The Math Department, like the rest of the Cornell community, was deeply saddened by the tragic passing of Cornell University President, Elizabeth Garrett. She and her family are in our thoughts.

MATHEMATICAL ART

LINDA B. GLASER

This fall twenty-five images were on display in Malott Hall in an exhibition, "SymmetryScapes: An Exhibition of Mathematical Art." Artist Frank Farris, who delivered the Harry S. Kieval '36 Lecture on campus in September, created the display's aluminum prints, purchased by Cornell's math department to celebrate the beauty and diversity of symmetry. The exhibition has now moved to the Sciencenter in Ithaca.

Farris, a mathematician at Santa Clara University, says symmetry seems to be a universal human experience: every known decorative culture produces some

"Icosahedral Lampflowers" by Frank Farris

version of repeat patterns. "We all seem to take delight in seeing that one part of a pattern exactly matches another," he says. "Symmetry connects to the rhythms of our bodies and the cycles of the seasons, making it a sort of comfort food for our eyes."

To create his art, Farris

LETTER FROM THE CHAIR

RAVI RAMAKRISHNA '88

We have wonderful students doing very exciting things! From solving open research problems to participating in Mathematical Contests in Modeling to tutoring in the Math Support Center, our students bring talent and energy to the table. The undergraduate math club sponsors lectures by students and faculty, organizes the annual Kieval Lecture and plans other events, e.g. *Origami and pizza* on December 1st to celebrate the end of the term. Our local chapter of the Association for Women in Mathematics (AWM), run by grad students, sponsors informal career chats with accomplished professionals and alumni, leads discussions about articles in the media related to women or girls in math, and sponsors social events.

We look forward to working with incoming President Martha Pollack. A computer scientist

Ravi Ramakrishna University Photography

by trade, she is well-suited to understand the central position Mathematics occupies at Cornell.

Much is happening at Cornell. The College of Arts & Sciences is undergoing a curriculum review that may impact our offerings. Computer Science enrollments here and across the country are shooting through the roof. The number of CS majors in our upper-level classes has tripled. The Department recently underwent a decennial review. This involved a yearlong self-study after which a team of distinguished outside experts visited. Their final report described us as "one of the top mathematics departments in the United States" and "remarkably collegial." It also identified areas in which we need to be mindful and take initiative, in particular the hiring of new faculty to replace a wave of upcoming retirements.

Read Math Matters online:
https://www.math.cornell.edu/m/News/MathMatters
The electronic version includes links to individuals' webpages and research articles

Faculty Spotlight - Inna Zakharevich Joins Faculty

Inna Zakharevich was born in Russia surrounded by mathematicians, "My mother has a math Ph.D., my grandmother has a math Ph.D....I grew up thinking that the first step is to get a math Ph.D., then you move on to the next thing you want to do." Inna decided her "next thing" was to be a computer programmer, as there were far too many mathematicians in her world. However, on a family ski trip at the age of sixteen, she spent the entire four days working on math problems and never hit the slopes. This is when she realized that she was a fifth generation mathematician.

Inna studied at Harvard and Cambridge before earning her Ph.D. from MIT in 2012. She then became a member of the Institute of Advanced Study in Princeton and an L.E. Dickson Instructor at the University of Chicago.

Inna joined Cornell during this past summer as an assistant professor. She finds the community friendly and the town beautiful. A particular draw of Cornell is that faculty study their own things - they aren't only working on what is trendy right now. "At Cornell, everyone is encouraged to research what interests them - no matter how off-the-wall."

Inna's primary research focuses on formalizing geometric cutting-and-pasting problems and studying them using methods from algebraic topology and algebraic K-theory. The main idea is to take the notion of cutting-and-pasting and replace it with an algebraic model that remembers the combinatorial aspects and forgets the geometric ones.

This formalism can then, using the methods of algebraic

Inna Zakharevich
*Photo credit, University Photography*

K-theory, be turned into a topological space, whose properties we can study. These properties should then reflect back on the geometric problems. Inna's main focus has been on applying this to studying scissors congruence (along the lines of Hilberts third problem) and the Grothendieck ring of varieties, although she is always looking for new applications.

