Department of Mathematics

The Department of Mathematics faced the many challenges of the Covid-19 pandemic that lasted the entire academic year. Given the department's central instructional and mentoring role at the Institute, department faculty members, lecturers, postdocs, and administrators maintained and further adapted to online remote instruction, which began in March 2020. There were many challenges, particularly in large-scale remote classes (as described below), but some innovations that were developed will carry through in future instruction. This was also the first full year the department coordinated with Course 6 on the design of the mathematics part of the curriculum for the common ground subjects of the MIT Stephen A. Schwarzman College of Computing.

This year, the department community discussed and considered many initiatives to address diversity, equity, and inclusion issues in academia. This will be a long-term effort. The past year provided a unique opportunity for members to reflect and participate in a number of online forums, both within the Institute and at mathematical societies and institutions, that examined these issues specifically in regard to mathematical education and culture. Since summer 2020, faculty, academic staff, and graduate students have made a special effort to maintain the department's extensive high school outreach programs, seen as critical to increasing the number of mathematically prepared high school students from diverse and financially challenged backgrounds admitted to MIT and other top programs.

Our department continues to be the largest mathematics department among private universities in the United States, and our coverage of mathematical fields is extensive, covering both pure and applied mathematics. We have expertise in many areas, including analysis, geometry, topology, algebra, number theory, physical applied mathematics, computational science, computational biology, theoretical computer science, combinatorics, probability, and statistics.

Faculty

New Faculty

Dor Minzer joined the mathematics faculty as assistant professor in July 2020. He works in the fields of mathematics and theoretical computer science. His interests revolve around computational complexity theory, Boolean function analysis, and combinatorics. He received his PhD from Tel Aviv University in 2018 studying under Muli Safra, and was subsequently a postdoc at the Institute for Advanced Study. Minzer's thesis, which made significant advances toward resolving the Unique Games conjecture, was awarded the 2019 Doctoral Dissertation Award of the Association for Computer Machinery.

Lisa Piccirillo also joined the mathematics faculty as Assistant Professor, following a postdoctorate at Brandeis University. She specializes in the study of three- and four-dimensional spaces, broadly interested in low-dimensional topology and knot theory. She received her PhD from the University of Texas at Austin in 2019 with John Luecke as advisor. During her doctoral studies, Piccirillo famously proved that the Conway knot

is not slice. This has been an open question for half a century, whose solution impacts modern knot theory and four-dimensional topology.

Faculty Changes

Associate Professor Jörn Dunkel received tenure effective July 1, 2020.

Haynes Miller retired as full professor while continuing as professor post-tenure of mathematics (as of July 2021). A graduate of Harvard, he received his PhD from Princeton under the direction of John Moore in 1974. Following assistant professorships at Harvard and Northwestern University, he joined the faculty of the University of Washington in 1977 and the faculty of Notre Dame as a professor in 1984. He joined the MIT mathematics faculty in 1986. An algebraic topologist, Miller has made seminal contributions to homotopy theory. Some 28 PhD degrees have been awarded under his direction. He served as editor for 11 mathematics journals, including a position as editor-in-chief of the *Bulletin of the American Mathematical Society*. Miller chaired the pure mathematics committee in 1992–1993 and the undergraduate mathematics committee from 2004 to 2013. He was appointed the Mathematics Department's first associate department head, serving from 2011 to 2013. He was the leading lecturer of 18.03 Differential Equations for many years and created 18.821 Project Laboratory in Mathematics. Since 2011, Miller has worked with the MIT-Haiti Initiative, and in 2017 he founded the electronic seminar on mathematics education. He was named a MacVicar Faculty Fellow in 2005. He received the Graduate Student Council Teaching Award in 2006 and the Alan J. Lazarus Award for Excellence in Advising in 2021.

Andre Negut was promoted to associate professor effective July 1, 2020.

Philippe Rigollet was promoted to full professor effective July 1, 2020.

Professor Chenyang Xu resigned from MIT for a professor appointment at Princeton University.

In Memoriam

Institute Professor Emeritus Isadore "Is" Singer, an enormously influential figure in 20th-century mathematics, died on February 11, 2021 at age 96. In a career that spanned more than 70 years, Professor Singer not only profoundly affected the development of mathematics but discovered connections between mathematics and physics that led to the creation of a new field, index theory.

Singer graduated from the University of Chicago with a master's degree (1948) and doctorate (1950) in mathematics, studying analysis with Professor Irving Segal. In Singer's final graduate year, Professor Shiing-Shen Chern arrived from Europe to introduce American scholars to the latest advances in geometry. Singer's notes from Chern's class were to prove critical to developing his research program in differential geometry. When Singer came to MIT as a CLE Moore Instructor in 1950, he worked closely with Professors Warren Ambrose and George Whitehead to advance the Institute's program in differential geometry, which eventually made the Mathematics Department a world center in the field.

