

# MATH MATTERS

DEPARTMENT OF MATHEMATICS CORNELL UNIVERSITY ITHACA NY DECEMBER 2014

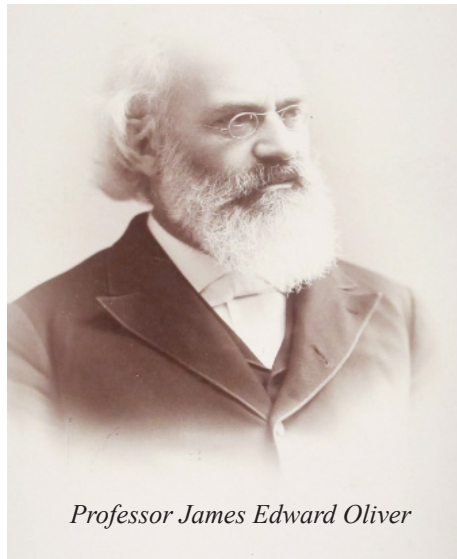
## LETTER FROM THE CHAIR, LAURENT SALOFF-COSTE

*This edition of Math Matters is dedicated to the memory of our colleague and friend, Eugene Dynkin, who passed away on November 14, 2014 at the age of 90 in Ithaca, NY.*

For almost 150 years, Cornell mathematicians have contributed to the development and growth of the outstanding institution they proudly serve. Embracing the revolutionary elective system promoted by our first president, A. D. White, the first two department Chairs, Evan Wilhelm Evans (serving from the opening in 1868 to his death in 1874) and James Oliver (the longest serving department Chair from 1874 to his death in 1895) transformed the mathematics undergraduate curriculum at Cornell and beyond and built a research department supporting faculty scholarship and an ambitious graduate program. In his autobiography, A. D. White noted with pride (and some surprise) that Evans and Oliver both strongly supported the introduction of modern English literature to the undergraduate curriculum, one of many revolutionary ideas that were introduced to, and flourished at

Cornell.

Starting with us this year



*Professor James Edward Oliver*

are Assistant Professors Karola Meszaros (combinatorics), Charlie Smart (partial differential equations), and Nicolas Templier (number theory). They are joined by Associate Professor Jason Manning, a topologist, and Professor Marcelo Aguiar who is an algebraist. We are also very happy to welcome former Engineering faculty Steve Strogatz and Tim Healey in their new

positions in the department as well as lecturer Meghan Anderson. The renewal of the faculty will continue at a rapid pace throughout the next decade.

Former department Chair Ken Brown, who joined Cornell in 1971 as an Assistant Professor, retired in June and is now Professor Emeritus. Betsy Collins is our new department manager, replacing Bill Gilligan who retired in July after many years of service at Cornell. Samantha Preston replaces Gayle Lippincott who retired as our accounts coordinator, and Michelle Mogil is our new computer consultant.

The gifts of individuals who have contributed to our endowed funds and our general gift fund allow us to sustain and enhance many key activities including working with local schools to enhance K-12 mathematics education, supporting research experiences for undergraduates and bringing research visitors to the department. Thank you all for your generosity.

The fifth Cornell Conference on Analysis, Probability, and Mathematical Physics on Fractals was held June 11 - 15, 2014. The conference was organized by Robert Strichartz (Cornell), Luke Rogers (University

## FRACTALS CONFERENCE

ROBERT STRICHARTZ

of Connecticut), former Cornell University postdoc, and Alexander Teplyaev (University of Connecticut), former Cornell University graduate student. The conference received support from the National Science Foundation.

There were 62 participants from outside Cornell, 35 lecturers, and two short courses. The purpose of the conference was to bring together mathematicians and physicists working in the area and

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also undergraduate and graduate students interested in learning about the area. The short courses were targeted to non-experts. Also notable was the fact that some of the lectures were presented by undergraduate and graduate students. Cornell has been running these conferences every three years. The original title was, "Analysis and Probability on Fractals," to underscore the idea

## FRACTALS CONFERENCE

that fractals are not being studied just for their own sake, but because there are interesting "differential equations" and random processes, where the underlying space is a fractal. We added "and Mathematical Physics" to the title because many physicists were joining in the work. An example of an important scientific problem that may be studied in the future using the methods now being developed

in this area is the following: sunlight hits the top of a cloud, how does the energy distribute through the cloud and what part gets reflected back in to space? The cloud should be modeled as a fractal, not as a pillow, and the standard methods of mathematical physics do not apply. For more information see the website: [www.math.cornell.edu/~fractals](http://www.math.cornell.edu/~fractals). The sixth conference is planned for 2017.