Inna describes her research as a 'garden of her own' as it is a bit obscure, but it delights her to be gardening at Cornell, where she can be a little off-the-wall.

Student Spotlight Vivian Kuperberg '17

Vivian Kuperberg will be graduating this year and will receive her first degree ever. She left Davis Senior High School in California without finishing, beginning her undergraduate career at the age of sixteen. Cornell appealed to Vivian. She was especially fond of the diversity on campus and has taken a wide variety of classes in the humanities. Vivian has been an all-star in the math department; a Rawlings Scholar working with Professor Bob Connelly,

SPUR participant, President of the Math Club, Head Tutor at the Math Support Center, and designer of the department t-shirt. Outside of math, she enjoys swing dancing, rock climbing, and juggling. Her
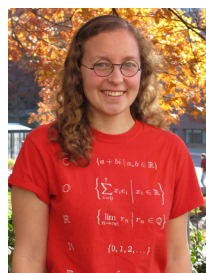
Vivian Kuperberg, wearing the Cornell t-shirt she designed

love for those hobbies, however, does not compare to her love of math.

As for mathematical research

passions, Vivian likes geometric group theory and algebra. Currently, she is collaborating with Professor Tim Riley on a project on sofic groups. It is not known whether all groups are sofic. She is studying groups that are variants of Higman's group, an important candidate in the search for a non-sofic group.

While Cornell will proudly bestow upon Vivian her first degree, it will not be her last. She is applying to PhD programs and will start in the fall of 2017. We look forward to following her career.

MATHEMATICAL ART

LINDA B. GLASER

begins with mathematical formulas that encode a certain type of symmetry pattern on a plane. He then uses a photograph that supplies colors that are transported to the plane based on the formulas. In the end, the formulas are invisible, but the colors reveal the symmetry pattern to the viewer.

Exhibit visitors will have their own chance to experiment with symmetry by manipulating transparency copies of the images on display over paper copies of the images.

"Symmetry is intuitive but it's also something that can be understood on many levels,

both visual and kinetic," explains Robert Strichartz, professor of
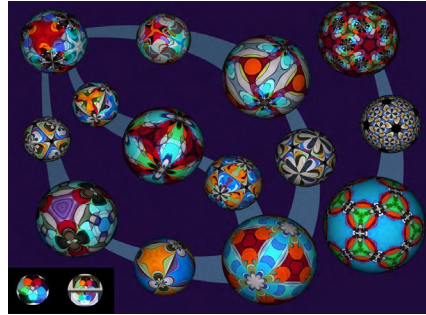
Frank Farris - A Polyhedral Sampler digital print on aluminum, 2015

mathematics in the College of Arts and Sciences and organizer of the exhibit.

Strichartz realized the appeal of Farris' work when he brought home the artist's book,

"Creating Symmetry."

"My grandkids saw it and were awed by the art," says Strichartz. "They're 13 and 10, so I thought Farris' work was something that would have a wide appeal and would be a great thing to bring to Cornell. I'm always interested in outreach that shows the fun in mathematics."

The exhibit includes two interpretive texts for each artwork, one explaining the concept of the image and one, labeled "Technical Talk," that explains the underlying mathematics in an accessible manner.

NEW RESEARCH PROJECT INVOLVES COLLABORATION BETWEEN MATH & ORIE

JAMOL PENDER, RICHARD RAND & ELIZABETH WESSON

A novel and exciting research project combines queueing theory and differential-delay equations. This work spans the campus, involving Assistant Professor Jamol Pender in the ORIE Dept., Professor Richard Rand and Visiting Assistant Professor Elizabeth Wesson in the Math Dept.

