-Planck-Institut für Mathematik in Bonn, Germany, June 16–20 and 23–27.

## Resource Development

The Department of Mathematics concluded its first ever campaign in spring 2008 for faculty recruitment and retention and for graduate student support. We surpassed our \$15 million goal that was set two years ago and raised \$16,684,573. The support from the campaign will allow us to keep MIT math at the top of our field; we will be able to attract the very best students by offering more graduate fellowships, and more endowed chairs will help us find, attract, and retain the best mathematicians in the world. We could not have accomplished this without our generous supporters. Visiting committee chair John Reed made a generous leadership gift of \$6 million, James H. Simons made a gift of \$3 million, the Leighton family, including professors Tom Leighton and Bonnie Berger Leighton and David T. and Helen M. Leighton, made a gift of \$3 million, the Liberty Mutual Corporation with the help of visiting committee member Edmund F. Kelly made a gift of \$1 million, Doug Ell made a gift of \$1 million, an anonymous donor made a gift of \$800,000, Ray Sidney made a gift of \$308,000, Diko Mihov made a gift of \$250,000, and generous planned gifts were made as well.

## Department Newsletter, History Text, and New Website

As part of renewed development and stewardship efforts, the Department will publish the third annual issue of its newsletter *Integral* in fall 2008, coinciding with the release of a new website. The Department will also release for publication its first-ever history of the Department, culled from extensive interviews with senior and emeritus faculty, *Recountings: The Lives of MIT Mathematicians*. The book is due out in January 2009. We are also very pleased to have on staff Erin McGrath, who is the development officer for both the mathematics and physics departments. She follows Elizabeth Chadis, who developed the position for the Mathematics Department two years ago.

## Education

### Graduate Students

There were a total of 115 graduate students in mathematics, all in the PhD program. Last year, 17 students received a doctoral degree and one received a master's degree. There will be 23 new graduate students (five women) in 2008–2009. Next year, all of the first-year students will receive fellowship support for the entire first year. This marks a long-term goal of the Department that has been part of our fund-raising campaign. We are pleased that one of our new women students will receive the Ida M. Green Fellowship, an Institute-wide fellowship given to eight new graduate female students each year.

Denis Chebikin and Aaron Tievsky received the Housman Graduate Student Teaching Award for their exceptional skill and dedication to undergraduate teaching.

Ruochuan Liu and Ting Xue were 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.

Marketa Havlickova and Yanir Rubinstein were selected for a 2007 Liftoff Fellowship by the Clay Mathematics Institute.

### Majors

During AY2008, there were 289 undergraduates majoring in mathematics, 259 in Course 18 Mathematics and 30 in Course 18-C Mathematics/Computer Science. Bachelor of Science degrees, including double majors, were awarded to 104 students—93 in Course 18 and 11 in Course 18-C.

The group of undergraduate MIT mathematics majors continues to be the best in the nation. By way of illustration, we consistently dominate the field in the premier collegiate mathematics competition, the William Lowell Putnam Mathematical Competition. The MIT mathematics team, composed of senior Eric Price and sophomores Hansheng Diao and Yufei Zhao, finished third in the 2007 Putnam Mathematical Competition. Participants included more than 3,700 undergraduates from 500 institutions across the United States and Canada. Two MIT undergraduates, freshmen Qingchun Ren and Xuancheng Shao, were among the six highest ranking individuals and were designated Putnam fellows. MIT had five other students who ranked in the top 24, and 13 more were given honorable mention for finishing in the top 74. A total of 107 MIT students took the exam. This extraordinary performance is due in part to the able coaching of professors Hartley Rogers and Richard Stanley and associate professor 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 Anand Deopurkar and Galyna Dobrovolska. Galyna was also a cowinner of the Alice T. Schafer Prize, given for excellence in mathematics to an undergraduate woman by the Association for Women in Mathematics.

Among seniors awarded degrees in mathematics, 22 were elected to Phi Beta Kappa.

## **Undergraduate and High School Summer Research Programs**

One reason for the increase in the number of highly talented undergraduates is the very active participation by the Department in the high school Research Science Institute (RSI) program, for many years under the leadership of professor Hartley Rogers. Professor Rogers also developed and directed a unique Summer Program in Undergraduate Research (SPUR). Direction of these programs passed into the hands of professor David Jerison in 2006. Both programs have been mainly supported by Departmental funds, but in 2008 the Lord Foundation will award a grant to cover half of each programs' costs.