Between 1952 and 1956, Singer held appointments at the University of California at Los Angeles, the Institute for Advanced Study, and Columbia University. It was during this period that he made deep contributions to analysis and geometry. In 1959, Singer and Professor Richard Kadison formulated the Kadison-Singer conjecture. The conjecture was later found to be equivalent to key problems in applied mathematics, engineering, and theoretical computer science and was finally proved in 2013, more than half a century after it was initially posed.

Singer returned to MIT as a full professor in 1956, and in 1970 he was appointed the department's first Norbert Wiener Professor. In 1979 he moved to the University of California at Berkeley (UC Berkeley), where he was appointed Miller Research Professor from 1982 to 1983. He rejoined the MIT mathematics faculty in 1983 as a John D. MacArthur Professor and was appointed Institute Professor in 1987.

In 1963, Singer and Professor Michael Atiyah of Oxford University developed the Atiyah-Singer Index Theorem. This theorem deeply tied together the mathematical fields of analysis, geometry, and topology. A key part of their work was Singer's rediscovery and generalization of the Dirac operator, fundamental to an understanding of the quantum theory of the electron. The newly generalized Dirac operator unlocked fundamental mysteries in mathematics and signaled a deepening connection between mathematics and physics that continues to this day.

Following development of the index theorem, Singer's career moved closer to the theoretical high-energy physics community, and he made numerous contributions to gauge theory, the theory of quarks, and anomaly cancellation. At UC Berkeley in the late 1970s, Singer developed his well-known weekly physics-mathematics seminar, which he later transferred to MIT. It became a source for innovative ideas, inspiring new collaborations between mathematicians and physicists.

Singer was equally committed to teaching, often describing exchanges with students as inspiration to his research. He advised many doctoral candidates (31 at MIT and two at UC Berkeley) and has some 180 academic descendants.

Singer's service to the mathematical and broader scientific community was prodigious. He chaired the National Academy of Sciences Committee of Science and Public Policy from 1973 to 1979. He co-founded the Mathematical Sciences Research Institute in 1982 with Shiing-Shen Chern and Professor Calvin Moore. From 1982 to 1988, Singer served on the White House Science Council. He was a member of the President's Committee on the National Medal of Science. Between 1995 and 1999, he served on the governing board of the National Research Council.

Singer's work and service garnered an exceptional number of distinctions. He was a Sloan Research Fellow and twice a John D. Guggenheim Fellow (1968 and 1975). He received the 1969 Bôcher Memorial Prize from the American Mathematical Society (AMS) for work in analysis and the 1988 Eugene Wigner Medal from the Group Theory and Fundamental Physics Foundation. In 1985, Singer was awarded the National Medal of Science. He was honored by AMS with the Distinguished Public Service Award in

1993 and the Leroy P. Steele Prize for Lifetime Achievement in 2000. In 2004, jointly with Sir Michael Atiyah, Singer received the Abel Prize from the Norwegian Academy of Science and Letters. In 2005 he was selected for the MIT James Rhyne Killian Faculty Achievement Award.

Singer was a fellow of the American Academy of Arts and Sciences (1959) and the American Mathematical Society (2012), a member of the American Philosophical Society (1985) and the National Academy of Sciences (1968), an honorary member of the London Mathematical Society (2004), and a foreign member of the Norwegian Academy of Science and Letters (2009).

Faculty Awards and Honors

The department's Program for Research in Mathematics, Engineering, and Science (PRIMES), which targets high school students, received MIT's MLK Leadership Group Award. The award recognizes individuals and groups for deep and coordinated commitment to improving diversity in mathematics and for embodying the spirit of Martin Luther King's work, including integrity, leadership, creativity, and positive outcomes.

Associate Professor Semyon Dyatlov, Professor Jonathan Kelner, and CLE Moore Instructor Pei-Ken Hung each received the 2020 Teaching with Digital Technology Award for enhancing on-campus and remote teaching. Lecturer Jerry Orloff received the 2021 Teaching with Digital Technology Award. The awards are student nominated and co-sponsored by MIT Open Learning and the Office of the Vice Chancellor.

Professor Alan Edelman was elected a fellow of the Association for Computing Machinery (ACM) "for contributions to algorithms and languages for numerical and scientific computing."

Professor Emeritus Daniel Z. Freedman and Professors Larry Guth and Gigliola Staffilani were elected members of the National Academy of Sciences. Professor Guth was also named a MacVicar Faculty Fellow.

Professor George Lusztig was awarded a 2021 Simons Fellowship in Mathematics.

Professor Minzer received the 2021 Alfred P. Sloan Research Fellowship. He was also selected by the School of Science Research Support Committee for the academic year 2021 (AY2021) Solomon Buchsbaum Research Fund.

Professor Piccirillo was selected for an inaugural 2021 Maryam Mirzakhani New Frontiers Prize, created in 2019 by the Breakthrough Foundation to recognize outstanding early-career women in mathematics. She also received the 2021 Clay Research Fellowship and the 2021 Alfred P. Sloan Research Fellowship. In 2020, she was named one of the WIRED25 People Who Are Making Things Better.