Queueing theory is the study of the dynamics of the lines in which we all wait. Common examples from daily life include lines of people at banks and supermarkets, lines of cars in toll plazas, or lines at telephone call centers. Our work considers the dynamics of queue changes

if information is delayed. Suppose for example that you were

in Disneyland, trying to decide which ride to go on next and you used their app which

Richard Rand

displays the waiting times of rides. Your choice might depend on these provided wait times, but if the information is old (i.e. delayed), the app might not indicate which ride has the shortest wait in reality. That is, the information provided to you would refer to the state of

the system at a previous time. Mathematically, this would result in queueing models based on differential-delay equations rather than ordinary differential equations.

Our research on this topic has shown that increasing the delay time can result in (unwanted) periodic behavior of the length of lines, a phenomenon which has been observed in U.S. hospitals. Mathematically, this change in behavior is caused by a Hopf bifurcation in the queueing model equations. If this sounds interesting to you, check out our first paper, "Managing Information in Queues: The Impact of Giving Delayed Information to Customers."

POWER MATH

John Guckenheimer co-chaired (with Thomas Overbye from UIUC) a National Research Council committee that produced the 160 page report "Analytic Research Foundations for the Next-Generation Electric Grid" published this year and available for download from the National Academy Press. The committee was formed in response to a request from the Department of Energy Office of Electricity Delivery and Energy Reliability. It had fifteen members, approximately half mathematicians and half power systems engineers.

The electric grid is perhaps our most complex critical infrastructure and modern society absolutely depends upon its reliability. It is also in a period of rapid change for several reasons:
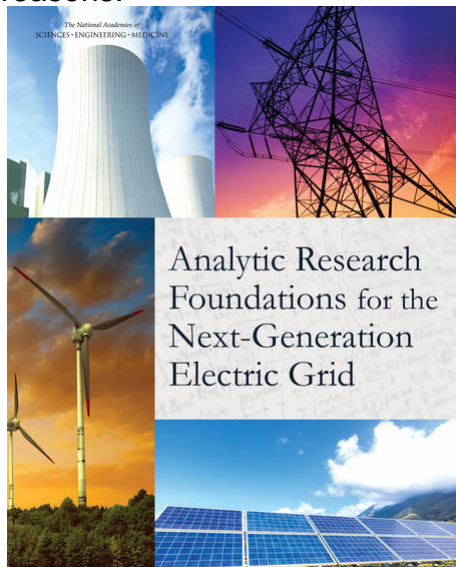
The Cover of the Report, Analytic Research Foundations for the Next-Generation Electric Grid by The National Academies Press.

1. There is rapid growth in renewable energy sources, notably wind turbines and photovoltaic solar cells. These energy sources are intermittent and have much less inertia than large conventional power plants. Distributed generation also enables "microgrids" that can supply power to local communities with less reliance on the national grid.

2. "Smart grids" with two way communication between customers and power producers are being put in place nationwide.

3. "Phasor measurement units" that provide much more rapid and detailed information about the state of the bulk transmission grid have been installed nationwide over the past decade. Funding came from the Recovery Act following the financial crisis of 2008.

Electricity is different from oil, gas, and water because it cannot be stored readily. Invention of cost effective electric storage devices would make operation of the grid much simpler. Today, the grid operates by adjusting generation in real time to meet loads. In much of the country, reliability is the responsibility of regional transmission organizations that run wholesale electric markets which determine which utilities will produce power at what times. There are daily auctions that are settled with the help of sophisticated optimization algorithms to produce low cost, reliable power. The items listed above all complicate this already complex system. As one example, the cost of power at times of peak demand is very high because the equipment that meets the marginal demand is used only infrequently. "Shaving" these peaks with smart grids that curtail loads at times of peak demand saves lots of money, enabling rates to be lowered. As the grid undergoes the changes described above, mathematicians have much to contribute by developing new theory and new algorithms that will support this incredibly complex system. The report identifies key issues and problems that need to be solved. It makes recommendations on how to build a multidisciplinary community of mathematicians and engineers that can tackle them most effectively. Not long after the release of the report, DOE and NSF signed a memorandum of understanding to begin implementation of the recommendations.

