
MATH MATTERS

DEPARTMENT OF MATHEMATICS CORNELL UNIVERSITY ITHACA NY DECEMBER 2012

REMEMBERING WILLIAM THURSTON

BY JOHN SMILLIE

Our colleague, William Thurston, died on August 21, 2012. He died peacefully in Rochester surrounded by family. He died from melanoma, which he had been battling for a year; he was 65 years old.

Thurston had an informal manner that made it impossible to think of him as anything other than “Bill.” Bill had been at Cornell since 2003, but many members of the department have known him much longer. Karen Vogtmann met Bill when they overlapped at graduate school at Berkeley. John Hubbard knew him for many years and was greatly influenced by Bill both specifically in his choice of topics to work on and generally in terms of his approach to mathematics. Allan Hatcher was an early collaborator of Bill’s, while Tim Riley and Kathryn Lindsey, a graduate student, are more recent collaborators.

There are a number of personal reminiscences and nice discussions of Bill’s career on the departmental

website. One can follow the links contained there for an overview of his life and career. In this note, however, I would like to focus on some of my own interactions with Bill over the years.



Bill was a member of the charter class of students to attend New College, a small experimental liberal arts college in Sarasota,

Florida. New College was started in the 1960’s with the idea that it was much easier for a college to maintain a high reputation than for it to improve a middling reputation. Thus they made a special effort to get the best possible students for the charter class in 1964. One way they did this was by being generous with financial support. According to college legend, the charter class was the “best class that money could buy.” Bill’s first wife, Rachel Findley, was also a member of the charter class. They graduated in 1967 and both went on to become mathematics graduate students at Berkeley.

I attended New College in 1971. New College was small, but it had a good library and a good math department. I read a lot of mathematics books while I was there and that was my first introduction to Bill, seeing his name on the library cards of many of these books. One

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LETTER FROM THE CHAIR, LAURENT SALOFF-COSTE

As I start my second term as Chair, I would like to thank the administrative staff of the department for their dedicated service: Your work is essential to allow the department to fulfill its mission. I also thank the faculty for the trust they have invested on my ability to serve the department. The last few years were challenging but

our department has a long tradition of strength that will help us tremendously as we go through a key renewal period. I would like to thank all the individuals who have contributed to our endowed funds and our general gift fund. Your generosity means a lot to us and has a significant impact on the scientific life of the department. It allows us

to sustain and enhance many key activities including working with local schools to contribute to K-12 education, sending undergraduates to conferences where they present their work on research projects, and helping attract and retain our superb faculty. One of the priorities

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REMEMBERING WILLIAM THURSTON

By JOHN SMILLIE

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of my New College professors, Roger Renne, had overlapped with Bill. During the summer of 1972, I went to Berkeley for an NSF summer math program for high school students with another professor, David Gay. David was hoping I would pick up something from interacting with the program, but my assignment from Roger was more specific: to meet Bill.

At Berkeley I introduced myself to Bill and he was very friendly. We talked about math and about fundamental groups of surfaces. When the conversation lagged he asked me how many groups there were of order 15. During that summer I sat in on a summer school course on geometry that Bill was teaching using Chern's mimeographed "Notes on Differential Geometry." Bill was clearly having a good time teaching this course and it was a fun course to take.

During Bill's time at Berkeley he worked on the theory of foliations. At this point Bill seemed to be getting ideas not from the books he was reading but from other sources. His thesis is available at the Berkeley math library and it has an interesting reference that seems appropriate. At one point a result is credited to "personal communications with myself."

The NSF summer program would have a weekly talk by a member of the mathematics department. Bill gave one of these talks in which he discussed the Poincare-Hopf theorem counting indices of vector fields on surfaces. He gave an

inspiring talk in which he explained the proof in a way that a high school student could follow. I remember a conversation at lunch after his talk where he mentioned that there were some interesting questions that mathematicians didn't think about. I asked for an example and he mentioned the idea of surfaces with curvature along "seams." (Years later when Bill was at Cornell he worked with Kelly Delp to create models of surfaces by gluing flat pieces along wiggly seams which give the impression of being surfaces of constant curvature.)