Professor Rigollet was named a fellow of the Institute of Mathematical Statistics.

Professor Scott Sheffield was elected a fellow of the American Academy of Arts and Sciences.

Associate Professor Nike Sun received the 2020 Best Paper award (one of 20 gold medal awards) from the International Consortium of Chinese Mathematicians.

Principal Research Scientist Andrew Sutherland was named a 2021 AMS fellow in recognition of his contributions to the theoretical and computational aspects of number theory.

Assistant Professor Yufei Zhao was awarded support by the National Science Foundation's Faculty Early Career Development Program for his project "Analytic and Spectral Methods in Combinatorics."

Postdocs Maggie Miller and Alex Smith received 2021 Clay Research Fellowships. These fellowships are awarded to recent PhDs who are potential leaders in research mathematics.

Lectures

The Covid-19 pandemic postponed a number of invited spring lectures throughout the mathematics community. Faculty who gave distinguished lectures in a virtual format are as follows.

Bjorn Poonen gave the Simons Public Lecture in January. He also delivered the University of Cambridge Rouse-Ball Lecture in May.

Gigliola Staffilani delivered the inaugural Ingrid Daubechies Lecture, hosted by Duke University, in January.

Nike Sun gave the Marston Morse Lectures, hosted by the Institute for Advanced Study, in April.

Administration

Michel Goemans completed his third year as department head and William Minicozzi his third year as associate department head. The senior faculty members who chaired the faculty committees listed below were the same as in AY2020.

Tobias Colding continued as chair of the Pure Mathematics Committee and Peter Shor as chair of the Applied Mathematics Committee. Davesh Maulik and Wei Zhang co-chaired the Graduate Committee in Pure Mathematics and Jonathan Kelner the Graduate Committee in Applied Mathematics. Ju-Lee Kim and Steven Johnson served as co-chairs of the Committee of Undergraduate Advisors. Bjorn Poonen chaired the Faculty Nomination Committee, and Alexei Borodin chaired the Moore Committee (for instructor hiring). Scott Sheffield continued as the postdoc officer. The department head's executive committee, which advises on issues arising in the department, consisted of Alexei Borodin, Pavel Etingof, William Minicozzi, Elchanan Mossel, Tomasz Mrowka, Paul Seidel, and Gigliola Staffilani.

Development

Despite the pandemic curtailing our efforts to engage one on one with alumni and friends, the department was successful in fundraising, particularly with respect to the priorities of raising funds for a number of new graduate fellowships and increasing support for MathROOTS and other PRIMES programs focusing on outreach to high school students (see below for more about a major gift establishing the Bershadsky PRIMES mentorship).

Simons Lecture Series and Conferences

The Simons Lectures, scheduled to be given by Bhargav Bhatt of the University of Michigan and Cynthia Dwork of Harvard University, were postponed for a second year due to the pandemic. The Mathematics Department did not directly host any conferences but did jointly organize the annual Current Developments in Mathematics with Harvard University, presented virtually in January 2021.

Education

The undergraduate program in mathematics continues to do extraordinarily well with a large number of majors, the third largest at MIT, and an unparalleled fraction of the strongest mathematics students worldwide. The undergraduate mission includes offering core, large-enrollment service subjects for the wider Institute and more advanced subjects for the mathematics major and related domains.

The pandemic led to many changes, most notably in terms of large-scale remote instruction. The situation was far from ideal, but some of the innovations will be positive going forward and we anticipate a much more normal semester this fall.

Curriculum Updates

The department has developed a number of classes in the past year and will add another this coming spring. Several of the new initiatives are part of the Common Ground for Computing Education in the MIT Schwarzman College of Computing. Associate Professor Ankur Moitra and Professor Pablo Parillo (Electrical Engineering and Computer Science [EECS] with a joint appointment in mathematics) created a class that covers linear algebra and optimization; the class will be part of the artificial intelligence and decision-making program. Professors Laurent Demanet and David Darmofal from the Department of Aeronautics and Astronautics created 18.0002 Introduction to Computational Science and Engineering as a variant of 16.0002 (same subject title) with a focus on computational science and engineering problems. In addition, Professor Edelman has been developing 18.S191/6.S083/22.S092 Introduction to Computational Thinking jointly with EECS. The class uses the Julia programming language to attack various problems computationally.

The department partnered with the Undergraduate Mathematics Association last year to develop a student-led Independent Activities Period (IAP) class that introduces mathematical thinking, abstraction, and proof. The goal is to ease the transition into upper-level classes. Along the same direction, Professors Dyatlov, Poonen, and Seidel are developing a 12-unit class that goes into greater depth with a similar goal; it will debut next spring.

Remote Learning: Response to Covid-19

In the past year, the vast majority of our classes were fully remote due to the pandemic. This was a particular challenge in large lecture classes, including the General Institute Requirements (GIRs), and in Communication Intensive classes. Many remote classes were conducted synchronously (in real time) via Zoom, while others were conducted asynchronously using several different technologies, including the automated lecture capture technology in rooms such as 2-190. Surveys of both faculty and students showed that the process was remarkably successful given the circumstances, but there were areas of substantial concern.