Malott Hall (right) with new signage on our Tower Road entrance, honors James Edward Oliver, *after whom our colloquium is named. He joined Cornell in 1871 and served as Chair of Mathematics for over 21 years.*

SUMMER PROGRAM FOR UNDERGRADUATE RESEARCH (SPUR)

ROBERT STRICHARTZ

During the summer of 2016 the Department hosted 22 undergraduates from Cornell, Princeton, Northeastern, The University of Hong Kong, and many other top-rate institutions around the world to conduct research in three areas; analysis of fractals (Prof. Robert Strichartz, TA: Abigail Turner), discrete geometry (Prof. Florian Frick, TA: Thomas Bååth), and nonlinear heat equations (Prof. Xiaodong Cao). The students have already begun to present their results at conferences, which are available on the SPUR website. We have run summer research programs at Cornell since 1994. Many alums from earlier summers are now prominent mathematicians in both academia and industry.

The analysis on fractals group worked on five separate projects, with each expected to yield a paper.

Surath Fernando, Haley Grant '18, and RJ Ragodos studied percolation clusters on products of fractal graphs, using experimental methods to explore questions that have been extensively studied on Euclidean lattice graphs. Their results are here.

Eric Goodman and Alex Siu studied infinite magic carpet graphs. The magic carpet is a fractal obtained from the standard Sierpinski carpet by gluing together all edges. They were able to prove estimates on the number of vertices in a graph metric ball of a given radius (on the order of the third power of the radius), and they were able to find the spectral resolution of the graph Laplacians. Here are their results.

Andrew Hahm and Jeffrey Kuan studied the spectral theory of a certain energy Laplacian and Schrödinger operation on the "spiral galaxy," an infinite blow-up of the Sierpinski gasket that has a spiraling periodic structure. They obtained strong experimental evidence that the energy Laplacian has a discrete spectrum, which are available here.

Jeff Marino and Diljit Singh discovered two different self-similar Laplacians on a fractal obtained from the hexagasket by gluing together all boundaries by identifying antipodal points. The fact that there are two distinct fully symmetric Laplacians came as a complete surprise. They were able to implement the method of spectral decimation for both Laplacians in order to obtain a complete description of the spectrum in both cases.

Shuangping Li and Prem Talwai '19 studied the problem of restrictions from Sobolev spaces on the Sierpinski gasket to line segments in the gasket. One such result that was previously proven by Alf Jonsson answers the question for the one specific Sobolev space (these spaces are parametrized by a positive variable s), so they looked for other values of the parameter s. Prem will be presenting these results in a talk at the Joint Mathematical Meetings in Atlanta in January 2017.

Zachary Munro '17, Jason Snyder '17, and Tom Stone

At Cornell Homecoming 2016, faculty and student volunteers from the Math Department created geometric balloon accessories for visiting children and alumni.

Mathematics Library Overview

Steve Rockey

The Math Library at Cornell, which began as two bookcases in the Chair's office in White Hall, has grown into the most heavily used collection on campus. Primarily a research collection, ours is one of the finest in the nation. It includes a wide range of scholarly materials as well as instructional, career, historical and expository works. With the transition of Physical Sciences and Engineering to virtual libraries the Math Library also houses and stewards the highest use legacy paper books from those collections in astronomy, theoretical physics, and mechanics.

A decade ago the Cornell Math Library moved began to transition to online materials. The initial transition was with journals. We invested heavily in online backfiles for journals. This has proved to be a wise decision as older materials often get as much or more use than the more current portion of the titles.

In 2009 we moved more towards online only books when possible with the caveat that we only want permanent ownership of books without limits on simultaneous uses or downloads. As with journals, we offer 24/7 availability on and off campus for e-books. We now hold approximately 30,000 titles, and the e-book collection's use is orders of magnitude higher than the paper book collection. Nonetheless, the use of the paper book collection in the stacks remains high and stable. For those books where the unit of use is a chapter, article, or section, users are satisfied with a PDF. For graduate textbooks and research monographs the situation is more complex. In those cases where the user actually needs to read and digest large portions of a book, paper is often preferred. We proactively acquire paper books in addition to the e-books for a few exemplary monographic series.