In summer 2007, 11 MIT undergraduates participated with six mathematics graduate student mentors in the Department's 11th SPUR program, a six-week experience of full-time research culminating in written papers and lectures to faculty. A jury of senior faculty members awards a prize to the best undergraduate along with his/her mentor. Three such joint SPUR prizes were given: the winners were junior Hansheng Diao and his mentor, Cathy Lennon; sophomore John Kim and his mentor, Xiaoguang Ma; and sophomore Charmaine Sia and her mentor, Hoda Bidkhor. Three undergraduates from SPUR 2007—Diao, Kim, and Rebecca Freund—have submitted papers based on their work to research journals.

Summer 2007 was also the 15th year of the Mathematics Department's participation in the RSI summer program for gifted high school students. Twelve mathematics graduate students served as mentors for 21 high school seniors for a five-week period. Subsequently, 10 of them became semifinalists (top 300) in the Intel Science Talent Search, and two reached the final round (top 40). Another RSI mathematics student, Sana Raouf, tied with two others for first place in the 2007–2008 Intel International Science and Engineering Fair. Her share of the prize money was \$60,000.

The future looks good for more top students to come to MIT. Of the six members of the US International Mathematics Olympiad team, one is a ninth grader and four will be coming to MIT in the fall.

## **Undergraduate Education**

### ***Service Teaching***

The faculty actively engaged in service teaching in the Department of Mathematics is undergoing a rapid turnover. For example, associate professor Denis Auroux and professor Gigliola Staffilani have been lecturing in the main calculus subjects over the past several years. Associate professor John Bush taught 18.02A Calculus in 2006–2007 and will continue to do so in alternate years. Associate professor Lars Hesselholt taught 18.022 Calculus in fall 2006 and fall 2007 and associate professor Kiran Kedlaya will be teaching it in fall 2008. Assistant professor Steven Johnson taught 18.06 Linear Algebra in fall 2007 and will teach it again in fall 2008. Assistant professor Jonathan Kelner taught 18.440 Probability and Random Variables in spring 2008 and will teach it again next year.

The Mathematics Department has had a long and close interaction with OpenCourseWare (OCW). Professors Arthur Mattuck and Gilbert Strang have contributed videotapes of their lectures in 18.03 Differential Equations and 18.06

Linear Algebra, respectively, and they are among the most heavily used portions of the entire OCW site. Last year video recordings were made of lectures by professors Denis Auroux and David Jerison in 18.01 Calculus I and 18.02 Calculus II, respectively, and they should be online by fall 2008. This will greatly enhance the impact of OCW in basic mathematics; for example, through the Highlights for High School OCW program.

We have also been involved in a variety of efforts to link the course material in our service courses more closely with where it is used in downstream courses. One aspect of this is the flash forward/flash back project (in collaboration with professor Karen Willcox of Course 16) in which explicit links are created between OCW versions of engineering courses and basic mathematics courses. Another aspect of this effort is a Spencer Foundation-funded project coordinated by the Teaching and Learning Laboratory and intended to bring together faculty from mathematics and engineering subjects to share language and examples. Yet another aspect is the increasing penetration into engineering courseware of the Java applets created by professor Haynes Miller under a grant from the d'Arbello Fund for Excellence in Education.

### ***Curriculum Renewal***

Last year we began a process of revision of the courses of the undergraduate major, beginning with the analysis offerings. Last year professor Victor Guillemin created and taught a new version of 18.101 Analysis II and developed a new course, 18.952 Theory of Differential Forms. Professor Richard Melrose has created 18.102 Functional Analysis. Next year a new algebra course, 18.712 Introduction to Representation Theory, will be offered by professor Pavel Etingof.

### ***Communication-Intensive Courses for Majors***

We have worked hard over the past few years to create subjects with which our majors can fulfill their Departmental communication requirement. This task has been harder in this Department than in most others because (1) the very diverse group of mathematics majors dictates an exceptionally flexible pathway through the major, making it hard to integrate training and practice of communication skills into a few subjects that all our majors take; and (2) the subjects taken by the largest groups of our majors are also taken by a wide range of nonmajors (for whom an added communication-intensive component serves as disincentive).