The transition to remote was costly, requiring new equipment, new training programs, and a tremendous amount of faculty and staff time. Perhaps the two largest issues were reductions in student engagements/interactions and the difficulty of remote assessment (especially in light of potential concerns about academic integrity).

The department took a number of steps to increase engagement and interaction, including several that were very successful and will be used going forward. First, we hired undergraduate assistants to work directly with students in many of the larger classes. They led problem sessions, served as informal mentors, and answered student questions in Zoom chats during lectures. Second, Andrew Sutherland developed an app called "p-set partners" that matched students to form problem set groups. This was especially valuable to students deprived of their "natural" means of meeting their peers and is now being used by many other departments.

Remote assessments were a challenge, especially in larger classes and with Advanced Standing Exams (ASEs) and the Mathematics Diagnostic Exam. There were obvious logistical issues (e.g., faulty Internet connections, power outages) as well as concerns about academic integrity. Many classes scaled back or eliminated exams, replacing them with problem sets or projects. This led to significant grade inflation in several classes. A number of instructors without final exams also reported student engagement falling off toward the end of the semester. Instructors of large mathematics classes were recently surveyed; virtually all plan to go back to pre-pandemic methods of assessment in fall 2021.

Our digital learning fellow, lecturer Jennifer French, has led an effort to create remote versions of the ASEs for 18.01 and 18.02 Calculus (summer 2020) as well as for 18.03 Differential Equations and 18.06 Linear Algebra (this past IAP).

The impact of the pandemic on the pre-MIT education of incoming students is a continuing concern. For instance, the department is requiring incoming students to pass the 18.01 Calculus ASE if they want 18.01 credit; we hope that this is a one-time departure from the previous system that allowed students with a score of 5 on the Advanced Placement (AP) Calculus BC exam to get 18.01 credit by passing a shorter diagnostic exam. (The AP Calculus AB exam refers to a comparable first half of 18.01; the AP Calculus BC exam is the more advanced exam, comparable to all of 18.01.)

We recently administered the 18.01 ASE to roughly 750 incoming MIT students, and the results were well below expectations. We expect to have the largest enrollments in 18.01 and 18.01A Calculus that we have had in years.

Service Core Curriculum

Mathematics is central to MIT education, and proficiency in the core mathematics subjects is crucial for students' success. The two GIRs in Course 18 are 18.01 Calculus (single variable) and 18.02 Calculus (multivariable). Large-enrollment classes further downstream include 18.03 Differential Equations, 18.06 Linear Algebra, 18.062 Mathematics for Computer Science (co-listed as 6.042), 18.404 Theory of Computation (an introductory class co-listed as 6.840), and 18.600 Probability and Random Variables.

The Education Committee has been evaluating the service core and has several ongoing initiatives to revise the curriculum. There are several factors driving change. Perhaps the greatest is the dramatic increase in demand at MIT for Course 6 and, especially, machine learning and artificial intelligence. This is particularly important now with curriculum updates in the MIT Schwarzman College of Computing that place greater emphasis on linear algebra, probability and statistics, and discrete mathematics versus the continuous mathematics emphasized traditionally in physics and many engineering disciplines. We have been working with other departments to ensure that our core classes address the mathematics that their students need.

The GIRs are required of all MIT students. Typically, roughly two thirds of students completely place out of 18.01 (it will be fewer next year); the remaining third are split more or less equally between 18.01 and 18.01A Calculus. Virtually all of the students in 18.01 have seen substantial amounts of calculus before and are proficient with basic manipulations in calculus; generally, they are less strong in terms of pre-calculus skills (e.g., trigonometry, logarithms, and exponentials) and conceptual questions or word problems. Many peer institutions cover the 18.01 material in a full-year sequence (with the first semester corresponding to the AP Calculus AB class). All of this creates substantial challenges for teaching 18.01.

Professor Guth has been leading the redesign of 18.01 over the last two years. This is ongoing; he will teach the class again in fall 2021. An important goal of the class redesign is to base the course on authentic problems, ones that ideally incorporate modeling of the world and involve multiple calculus topics or methods. This approach is task-centered instruction. The result will be a reorganized class wherein each unit is based around an authentic problem. The problem will incorporate several calculus ideas already developed, as well as one new calculus idea.

The Education Committee has also been rethinking the content in 18.02 (multivariable calculus). In the process, we have reached out to instructors of the largest downstream classes that use 18.02, such as the physics GIRs, unified engineering, machine learning, and differential equations. The 18.02 class is fast paced, covering differential and integral multivariable calculus in one semester. Many peer institutions (e.g., Princeton and Columbia) have classes that cover similar material in two semesters; Stanford does so in two quarters in its math 50 series. One consequence of this is that we have found that a majority of the students have trouble retaining the integral calculus material at the end of the class. We have been looking at options for simplifying this material (the most general versions are not used by most of the downstream classes). The extra space would then be used to expand the material on vectors and matrices used by many

downstream classes. This revision would have the benefit of moving material up that is currently duplicated in both 18.03 Differential Equations and 18.06 Linear Algebra, relieving pressure on a packed 18.03 curriculum.