Those two book cases will be used for a long time to come!

Prison Education Program Volunteers

Jeff Bergfalk

During the of fall 2015, graduate students Jeffrey Bergfalk, Frederik De Keersmaeker, Benjamin Hoffman, Aaron Palmer, Ahmad Rafiqi, Valente Ramirez Garcia Luna collaborated, through Cornell's Prison Education Program (CPEP), to teach and tutor a college algebra course at Auburn Correctional Facility. CPEP brings together Cornell faculty and graduate students to teach a free college-level liberal arts curriculum to a select group of inmates across different prisons in the state of New York. The credits can be applied toward an associate degree from Cayuga Community College; three students
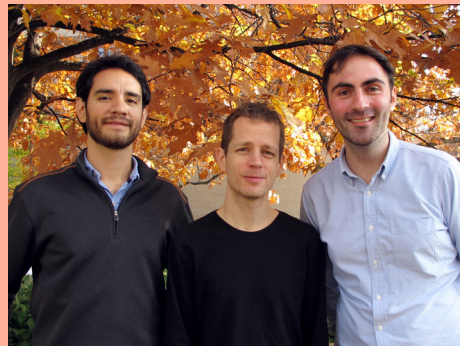
Some of our volunteers from left to right: Valente Ramirez Garcia Luna, Jeffrey Bergfalk, and Frederik De Keersmaeker

from that fall 2015 algebra course earned this degree in October. In the semesters since, several instructors from the original group have expanded CPEP's math offerings: in collaboration with graduate students from the physics and science and technology studies departments, they've taught and tutored college algebra and math preparation courses at both Auburn and Cayuga Correctional Facilities, and this fall, Valente is co-teaching Cornell's own MATH 1300, Math Explorations, again for credit towards a degree. Ahmad Rafiqi describes the experience as follows: "It's very fulfilling, to try to understand things with these students. Many of them are very smart, very willing to listen, and more mature than the students we tend to encounter at Cornell. They're making very conscious decisions, and often go through a lot to be in class, and tend to be grateful for the teaching we're able to provide."

Mathematics Department hosts Family Mathematics Program

Anna Carmichael

Families from across the state, as well as New Jersey, Connecticut, Rhode Island, Massachusetts, Maryland, Pennsylvania, and Delaware, traveled to Cornell in November for a Family Mathematics Program hosted by the outreach program of the Cornell Department of Mathematics and the Johns Hopkins University Center for Talented Youth. This is the fifth time the Department of Mathematics has hosted the program.

The day-long program Nov. 5 consisted of interactive activities geared at introducing students from grades 7-10 and their parents/guardians to mathematical topics they wouldn't necessarily learn in school. The hands-on activities and interactive discussions helped participants learn about geometry, topology, and other specialized topics.

Aruul Avaralt-Od, a middle schooler who attended the event said, "I thought it would be fun to learn about different topics in mathematics."

Her father, Avaralt, explained, "I wanted my children to attend this event because I thought it would be interesting for them to see numbers in application."

Professor Tara Holm gave the keynote lecture, "The Topology of Trousers," which encouraged participants to look at topology in everyday objects. Each participant was given pieces of perforated paper, and during the lecture Holm had them tape together the paper, and rip along the perforation. When they taped and ripped the paper, they were able to make new shapes.

Holm first had participants make a simple cylinder with the paper, and then they were asked to rip along the perforation, which then formed a

*Prof. Tara Holm,
University Photography*

Möbius strip, a twisted cylinder.

After the lecture, three one-hour break-out sessions were offered. As each student cycled through the three sessions, their parent/guardian attended the same sessions, but in a different room. The breakout sessions were taught by graduate students and helped participants think about how mathematics is applicable in their everyday lives. Sessions focused on mathematics in dancing, how mathematics can help you win, and how mathematical patterns can explain chaos.

According to Mary Ann Huntley, director of mathematics outreach and K-12 education activities, this is a wonderful opportunity for graduate students to practice presenting advanced mathematical ideas to a non-specialist audience.