Bill had not been a superstar as an undergraduate (according to Roger Renne it was Rachel who was viewed as the rising star), but in graduate school his work on foliations attracted wide attention. After Berkeley, Bill went to the Institute for Advanced Study for a year as an assistant to John Milnor. Following that, he took an Assistant Professor position at MIT. During this period Bill was transforming the theory of foliations. He was later awarded the Veblen prize for this work. After one year at MIT he was offered a full professorship at Princeton. Apparently, it took some work for the Princeton math department to convince their dean that such an offer was justified. The turning point occurred when the dean admitted that if someone older had accomplished what Bill had accomplished, it would clearly be worthy of a full professorship.

After New College, I went to the University of Chicago as a graduate student. During that time I remember attending a conference in St. Louis on foliations where Bill

gave a talk on Gromov's immersion theorem, explaining that the principle was the same as the operating principle for television. It was a talk unlike any other math talk I had heard.

After I graduated from Chicago in 1977, Bill offered me a lectureship at Princeton. At Princeton, Bill shifted his focus from the theory of foliations to the theory of hyperbolic 3-manifolds with side projects in many other areas. I had an opportunity to participate in Bill's legendary topology course. Bill's version of topology was unlike anything I had seen at Chicago. I was amazed at the way Bill drew ideas from a variety of fields including geometry, analysis and dynamical systems to attack problems in topology. The notes for this course were copied and distributed in large mailings to mathematicians around the world. In 1997, the first three chapters of these notes were published as a book, which won the AMS Book Prize in 2005.

The talks in Bill's course were sometimes hard to understand, sometimes brilliant, but always new. One day when he had to stay home with a sick child he got a little undisturbed time to think. The next class he explained how his geometric theory of 3-manifolds together with ideas from differential geometry and the theory of discrete groups led to a proof of the hitherto unsolved "Smith conjecture." Bill won the Fields Medal for his work on foliations and 3-manifolds in 1982.

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LETTER FROM THE CHAIR

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of the department is to offer a more substantial postdoctoral program, in line with peer institutions. This will have a tremendous positive effect upon the entire spectrum of our activities from undergraduate education to graduate education and research.

Our strength is built upon the high demand for quality mathematics instruction generated by the needs of the different colleges and programs at Cornell. Our own upper level undergraduate program is more popular and stronger than ever. It serves a wide variety of students from a rather wide variety of majors. Our recent math major graduating classes are double those of a decade ago and there are strong indications that they will continue to grow.

Our graduate students are an integral part of the fabric of the department. Indeed, I believe that the quality of our graduate program

is one of the keys to our future success. I am happy to report we had a very successful year in recruiting new graduate students. Talented and dedicated graduate students play an important role in our ability to deliver high quality undergraduate education. They take part in the research activities of the faculty and

contribute to the scientific output of the department. Most importantly, the quality of our graduate program has a significant impact on our ability to attract and retain faculty.

I look forward to reporting on our progress in the next few Math Matters!



The Cornell student chapter of the Association for Women in Mathematics celebrated Pi Day on March 14th by sponsoring a pie-eating contest. Senior Lecturer Maria Terrell (left) emerged victorious, polishing off an entire sweet potato pie in 13 minutes. Lucien Clavier (right), a PhD student, works on a lemon meringue pie.

REMEMBERING WILLIAM THURSTON

By JOHN SMILLIE

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In 1991, Bill left Princeton to become the head of the Mathematical Sciences Research Institute. In 1996 he moved to UC Davis and in 2003 he moved to Cornell. It was a pleasure having him as a colleague. While at Cornell, Bill gave a course whose subject matter varied according to Bill's interests. I did not attend his course but I would get regular reports from graduate students who were attending.

I heard Bill's last mathematics lecture which he gave at Park City Math Institute in July of this year. Bill started by saying that because of advances in medicine he had had an extra year of life and he was grateful for it. His son Dylan, who is also a mathematician, was traveling with him. Since speaking was difficult for Bill and his voice was hard to understand, Dylan served as translator. Bill talked about his recent work on the dynamics of complex

polynomials of degree greater than two. He had been busy in his last year of life working on low dimensional dynamics and entropy.

Bill got a little frustrated at the slowness of the process of having everything translated. After an hour of speaking Dylan suggested that they should wind things up. Bill said, in a quiet voice, "Already?" As Dylan said in Bill's NYT obituary, "Math was always very fun for him."