Finally, as mentioned, we are coordinating with Course 6 on the design of the mathematical portion of the curriculum for the MIT Schwarzman College of Computing; the Common Ground for Computing Education is an interdepartmental teaching collaborative that will facilitate the offering of computing classes and computing-related curricula across academic units. It is essential that math be involved at these early stages to ensure that we are meeting the mathematical needs of the Institute.

Mathematics Major

The mathematics major continues to thrive. Our students are coveted by top graduate schools and employers, and the major continues to be one of the largest at MIT: the combined total of first and second majors has increased by 30% in the past decade or so.

The success of the major creates a challenge in terms of addressing the broad range in student preparation. A large number of students, many of whom are active in the William Lowell Putnam Mathematical Competition, arrive at MIT having already spent years thinking about higher level mathematics. Many of these students are immediately prepared for advanced classes and, in some cases, graduate classes. Conversely, the flexibility of the major attracts students who are much less advanced as well. This creates academic challenges, but perhaps more important it creates social challenges in building a community and can be intimidating for some students. The department has tried to mitigate these effects via social events, community building, and mentoring and advising (as described below).

A number of our majors find the leap from the 18.0 courses to the advanced classes to be extremely challenging. The service core classes teach foundational mathematical skills, while advanced classes often focus on proof and have a very different level of rigor and abstraction. Classes such as 18.100 Real Analysis, 18.200 Principles of Discrete Applied Mathematics, 18.650 Fundamentals of Statistics, 18.701 Algebra I, and 18.901 Introduction to Topology are simply at a different level than the service core. We are taking a number of steps to help students bridge this gap. First, we offer four different versions of 18.100 at different levels of abstraction (and with or without a communications component). Second, we have introduced a new undergraduate geometry class, 18.900 Geometry and Topology in the Plane (developed by Professor Seidel at an intermediate level), that allows students to acclimate more gradually to abstraction and proof. This class has been a success, earning strong student evaluations, and we are looking for similar opportunities in other classes. Third, we have added recitations to 18.600 and 18.650 to ease the transition. Fourth, we are making tutoring available for gateway classes in the major (18.100, 18.200, 18.600, 18.650, 18.700, 18.701, 18.702, 18.900, and 18.901) in the Math Learning Center. The center is open four hours a day Monday through Thursday and has traditionally provided drop-in tutoring for the service core by capable undergraduates. The department has been experimenting with offering more advanced tutoring; this was popular with students.

MITx

The 18.01x Calculus and 18.03x Differential Equations series and the 18.650x Fundamentals of Statistics class continue to run on edX globally, making math content available for free or for a low cost (to earn a certificate). The MITx math team has developed a new suite of 3D mathlets for the 18.02x multivariable calculus series and for use on campus.

The use of MITx changed and evolved in AY2021, with courses mostly taught online due to the pandemic. The MITx math team facilitated and supported other digital tools beyond MITx.

Surveys of faculty, instructors, and graduate students asking about challenges with online teaching in fall 2020 were used to design drop-in Zoom sessions over IAP 2021 to share best practices and solutions to common issues.

In AY2021, several on-campus classes moved to a "flipped classroom model," with first exposure to new material coming from MITx content and canvas videos/outlines. Because classes were taught online, the move to the flipped classroom model allowed faculty to spend synchronous time with students doing more problem solving and answering questions. Classes that moved to the revised model were as follows:

- 18.01A Calculus (fall 2020; David Jerison)
- 18.03 Differential Equations (fall 2020; Tristan Collins, who received a teaching award)
- 18.650 Fundamentals of Statistics (Philippe Rigollet)
- 18.031 System Functions and the Laplace Transform (IAP; flipped before AY2021)
- 18.01 Calculus (spring 2021; flipped before AY2021)

Since 2015, 18.03 and 18.01A have used MITx to offer frequent quizzing with immediate feedback. During AY2021, the following classes also used MITx for this purpose due to its robust problem-solving and randomization capabilities:

- 18.02 Calculus (fall 2020; Semyon Dyatlov)
- 18.701 Algebra I (spring 2021; Bjorn Poonen)
- 18.783 Elliptic Curves (spring 2021; Andrew Sutherland)

In spring 2021, the 18.03 MITx site included several new review sections that aimed to improve cognitive retention through spaced retrieval.

Online Advanced Standing Exams

The 18.01 Advanced Standing Exam, designed as a fully online randomized exam on the MITx platform, ran during summer 2020 and IAP 2021. The 18.02 ASE was run as an online semi-randomized exam in summer 2020 and as a half online and half paper-submitted-online exam in IAP 2021. Both the 18.03 and 18.06 ASEs were run in IAP 2021 as half online randomized exams and half paper-submitted-online exams.