"I learned how to more effectively communicate results to people outside of my field. Having the opportunity to work with parents was really rewarding for me," a graduate student noted.

The Johns Hopkins Center for Talented Youth is a nonprofit center that nurtures young people's intellect and personal growth through programs such as this one.

The program concluded with an optional campus tour so that families could explore Cornell.

Other valuable outreach programs have been featured by the Cornell Chronicle, and more information is available online.

University Photography

7

Letter From The Chair Continued

We have made a very good start in this direction by hiring eight new faculty in the last five years. Inna Zakharevich, a topologist, joined us this summer. Next year probabilist Philippe Sosoe will arrive after he finishes his postdoc at Harvard. Inna and Phil are key players in our efforts to rebuild our world-class groups in topology and probability.

As reported in previous issues of Math Matters, several faculty have begun to use engaged learning techniques in their classrooms. We are now taking this to the next level. Senior Lecturer Kelly Delp and Professors Dan Barbasch, Tara Holm, Tim Riley, Steven Strogatz and Ed Swartz have put forth a proposal to develop materials as we transition calculus (and a few other classes) from lectures to a hybrid of lectures and active learning modules. We expect our students will have a more rewarding experience in this new format.

Nicolas Templier, a number theorist who recently joined us from Princeton was promoted to associate professor. Alex Vladimirsky, who created and continues to run our highly successful Math Modeling Contests was promoted to full professor. Congratulations to Nicolas and Alex!

Laurent Saloff-Coste stepped down as Chair in January after six and a half years at the helm. Laurent led the department through the budget cuts following the financial crisis, the recent decennial review and our ongoing replenishment of the faculty. We thank him for his efforts and welcome him back to the role of being just a professor.

Finally, we are very grateful to you, our alumni for your support and advice. Please drop by Malott the next time you are in Ithaca. We look forward to hearing about your time on the hill and what you are doing now!
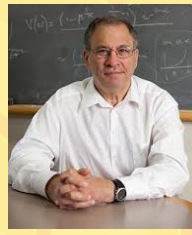
🐝 DEPARTMENT BUZZ

Professors Yulij Ilyashenko (L) and Robert Strichartz (R) have been named 2017 AMS Fellows.

Simon A. Levin was awarded the National Medal of Science at a White House ceremony in May. Levin started his career in the department of mathematics at Cornell University in 1965.
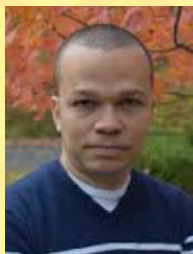
Princeton University, Brian Wilson (2011)

Christopher Ré '01 was named a 2015 MacArthur Fellow for his work on deomocratizing big data analytics.

Fernando Codá Marques received his PhD in mathematics from Cornell University in August 2003 under the late José Escobar. Marques was named the 2016 AMS Oswald Veblen Prize winner. He delivered the Evans Lectures at Cornell in November.

Thomas Church '06 (L) and Matthew Hirn '04 (R) were awarded 2016 Alfred P. Sloan Research Fellowships for their outstanding research.

Professor Tara Holm presented an AMS-MAA joint invited address at MAA MathFest 2016. Holm's talk title was, "Understanding Symplectic Geometry and Topology through Polytopes and Lattice Points."

Summer Program For Undergraduate Research (SPUR)

worked in the heat equation group. They studied differential Harnack inequalities for the Newell-Whitehead equation and the Burger's equation. The are writing two papers according to those results.

The project "Topological methods in discrete geometry" focused on the study of intersection patterns of convex sets and their continuous relaxations as well as problems of fair division.

Ryan Chen, Frederick Huang '17, Maxwell Polevy, David Stoner, and Zoe Wellner '18 proved higher-dimensional and convex-geometric analogs of Conway's thrackle conjecture from graph theory. Megumi

Asada, Ryan Chen, and Ling Hei Tsang established new lower bounds for a conjecture of Reay on pairwise intersections of convex hulls of finite point sets in Euclidean space, and showed that a constrained "colorful" weakening of the conjecture holds. The results of these two projects were written up in a joint paper that has been submitted for publication.