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## KAREN VOGTMANN RECEIVES HUMBOLDT RESEARCH AWARD



*Karen Vogtmann,  
Goldwin Smith Professor of Mathematics*

The Humboldt Research Award is an award given by the Alexander von Humboldt Foundation to academics whose fundamental discoveries, new theories, or insights have had a significant impact on their own discipline and who are expected to continue producing

cutting-edge achievements in the future.

Vogtmann was cited as an internationally renowned leader in geometric group theory who has made important contributions to our understanding of the automorphism groups of free groups.

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## UPDATES FROM THE MATH LIBRARY

BY JILL WILSON

**W**ithin this past year, the Report of the Committee to Consider the Future of Access to the Mathematical Literature at Cornell was accepted by the University Librarian and the Faculty Library Advisory Board (FLAB). As you may recall, the committee recommended that a graduate study room be built within the Math Library, and a multimedia room to be constructed in the current periodicals space. Both of these projects, while highly desired, have been put on hold due to financial constraints. If you have any questions or concerns, please contact Steven Rockey, Director of Engineering, Math and Physical Sciences Libraries (swr1).

The Math Library, in conjunction with the Engineering Library and Physical Sciences Library, continues to offer outreach opportunities to graduate students, faculty and staff.

This fall semester, a data management workshop was held to teach students the basics of organizing research and data. Another popular workshop offered for the first time was LaTeX, which taught attendees everything from installing TeX to using the program to create beautiful documents.

Finally, the libraries brought its bi-annual Coffee Hour Book Talk series back to the Math Department, featuring Mircea Pitici and his latest edition of *The Best Writings on Mathematics*.

For more information about upcoming workshops, instruction and other events, keep an eye out on the allmath e-list, or follow the libraries on Facebook (EMPSLibraries) and Twitter (@EMPS\_Libraries)

Steve Rockey will retire from his position of Director of EMPSL but will remain part-time starting January 1, 2015 as Mathematics Librarian. He is looking forward to fully devoting his time and energy to the Math Library. Erla Heyns, the Director of the Vet Library, will become the coordinator for the Engineering, Math, and Physical Sciences cluster starting January 1. If you find yourself in the library, feel free to stop by to say hello and ask us any questions!



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# CONFERENCE CELEBRATES LEGACY OF BILL THURSTON

BY KATHRYN LINDSEY, POSTDOCTORAL ASSOCIATE, UNIVERSITY OF CHICAGO



Attendees of the, “What’s Next? The mathematical legacy of Bill Thurston Conference,”

Credit: Anne Thomas, University of Glasgow

This past June, over 250 mathematicians came to Cornell to participate in a one-week conference celebrating the mathematical legacy of Bill Thurston. The diversity of the conference participants – from Fields medalists to beginning graduate students – is a testament to the extent to which Thurston’s paradigm-shifting discoveries both revolutionized and continue



Professor William P. Thurston, 2006

to influence numerous fields of mathematics.

Bill Thurston served as Jacob Gould Schurman Professor of Mathematics and Computer Science at Cornell University from 2003 until his death from cancer in 2012. Widely recognized as one of the most innovative and insightful mathematicians of the past century, Thurston garnered numerous

honors over the course of his mathematical career, including the Fields Medal, the Oswald Veblen Prize in Geometry and the Leroy P. Steele Prize.