The support of Digital Learning Laboratory scientists and fellows who work in the department in developing digital content is essential to the successful running of the ASEs, the online edX classes, and the MITx content used at the Institute.

Graduate Students

There were 116 graduate students in mathematics in AY2021, all in the PhD program. A total of 26 students received their doctoral degrees between September 2020 and June 2021.

A majority of the students who completed their PhD degrees advanced to postdoctoral positions in mathematics and related departments at other universities, including appointments at Columbia, Harvard, the Institute for Advanced Study, Princeton, Stanford, the Simons Center at Stony Brook, and the University of California at Berkeley. Students also continued to international appointments at the Polish Academy of Sciences and IPMU/Tokyo. A smaller number elected to pursue jobs in industry, with the most popular option by far being finance. In addition, one student began work as a system developer, one took a position with a venture capital company, and one left mathematics to enter a seminary.

Thirty new students will enter the mathematics doctoral program in September 2021. The entering class includes six women and two members of underrepresented minority groups. The department continues the policy of offering all first-year doctoral students full fellowship support and guaranteed support for five academic years.

Graduate Student Awards

Andrei Ionov received the Charles and Holly Housman Award for Excellence in Teaching for his exceptional skill in and dedication to undergraduate teaching, especially for the challenging job of providing faculty and student support during the past year's pandemic remote teaching. The Charles W. and Jennifer C. Johnson Prize for an outstanding research paper accepted in a major journal was awarded to Jonathan Tidor.

Mathematics Majors

The mathematics major is the third largest major at MIT and the largest within the School of Science. According to the official fall fifth-week tally for AY2021, 377 students listed mathematics as their major: 267 were in Course 18 (Mathematics) and 110 were in Course 18C (Mathematics with Computer Science). Enrollment had increased slightly by the spring 2021 term (but remained below our usual 400 or more undergraduates due to the absence of early sophomore standing this spring). Of these students, 149 graduated with bachelor's degrees in mathematics (96 with mathematics as a first major and 53 with mathematics as a second major).

Our data, based on our senior survey and supplemented by information from students' advisors, are far from complete. However, of the 45% of graduating class members whose postgraduate plans are known, 22 will continue in graduate programs in mathematics, 10 in programs in computer science, five in programs in physics, and a handful in other fields such as economics, nuclear engineering, and business. A smaller number will pursue non-academic opportunities, with five entering jobs in computing

and software engineering, 10 entering the financial sector, three joining consulting companies, a few pursuing other opportunities (e.g., in aerospace engineering), and several taking a year off to travel or continue job searching.

Undergraduate Awards

The Jon A. Bucsela Prize in Mathematics, given in recognition of distinguished scholastic achievement, professional promise, and enthusiasm for mathematics by a mathematics major, was awarded to seniors Qiuyu Ren and Junyao Peng. Seniors Korina Digalaki and Vanshika Jain received honorable mention for the Alice T. Schafer Prize for excellence in mathematics by an undergraduate woman. Ashwin Sah and Mehtaab Sawhney, now graduate students in the department but previously undergraduate math majors, shared the Frank and Brennie Morgan Prize for outstanding research in mathematics by an undergraduate student.

There was no formal Putnam exam in December 2020. A self-administered online exam was available for those who wanted the practice of taking it.

Undergraduate and High School Summer Research Programs

Due to the Covid-19 pandemic, all programs described below were conducted online.

Summer Program in Undergraduate Research

In summer 2020, the department hosted its 24th Summer Program in Undergraduate Research (SPUR), a six-week intensive mathematical research experience for MIT undergraduates in which each undergraduate pursues an individual or team project with a graduate student mentor. There is also an extended version, SPUR+, that targets top women and members of minority groups and begins three weeks earlier. The summer 2020 SPUR+ proved successful in expanding the overall program to more women and underrepresented minority (URM) students. Altogether, nine MIT undergraduates participated in the 2020 SPUR program (including two female students) and four in the SPUR+ program (all female students), mentored by 10 graduate students. The 2020 Hartley Rogers Jr. Prize for best project was shared by SPUR teams Carl Schildkraut ’23, William Zhao ’23, and mentor Chun Hong Lo; Hans Yu ’21 and mentor Jonathan Tidor; and Kevin Chang ’21 and mentor Robert Burklund. David Jerison and Ankur Moitra continued in their role as faculty supervisors.

Undergraduate Research Opportunities Program

MIT’s Undergraduate Research Opportunities Program (UROP) plays a key role in giving students their first research experience. In our UROP+ program, initiated in 2014 by Professor Etingof and lecturer Slava Gerovitch, graduate students are compensated for mentoring UROP students on research projects or doing guided reading full time with students. The students meet weekly with their mentors and then write up a final research paper and give a talk. Seventeen undergraduates participated during the summers of 2018 and 2019, including four women and two URM students. In summer 2020, 14 students participated, including three female/nonbinary students. In 2020, the program was managed by Professors Jerison and Moitra.