Megumi Asada and David Stoner investigated necklace splittings and extended Noga Alon's fundamental result in certain cases via hyperplane mass partitions. Vivek Pisharody '18, Maxwell Polevy, Ling Hei Tsang, and Zoe Wellner found strengthenings of the existence result of optimal envy-free division of goods and Sperner-type results that are of interest in economics. The two groups are currently in the process of writing up their results in a joint manuscript.

The results of this project have been presented at the Young Mathematicians Conference, the Applied Algebraic Topology Research Network online seminar, and at Women in Mathematics in New England; they will also be presented at the Joint Math Meetings 2017 in Atlanta.

The SPUR program will continue in summer 2017.

DEPARTMENT BUZZ

H.C. Wang Assistant Professor Florian Frick was awarded the Richard Rado Prize for his 2015 BMS PhD thesis entitled "Combinatorial Restrictions on Cell Complexes".

PhD candidate, Kelsey Houston-Edwards, was named AMS-AAAS Mass Media Fellow and spent the summer working at NOVA.

Kelsey is currently hosting a PBS math show online called "PBS Infinite Series." This is a YouTube show that tackles the mysteries and the joy of mathematics. "PBS Infinite Series" uploads a new episode every Thursday.

Drew Zemke won the Gitner Prize for Teaching Assistants. The prize is awarded to teaching assistants who have demonstrated their excellence in and devotion to undergraduate teaching.

Malabika Pramanik, University of British Columbia Associate Professor and former Cornell University Michler Fellow is the recipient of the 2016 Krieger-Nelson Prize for her outstanding research contributions.
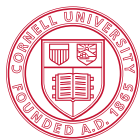
Giving Day 2016
Math received **21 gifts** totalling over **$6,000**

We are grateful for the generosity of our alumni, students, and faculty who contributed.

Thank you for your support!

GIVING DAY

MATHEMATICS DEPARTMENT ENDOWMENTS & GIFTS

We are grateful to alumni, friends, and family for their generosity in supporting our endowments or providing other gifts and donations to the department.

The **Ruth I. Michler Memorial Prize,** established by Gerhard and Waltraud Michler of Essen, Germany, in memory of their daughter, provides funding for the Ruth I. Michler Memorial Prize of the Association for Women in Mathematics. The awardee spends a semester here without teaching obligations.

The **Chelluri Lecture Series** was established by Raju Chelluri's parents in his memory. Funds are used to invite distinguished mathematicians to give annual lectures.

The **Michael D. Morley Senior Prize in Mathematics** is presented annually to an Ithaca High School student who has excelled in mathematics and who has demonstrated originality and innovative power in mathematics.

Teaching Awards for Graduate Students and faculty were created in 2001. Prizes are awarded to graduate students.

The **Colloquium Endowment Fund** was instituted to invite distinguished scientists to speak at the Oliver Club seminars. (See www.math.cornell.edu/~oliver/.)

The **Eleanor Norton York Endowment** was established in honor of Eleanor Norton York to recognize outstanding graduate students in both Astronomy and Mathematics.

The **Faculty Book Endowment** is dedicated to providing the Cornell community with access to one of the world's finest collections of mathematics books and publications.

The **Israel Berstein Memorial Fund** was established in honor of Israel Berstein, a professor in this department from 1962-1991. The memorial fund is intended to help young mathematicians in the field of topology.

The **Logic Endowment** was started with a generous gift from a former Cornell undergraduate to support promising logic students.

The **Robert John Battig Endowment** was established by his parents after his untimely death. Robert was awarded a January 1998 Ph.D. in mathematics. The fund provides an annual prize to an outstanding continuing graduate student in mathematics at Cornell.

If you would like to contribute, please make your check payable to Cornell University, indicate the endowment, or that it is a gift in support of Mathematics, and send it to:

Department of Mathematics Endowments & Gifts
310 Malott Hall, Cornell University
Ithaca, NY 14853-4201

Gifts can also be made online at
www.giving.cornell.edu