The structure of the conference reflected Thurston’s commitment to promoting both top-level research mathematics and novel ways to communicate and visualize mathematics. Thurston viewed math as a rich intellectual playground that welcomes all-comers, and, throughout his career, he sought creative ways to share his enjoyment of this rich world with others. Research talks were given by Ian Agol (Berkeley), Mladen Bestvina (Utah), Michel Boileau (Toulouse), Danny Calegari (Chicago), Benson Farb (Chicago), Etienne Ghys (CNRS), Rick Kenyon (Brown), François Labourie (Paris), Tan Lei (Angers), Vlad Markovic (Caltech), Dusa McDuff (Barnard), Curtis McMullen (Harvard), John Milnor (Stony Brook), Yair Minsky (Yale), Yi Ni (CIT), Alan Reid (Texas), Mitsuhiro Shishikura (Kyoto), Anna Wienhard (Heidelberg), Dani Wise (McGill) and Anton Zorich (Rennes). Non-traditional conference activities

included a presentation by Kelly Delp (Ithaca College) on her work with Thurston on modeling surfaces, an introduction to the SnapPy program by Nathan Dunfield (UIUC), a demonstration by Richard Schwartz (Brown) of his software for geometric visualization, a public lecture on “The Shape of Space” by Jeff Weeks, an evening “Film Festival” organized by John Smillie and Kathryn Lindsey, a panel discussion on communicating mathematics featuring Benson Farb, Etienne Ghys, Curtis McMullen, Steve Strogatz and Jeff Weeks, and an exhibit of mathematical art curated by Dylan Thurston (Indiana) and Sarah Koch (Michigan). At a banquet at the Statler Hotel, family members and various colleagues spoke about Thurston and how he touched their lives.

Financial support for the conference was provided by the National Science Foundation, the GEAR Network, and Cornell University. Karen Vogtmann, David Gabai, John Hubbard, John Smillie and Dylan Thurston comprised the scientific committee. The local

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organizing committee included Hyungrul Baik, Kelly Delp, Martin Kassabov, Allen Hatcher, Sarah Koch, Kathryn Lindsey, Jason Manning, Justin Moore, and Tim

Riley.

The title of this conference asks a question: “The Mathematical Legacy of Bill Thurston: What’s Next?” What is clear, as we

continue to discover “what’s next,” is that Bill Thurston’s influence will continue to shape mathematics and the mathematical community for a long time to come.

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## REFLECTIONS BY THE 2013-2014 ITHACA HIGH SCHOOL SENIOR SEMINAR PARTICIPANTS

### QUOTES COLLECTED BY SEVERIN DRIX AND MARY ANN HUNTLEY

*Senior Seminar at Ithaca High School is a course, taught by math and applied math graduate students, on content that students typically do not see until college. Its goal is to increase the number of high-school students who major in mathematics in college.*

...there’s a different kind of ease I feel when I am taught by someone closer to my age.

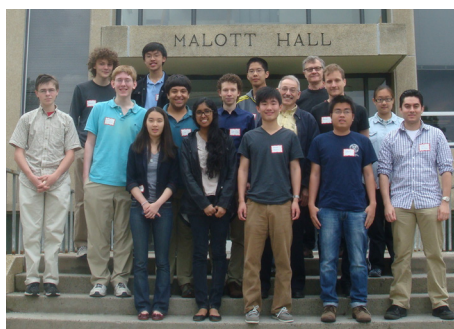
- **Gayathri Ganesan**

Math Seminar has shown me the vital importance of collaboration in mathematics. Who says insight has to be autonomous? After all, together we learn some pretty wonderful things.- **Tracy Lai**

I felt it was an amazing opportunity and it was great to have the freedom to learn at my own pace. - **Rex Lei**

There was a strong focus on working on challenges, and even if we didn’t always succeed, we always learned.- **Jensen Lo**

Math Seminar was a great class for me to have taken, and I am very glad that it was offered this year. - **Devon Loehr**



2014 - Ithaca High School Senior Seminar Participants

**First Row:** Tracy Lai, Gayathri Ganesan, Jesse Yuan, Hung Tran, Sergio Da Silva **Second Row:** Samuel Stromswold, Devon Loehr, Aryeh Zax, Sam Saloff-Coste, Severin Drix, Balazs Elek, Dekang Meng **Third Row:** Connor Simpson, Jensen Lo, Rex Lei, and Laurent Saloff-Coste