Research Science Institute

Summer 2020 was the 28th year of the department's participation in the Research Science Institute program for gifted high school students. Five graduate students and faculty members mentored nine high school students in the six-week program. The students came from six different states as well as Bulgaria, Hong Kong, and South Korea. Several students were recognized for their research projects. Yunseo Choi won first place at the 2021 Regeneron Science Talent Search, was a 2020 S.-T. Yau High School Science Award finalist and gold medalist, and received an honorable mention at the 2021 Mathematical Association of America (MAA) Undergraduate Poster Session. Andrei Mandelshtam was a finalist in the 2021 Regeneron Science Talent Search and won the 4th Grand Award (in math) and 3rd Special Award (from AMS) at the 2021 International Science and Engineering Fair (ISEF). Gregory Li won the 4th Grand Award (in math) at the 2021 ISEF.

Program for Research in Mathematics, Engineering, and Science

The department held its 11th annual Program for Research in Mathematics, Engineering, and Science. Twenty-three gifted high school students from the greater Boston area are working with 11 postdoctoral researchers and graduate student mentors on research projects or participating in reading groups in the mathematical section of PRIMES. Additionally, in the PRIMES-USA math section, 24 exceptional out-of-state students selected from a national pool are conducting projects or participating in reading groups under the supervision of 20 graduate students, postdoctoral associates, and outside faculty.

In fall 2020, PRIMES and PRIMES-USA math students successfully completed 29 individual and group research projects they had worked on during calendar year 2020. Three students were finalists and 12 won national scholar awards in the 2021 Regeneron Science Talent Search competition. Jessica Zhang and William Li won the 2nd and 3rd Grand Awards in Math, respectively, at the 2021 Regeneron ISEF. Math students also received the following honors at the 2020 Yau High School Science Award competition: Kenta Suzuki won the USA Gold Math Award, Lucy Cai the USA Silver Math Award, and Hyunwoo Lee, Alex Wei, and Daniel Hong the USA Silver Computer Science Award. Six other students were USA Bronze medalists and eight were USA semifinalists. In addition, seven students received Outstanding Presentation Awards at the MAA Undergraduate Poster Session.

PRIMES Circle and MathROOTS are more specifically designed for female and URM high school students than other PRIMES programs. PRIMES Circle completed its eighth year, offering an enrichment curriculum for students in the Boston area. A total of 23 students from urban public high schools, including one Hispanic student, one African American student, and 14 female students, participated in the 2021 program.

Beginning on June 18, 2021, the department hosted its seventh MathROOTS summer camp program, with all camp activities conducted online. A total of 19 students participated; eight self-identified as female, five as African American, 12 as Hispanic, and two as mixed race. Thus far, of 120 MathROOTS alumni (from 2015–2020), 47 have enrolled at or delayed entry to MIT.

In June, PRIMES held its 11th annual spring-term conference online. Organized by Pavel Etingof and Slava Gerovitch, the conference featured 23 presentations by 52 students from MIT PRIMES, PRIMES Circle, and the PRIMES Solve-Theorize-Explore-Prove (STEP) program for seventh- to ninth-grade students. This well-attended event demonstrated the solid success of the program. Several projects will likely lead to publication in professional journals and will be strong contenders at national science competitions for high school students. The remaining PRIMES and PRIMES-USA students will present their projects at the fall-term online conference in October 2021.

Thirty-one PRIMES alumni will enroll at or delay entry to MIT as first-year students in fall 2021 and will likely continue their research through UROP.

Named Mentorships

Through the generosity of Professor George Lusztig, the Lusztig PRIMES mentorships are annually awarded to continuing PRIMES mathematics mentors for exceptional mentoring service in prior years. The 2021 Lusztig PRIMES mentors were graduate students Peter Haine (PRIMES Circle coordinator), Chun Hong Lo, and Adela (YiYu) Zhang.

In September 2020, Michael and Victoria Bershadsky made a major gift toward the PRIMES endowment. This made it possible to establish the Bershadsky PRIMES mentorship, which will be awarded each year to a continuing PRIMES mathematics mentor for exceptional mentoring service in past years. The first Bershadsky mentor was graduate student Andrey Khesin, a PRIMES mentor and MathROOTS program director since 2020.

Building Community, Diversity, and Inclusion

Professor Staffilani continued to chair the Diversity and Community Building Committee. She also served as one of the co-chairs of the School of Science Gender Equity Committee. The Diversity and Community Building Committee met several times and focused on a number of issues:

- Results from the MindHandHeart Department Support Project data report for the Mathematics Department were reviewed, along with 2020 Quality of Life Survey updates.
- There were ongoing discussions of the department's diversity web page, with a rough mock-up of the page provided by staff member Elise Brown.
- A group of graduate students started the Grad-Undergrad Math Mentoring Initiative, a math mentoring program in which graduate students offer advice and support to undergraduates considering a graduate degree in mathematics.
- A new student group was formed: the Council for Math Majors. This student-run advocacy group solicits input and experiences from math majors to present to faculty on relevant practices that could benefit from revision. A faculty liaison meets regularly with the group to review proposals and requests.
- A read-through and lively discussion took place regarding the first draft of MIT's Five-year Strategic Action Plan for Diversity, Equality, and Inclusion.