We have addressed these obstacles by creating a 15-unit version of the gateway theoretical mathematics course, 18.100B Analysis I, known as 18.100C, and a version of the gateway applied mathematics course, 18.310C, both carrying CI-M credit.

Nevertheless, the principal mode of fulfilling the communication-intensive requirement in mathematics continues to be through the undergraduate seminar system. These subjects are capped at 12 students. The students lecture, do exercises, and write a revised paper. We now offer the following undergraduate seminars: 18.104 Analysis, 18.304 Discrete Mathematics, 18.384 Physical Mathematics (first taught in spring 2008 by associate professor John Bush), 18.424 Information Theory, 18.434 Theoretical Computer Science, 18.504 Logic, 18.704 Algebra and Number Theory, 18.784 Number Theory (first

taught in spring 2008 by assistant professor Benjamin Brubaker), 18.904 Topology, and 18.994 Geometry.

The Project Laboratory in Mathematics, our Institute laboratory subject and a CI-M course, is now given to full enrollments of 30 students every semester. Six senior faculty members have been involved in leading this course, which has commanded excellent buy-in by the faculty.

We also continue to offer 18.096 Principles of Mathematics Presentation, led in some form for many years by professor Steven Kleiman.

### ***The Undergraduate Mathematics Office and Undergraduate Advising***

The Undergraduate Mathematics Office (UMO) has served for many years as the administrative center for undergraduate education. Last year the room was renovated, to excellent effect.

We have moved on many fronts to improve control over the level and content of undergraduate course offerings.

- We are collecting and approving standard syllabi of courses.
- We have scanned the “complete records” from many years of our standard undergraduate courses. These records will be made available on a website for use by faculty teaching these courses, providing sample lectures, exams, and homework problems.
- We have reviewed and revised the prerequisite structure within the major.
- For each course, we have designated a faculty member with oversight responsibilities.
- For each postdoc, we have designated a faculty mentor.

The UMO also provides administrative infrastructure for advising our majors. Professor Michel Goemans has overseen the creation of a sophisticated web-based access point for information about students, classes, and faculty teaching assignments. Most importantly, this site delivers a checklist for each student, tracking the student’s progress through the MIT graduation requirements.

Two years ago we initiated a start-of-year meeting for Departmental advisors, inviting, for example, the head of the MIT Mental Health Services to give a talk. This year, we have instituted a system of midsemester flags: instructors of Departmental courses alert the UMO to students who are not doing well, and this information is relayed to the student’s advisor. In parallel with this, we are requiring a midsemester meeting between students and their advisors. As a further advising innovation, beginning next year our second majors will have faculty advisors.

## Teacher Training

The Department of Mathematics continues to do a careful job in training its new recitation leaders, both graduate teaching assistants and incoming instructors.

Graduate students and undergraduate recitation instructors must first observe an ongoing recitation and then teach a portion of one class. Their mentor discusses their performance and student feedback with them. They must then pass the six-hour microteaching workshop that the Department offers under the directorship of associate professor Denis Auroux just before the start of each semester. Incoming instructors are included in this workshop. All new recitation teachers are videotaped, and a faculty member (professor Arthur Mattuck in recent years) observes the tapes and writes detailed comments, which are delivered to the teacher.

We have also begun to offer a workshop for leaders of our undergraduate seminars to help them develop ideas and skills connected with this form of education and the communication training and grading that it entails.

## Research Highlights

Denis Auroux is investigating geometric aspects of mirror symmetry, a mathematical phenomenon predicted by theoretical physics that establishes a broad correspondence between complex algebraic geometry and symplectic geometry. Auroux's research involves more specifically the construction of mirror pairs using special Lagrangian fibrations and suggests a far-reaching generalization of the mirror symmetry conjectures to new classes of geometric spaces.

Tobias Colding continues his research in geometric evolution equations. His main interest is investigating singularities and singularity formation of these equations, in particular in low dimensions, and in applications of such results.

Richard Dudley completed a paper with doctoral students Sergiy Sidenko and Zuoqin Wang, to appear in *Annals of Statistics*, on research extending the notion of mean vector and covariance matrix to location vectors and scatter matrices for general random observations for which the mean vector may not exist.