... I learned a lot from seminar both about concepts and what math really is. - **Dekang Meng**

It truly opens your mind to what is possible with math, and gives a kind of satisfaction that a normal class simply does not grant... - **Connor Simpson**

It has...shown me that math is a huge machine full of parts that look completely different but are still related. Most importantly, it made me want to explore this machine. - **Sam Saloff-Coste**

I particularly enjoyed the independent project we worked on at the end of the year... - **Samuel Stromswold**

Math Seminar...challenged me far more than any mathematics course I have taken in the past...I am very grateful for this opportunity, and I plan to participate in Math Seminar next year as well. - **Jesse Yuan**

I have fond memories of afternoons spent sitting in coffee shops with our mentors and staring off into the distance the moment that everything clicked in my mind. - **Aryeh Zax**

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## SATURDAY WORKSHOPS FOR MATH TEACHERS

BY MARY ANN HUNTLEY

Each academic year the Mathematics Department hosts four full-day workshops for local secondary mathematics teachers. During the 2013-2014 academic year, four mathematicians within the Department—Quincy Loney,



Karola Meszaros, Justin Moore, and Mike Stillman—gave presentations at these workshops. In the photo shown here, Justin Moore is explaining geometric rules that govern the shape of soap film.

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# STEVEN STROGATZ'S RULES OF ENGAGEMENT

CONTRIBUTING AUTHOR, LINDA B. GLASER

Steven Strogatz, the Jacob Gould Schurman Professor of Applied Mathematics, continues to make



*Professor Steven Strogatz  
Credit: University Photography*

headlines.

Accomplishments from 2014 include winning the AAAS Public Engagement with Science Award and the Euler Book Prize.

The AAAS Public Engagement with Science Award is awarded by The American Association for the Advancement of Science (AAAS) and is given to recipients that have, “exceptional commitment to and passion for conveying the beauty and importance of mathematics to the general public.” In 1995, Cornell astronomer Carl Sagan won the same award.

The Euler Book Prize was awarded to Strogatz for his book, *The Joy of  $x$* . This prize, “is intended to recognize authors of exceptionally well written books with a positive impact on the public’s view of mathematics and to encourage the writing of such books.”

This year Professor Strogatz has been interviewed on NPR’s “Science Friday” twice, and once on Radiolab’s, “For the Love of Numbers.”

Over the summer, Strogatz

taught an inquiry based learning workshop titled, “Discovering the Art of Mathematics; Mathematical Inquiry in the Liberal Arts (DAoM),” an experience for non-math majors, hoping to make math a creative and enjoyable experience where math is made, not just memorized.

Those inquiry learning based workshops have blossomed into Strogatz’s new Arts and Sciences course, “Mathematical Explorations.” The course fulfills the math distribution requirement, and those that experienced mathematical anxiety in the past are eager to learn with Strogatz.

The class is based on an engaged learning approach called inquiry-based learning, developed at Westfield (Massachusetts) State University. Before beginning his new class, Strogatz, in collaboration with Cornell’s Center for Teaching Excellence, arranged for Westfield instructors to do a workshop at Cornell, to which Cornell and Ithaca College faculty from math and engineering fields were invited; 51 professors attended.

Because his class is not a prerequisite for a higher math course, Strogatz aims for students to have “genuine math experiences,” rather than to master specific formulas. He uses hands-on activities extensively – like teaching symmetry through mirror dances -- and constantly challenges the students to think things through for themselves.

For English major Megan Flynn ’15, the class has made concepts

she’d memorized in high school but didn’t understand “present in real life. Last week we used Cheez-Its to explain squares; seeing something as regular as Cheez-Its was weirdly enlightening, and that happens every class.”

At the end of class, Strogatz invited the students to ponder why there are 180 degrees in a straight angle. Is that something humanity discovered? Or invented? “The numbers are arbitrary but the ideas behind them aren’t,” responded Rush Imhotep ’15, Africana studies. “It’s like the human language: You make words to express them, but the expressions are real.” The class applauded.