The department's code of conduct poster is ready to be placed in the Simons Building when the campus reopens in fall 2021. It should serve to remind students of the mathematics community's values of inclusiveness and respect for all individuals.

For the second year, the department ran its Open Advising Hours program for math majors (particularly first-year undergraduates) who are advanced in math but have not declared mathematics as a major. The program, which provides access to academic advice from math faculty (in addition to what students would have received from their assigned academic advisor), was conducted via Zoom because of the pandemic.

The department continued its participation in the Society for Advancing Hispanics/Chicanos and Native Americans in Science national conference, which for the first time was held in a completely virtual format. This offers the advantage that academics can more easily schedule time at their home institution to mentor individual students and exhibitors at the conference. MIT provided two virtual booths, staffed in part by a mathematics administrator.

The pandemic did prevent some recently implemented campus activities designed to acquaint undeclared undergraduates with the mathematics major through interactions with department members. These activities will be resumed in AY2022 when conditions allow.

Directed Reading Program

The Directed Reading Program has proven to be a very valuable tool for promoting interest in mathematics research among math majors, including women and URM students. The program pairs an undergraduate with a graduate student mentor to work through one or more math texts over IAP. Since the department's commitment of more funding in AY2019, there has been a noticeable increase in student participation each year (from 24 in AY2018 to 70 in AY2021), with 16% URM and 36% female undergraduates in AY2021.

Martin Luther King Visiting Professorship Program

The MLK visiting faculty program affords the department the experience, know-how, and engagement of leading women and URM mathematics faculty. They have provided a teaching and mentoring presence for our students, particularly for minority students, and have been critical research collaborators with faculty and postdocs and advisors for the department's diversity outreach efforts. Over the years, we have seen an increase in the number of women and minority faculty who express interest in the program.

During the year, no new nominations were submitted given that last year we completed arrangements to appoint two African American visiting faculty. Professor Sean Paul of the University of Wisconsin, Madison began his appointment in January 2021 and will continue teaching a class through fall 2021. Assistant Professor Stephen J. Kleene of the University of Rochester will teach during both AY2022 terms. Both visiting faculty will contribute to the Diversity and Community Building Committee in the coming year.

We have also been pleased to see how the MLK program has impacted some of our visiting faculty. A case in point is Professor Kasso Okoudjou, MLK visiting professor from 2018 to 2020. He was able to relocate to the Boston area with a faculty appointment at Tufts University. He also co-chaired the AMS Towards a Fully Inclusive Mathematics Profession Task Force, which explored the historical role AMS has played in racial discrimination in mathematics. The self-examination of the AMS is an inspiration and model for individual departments to undertake. In March 2021, the task force submitted its final report.

Building a Community for Women

This year marks the 50th anniversary of the founding of the Association for Women in Mathematics (AWM). One notable speaker during the association's virtually hosted We Speak Series was Gioia De Cari, the solo writer of and performer in the play *Truth Values: One Girl's Romp through M.I.T.'s Male Math Maze*. Her talk, presented on April 30, was titled "Perspectives on Women in STEM from a 'Recovering Mathematician.'"

May 12 is International Women in Math Day. On that day in 2021, the Mathematical Sciences Research Institute hosted the Celebration of Women in Mathematics, which focused on imposter syndrome and racial justice issues facing minority women mathematicians. At the Institute level, My Sister's Keeper and the Black Women's Alliance offered their career panel discussion on March 31, with five alumnae discussing their lives at MIT and after.

Continuing Activities

- Professor Staffilani's annual fall hosting of the women in mathematics dinner (for women math students, postdocs, and faculty in the greater Boston area) at her home had to be canceled in AY2021.
- The department's Women in Math Lunch Seminar series, scheduled to take place three to four times a term, continued via Zoom throughout the year. The series features a senior woman mathematician who discusses her research and career in academia or industry. The seminar is open to women faculty, postdocs, graduate students, and undergraduates (whose participation has been increasing).
- Due to the pandemic, MIT was unfortunately not able to host the Advantage Testing Foundation's Math Prize for Girls competition on its campus. The event took place virtually on October 10 and 11, 2020. (MIT has also had to cancel its on-campus hosting in October 2021.) This is very unfortunate because the Math Prize for Girls has been a resource to attract strong young women in high school to matriculate at MIT. The hope is that hosting of the competition will resume on the MIT campus in AY2023.
- MIT women math majors, graduate students, and alumnae have continued to offer girls in middle school online mentoring at Girls' Angle: A Math Club for Girls in Cambridge. The department also supported an affiliate appointment for its head mentor, Professor Grace Work, for a second year. She will begin a faculty appointment at the University of Wisconsin in July 2021. For the second year, Girls' Angle had to cancel its SUM+IT event scheduled to be held at MIT.

The department continued its funding support for numerous on-campus events and organizations for women and members of minority groups.

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