Steven Johnson's recent work with collaborators and students has focused on novel approaches to challenging mathematical and numerical problems in nanophotonics. In the quantum-optical regime, they have demonstrated one of the first approaches capable of modeling quantum Casimir forces for arbitrary geometries and materials, using imaginary-frequency Green's functions. For classical problems, they have extended Maxwell's equations to fictitious dimensions in order to develop the first technique for the spectra of photonic quasicrystals (aperiodic structures with long-range order) that achieves better than first-order accuracy. They shed light on the role of discontinuities via new perturbative methods for boundaries between anisotropic materials and on the role of smoothness in developing efficient absorbing layers for structured media. In the realm of purely analytical results, they proved a strong theorem about conditions for localization of light in microstructured optical fibers.



Steven Kleiman has been developing a new notion of multiplicity for application to the Whitney equisingularity theory of a family of arbitrary isolated complex analytic singularities, in collaboration with an MIT undergraduate, Antoni Rangachev, who is working on an Undergraduate Research Opportunities Program.

James McKernan is studying problems in higher-dimensional algebraic geometry, extending the Mori program to characteristic  $p$ .

Haynes Miller focuses on the study of algebraic objects in homotopy theory. This encompasses a broad range of specific objects of study: homotopy-theoretic analogues of Lie groups, commutative rings, and moduli. The methods are cohomological and operadic. Professor Miller was an invited speaker at the 2008 Interdisciplinary Symposium of the Miller Institute, University of California, Berkeley.

Paul Seidel completed his book, *Fukaya Categories and Picard-Lefschetz Theory*, to be published by the European Mathematical Society Publishing House in August 2008.

### **Lecture Series, Seminars, and Conferences**

The Mathematics Department hosts some 33 seminars, series, and colloquia, including a number organized by graduate students. Last year Denis Auroux and Paul Seidel obtained a Focused Research Group grant from the National Science Foundation to study the phenomenon of homological mirror symmetry, in collaboration with Ludmil Katzarkov at the University of Miami. Among other activities covered by this grant, they are organizing two conferences on mirror symmetry each year. The first of these took place at the University of Miami in January 2008 and the second was at MIT in May 2008.

### **Simons Lecture Series**

Eight years ago, the Mathematics Department launched the Simons Lecture Series, named after its benefactor, former colleague and friend James H. Simons. Each speaker gives three lectures on various mathematical topics. The lectures now host two series, run over a two-week period in the spring term and given by distinguished mathematicians in a broad range of fields. Four of these lecturers were recent recipients of the Fields Medal. Last year's Simons lecturers were John Conway of Princeton University and Peter Teichner of the University of California, Berkeley. Professor Conway, inventor of the "game of life," the world's best-known example of cellular automata, talked on the lexicode theorem and on nearly universal ternary quadratic forms. Professor Teichner lectured on Euclidean field theories.

### **Women in Mathematics: A Celebration**

Last spring the Department also hosted *Women in Mathematics: A Celebration*, a two-day conference proposed by Susan Landau (PhD '83) of Sun Microsystems and organized by professor Gigliola Staffilani and assistant professor Katrin Wehrheim to celebrate the achievements of women who received their PhD in mathematics from MIT. The conference offered lectures on mathematics as well as panel discussions on breaking into the field today and the challenges facing women graduates of past decades. A lunch-time talk by Margaret Murray, who wrote *Women Becoming Mathematicians: Creating a*

*Professional Identity in Post-World War II America* (MIT Press, 2000), reviewed the history of women in American mathematics. There were some 160 participants, including students from MIT and other universities, and professor Domina Eberle Spencer of the University of Connecticut, who was the third woman to receive the MIT PhD in mathematics in 1942. President Susan Hockfield and Marc Kastner, dean of Science, spoke to attendees at the main dinner about MIT's efforts to attract women faculty and students—the successes to date and what more needs to be done.

### **Upcoming Events**

There will be a birthday celebration in honor of professor Isadore Singer's 85th birthday at MIT, Harvard, and the National Academy of Sciences, May 22–24, 2009.

**Michael Sipser**  
**Department Head**  
**Professor of Applied Mathematics**

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