The accolades continue. Strogatz was honored at the National Museum of Mathematics “Chaos Ball” on October 14, 2014. At the annual gala in New York City, Strogatz and Alan Alda were recognized for bringing math to the public while increasing



*Strogatz’s, Chaos Ball Award is displayed on the third floor of Malott Hall.*

understanding and appreciation.

The Cornell Chronicle recently quoted Strogatz as saying, “It means the world to me that my colleagues appreciate my attempt to help the wider public see what our subject is all about and why we love it so much.”

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# RESEARCH EXPERIENCE FOR UNDERGRADUATES

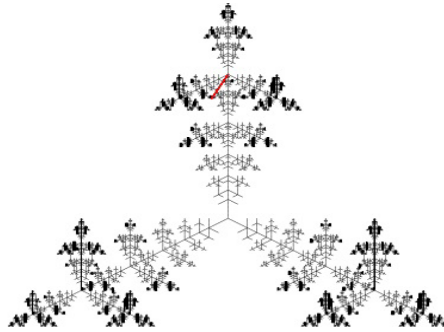
BY ROBERT STRICHARTZ (DIRECTOR)

The REU program has been operating since 1994 with support from the National Science Foundation. During the summer of 2014, 20 students were involved in research in three areas: Analysis on Fractals, directed by Robert Strichartz with assistance from graduate student Baris Ugurcan; Nonlinear Heat Equations, directed by Xiaodong Cao, with graduate student Melanie Stam, and Graphs, Chip-firing Games and Algebraic Geometry directed by Farbod Shokrieh with graduate student Mathav Murugan.

The students in the “Analysis on Fractals” group worked on five projects. Jonathan Fox (Cornell) and Helcio Martinha Junior (visiting Cornell from Brazil) studied the spectrum of the Laplacian on Magic carpet fractals (MCs). Different MCs are created out of the classical Sierpinski carpet (SC) by identifying pairs of boundary edges. If you start with a square and identify the horizontal and vertical edges preserving orientation you obtain a torus (T). But if one pair is identified with reversed orientation you obtain a Klein bottle (K) and if both pairs have orientation reversed you obtain a projective plane (P). There are infinite sequences of pair identifications in passing from SC to MC, and so you can obtain infinitely many distinct MCs by choosing a sequence of symbols T, K, or P. The goal of the project is to understand how the choice of the sequence manifests itself in the spectrum of the Laplacian.

Shuyi Weng (Bard College)

studied a new family of fractals called tri-arrows, defined by four contractive similarities in the plane with fixed points at the vertices and center of an equilateral triangle. Here is an example:



The contraction ratio  $\alpha$  is the same for the three vertices, with a different ratio  $\beta$  at the center, producing a two-parameter family of tri-arrows  $K(\alpha, \beta)$ . The main question we considered is identifying the “Mandelbrot set”  $M$  of parameters corresponding to connected fractals  $K(\alpha, \beta)$ , and among these the parameters  $M_f$  for which  $K(\alpha, \beta)$  is finitely ramified (self-similar cells intersect at only a finite number of points.) We believe  $M_f$  is more or less equal to the boundary of  $M$ .

Jens Malmquist (Berkeley) studied numerical approximations to integrals for functions on the Sierpinski gasket (SG), and obtained interesting error estimates involving the smoothness of the function and the geometry of the set of evaluation points, similar to the classical Koksma-Hlawka estimates. Iancu Dima (Ithaca College) and Rachel Popp (Colorado State) constructed a surface in 3-space with fractal curvature. The surface is a limit of convex polyhedra

and is flat everywhere except on pieces that resemble SG. They also computed the spectrum of the Laplacian on this surface.

Samantha Fairchild (Houghton College) and Rafael Setra (University of Maryland) studied sandpile models on fractal graphs, continuing work that was begun in the 2013 REU program. They were able to prove sharp estimates for the rate of diffusion of the sandpile, and were able to find conjectured periodicity properties in many cases. The website [www.math.cornell.edu/~skayf](http://www.math.cornell.edu/~skayf) shows many of these results.

The “heat equation” group consisted of Derek Booth (Harvard), Jack Burkart (Notre Dame), Nicholas McCleerey (Rice) and Jack Sempliner (Chicago.)

We focused on three nonlinear diffusion-reaction equations, the heat equation with power law non-linearity, the Newell-Whitehead equation, and Burger’s equation. We proved a number of interesting Harnack estimates for positive solution of all three equations.

The “Graphs, Chip-Firing Games, and Algebraic Geometry” group was comprised of eight students, four students came from Cornell. They worked on four different projects related to the connections between (elementary) combinatorics and (deep) algebraic geometry arising from topical geometry provides us with numerous new combinatorial results and conjectures, as well as novel techniques to revisit algebro-geometric

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questions. Chip-firing games (also known as sandpiles) are games played on graphs, and were central to all these projects.

Avery St. Dizier (Louisiana State University) and Esco He (Cornell University) studied the generalization of certain aspects of chip-firing games on graphs to the more general setting of regular matroids. Specifically they studied the generalization of Jacobian groups for regular matroids. They constructed a family of bijections between Jacobians and the set of bases of matroids. The new family of bijections is novel even when we revisit the special case of finite graphs.

Iain Carmichael (Cornell University, now at UNC Chapel Hill), Giang Nguyen (Cornell University), and Jaclyn Porfilio

(Williams College) studied various algebraic questions that arise from chip-firing. Specifically they studied the generating function of these numerical invariant (sometimes called Poincaré polynomial). They found a formula that bypasses all the complicated algebraic computations, and states the Poincaré polynomial in terms of the Möbius function on the lattice of flats of the associated matroid.

Christopher Eur (Harvard University) and Mark Greenfield (California Institute of Technology) studied the geometry of "special divisors" on metric graphs (tropical curves). The geometry of special divisors on algebraic curves has been the subject of extensive study, and it relates to some of the deepest questions in classical algebraic geometry. Chris and Mark worked

out several excellent examples and came up with various nice conjectures as well as new proofs of known theorems. They continue collaborating with Farbod on their project.

Louis Brown (Cornell University) studied a very intriguing question: the set of spanning trees are in bijection with a finite group. Is it true that the set of spanning trees is indeed a torsor over that group? There are two recent approaches to this problem. Both approaches give an affirmative answer to this question in the case of planar graphs, and these two seemingly different approaches coincide in the case of planar graphs. Louis's work was on understanding each approach the relation between the two.

We have applied to the NSF for renewed funding starting in summer 2015.

## MATTHEW FARRELL WINS TRJITZINSKY AWARD



Cornell University mathematics major, Matthew Farrell '16, has been awarded the Waldemar J. Trjitzinsky Memorial Award. This is an impressive honor for Matthew as this is one of the few scholarships awarded by the AMS each year.

## CORNELL UNIVERSITY TURNS 150!



Cornell University's sesquicentennial website celebrates 150 years of mathematics.

You should check it out!

<http://as.cornell.edu/150/math.cfm>

## MATH MAJORS GRADUATING WITH HONORS - 2014

### Summa Cum Laude

Walter Cai  
Benjamin Fayyazuddin-Ljungberg  
Eric Primozić

### Magna Cum Laude

Elliot Cartee  
Sean Li  
Jia Liu  
Hunter Swan

### Cum Laude

Iain Carmichael  
William Feldhusen  
Robert McGehee  
Shu Wang  
Xuan Zhang

### Kieval Prize

Benjamin Fayyazuddin-Ljungberg  
Eric Primozić

## DOCTORAL DEGREES AWARDED 2014

|                        |                         |
|------------------------|-------------------------|
| Margarita Amchislavska | Andrew Marshall         |
| Hyungryul Baik         | Robyn Miller            |
| Adam Bjorndahl         | Diana Ojeda Aristizabal |
| Youssef El Fassy Fihry | Hung Tran               |
| Chi-Kwong Fok          | Baris Ugurcan           |
| Kathryn Lindsey        |                         |



**Cornell University**  
**Department of Mathematics**

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## 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/](http://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  
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Gifts can also be made online at  
[www.giving.cornell.edu](http://www.giving.cornell.edu)