UPDATES FROM THE MATH LIBRARY

BY JILL WILSON

The mathematics library continues to experience high digital collections usage as well as healthy circulation rates of print materials. The space itself attracts many students needing quiet study space, checking out reserves for math and physical sciences courses and seeking librarian's help with reference questions.

In addition to the growing robust collections, the library has increased outreach efforts to the mathematics department. Last December, the library hosted a book talk in the faculty lounge during the study period before finals. Mircea Pitici, editor of "The Best Writings on Mathematics" and PhD candidate in mathematics education at Cornell was the featured speaker. He gave a lively and informative talk about the process of collecting articles for his book as well as his career in mathematics. Refreshments were served and an autographed copy of the book was raffled off as a door prize to the 30 people in attendance.

In the spring, the library sponsored events for reunion weekend, including a showing of the film *Brilliant Madness* with popcorn and other refreshments. The film chronicles the life of mathematician, John Nash. (The 2001 Hollywood film, *A Beautiful Mind*, focused on Nash's life as well)

The library also organized unique book display for reunion attendees featuring some of the more eclectic collections of the library. On display were books on math puzzles and riddles that complimented the handout of math puzzles compiled for those who visited

the display. Also featured were fiction novels, Hollywood films and television DVDs featuring mathematical themes, and other categories such as "math and music" and "math and politics". In conjunction with the timely political theme, the library's current display for this fall are items featuring mathematics and its role in elections, voting and politics. Several of these popular DVD titles were purchased from a generous donation from a faculty member in the department.

In preparation for the fall semester, the librarians revised the popular LibGuide on the Mathematics Library. The guide is specifically tailored for library users in the mathematics departments and is well-liked by users for its easy to navigate interface for accessing mathematics library materials. It supplements the mathematics library website and includes additional information such as citation searching, resources on staying current in the field and guidelines for remaining academically ethical

when conducting research. This LibGuide served as the basis for an orientation session one of the math librarians taught to new graduate students in the department. The orientation session provided an overview of the library, demonstrations of key mathematics databases and information on how to contact a librarian for help. Several of the new graduate students attended along with one faculty member for the 45 minute session.

To end our semester, the Engineering Library will be featuring Steven Strogatz, the Jacob Gould Schurman Professor of Mathematics and Mechanical and Aerospace Engineering. As we look towards spring semester 2013, the math library plans to offer additional instruction sessions on the MathSciNet and Google Scholar databases. All our events and information continues to be disseminated through popular communication channels: our blog (blogs.cornell.edu/problemsolved), Facebook, Twitter and department listservs.

MATH PUZZLE NIGHTS

Anastasia Raymer, a Visiting Assistant Professor, organized a monthly puzzle session on the first Thursday of every month during the Spring 2012 semester. She and the Math Club provided middle and high school students with a fun, non-competitive, enthusiastic environment in which to explore mathematics.



Robert Barker/University Photography

Visiting professor Tasia Raymer explains a math puzzle to one of the local high school students during the Math Club Puzzle Night in Mallott Hall.

MATH AWARENESS MONTH

BY MARY ANN HUNTLEY



This year's theme for Math Awareness Month was "Mathematics, Statistics, and the Data Deluge." Consistent with this theme, Paul Velleman (Associate Professor, Department of Social Statistics, School of Industrial and Labor Relations) gave a public lecture on April 21, 2012 entitled, "Surfing the Data Deluge." Approximately 35 people attended the lecture, which was planned to coincide with the final workshop of the semester for local mathematics teachers.

Also, to celebrate Mathematics Awareness Month, the department partnered with Ithaca High School on its annual t-shirt design contest. Thirty-five students submitted designs and faculty at the high school voted for their favorites. The winning design was developed by IHS student Sofia Escobedo-Tejado.

An account of Professor Velleman's talk was published in the Cornell Chronicle and can be read online at:

www.news.cornell.edu/stories/April12/VellemanData.html

STROGATZ BOOK GIVES A 'GUIDED TOUR OF MATH'

BY MIKHAIL YAKHNIS OF THE CORNELL CHRONICLE

How many people should you date before settling down? How should you flip your mattress to get maximum wear? How does Google search the Internet? These seemingly unrelated questions and more are answered by Steven Strogatz, the Jacob Gould Schurman Professor of Applied Mathematics, in his new book, "The Joy of X: A Guided Tour of Math, From One to Infinity" (Houghton Mifflin Harcourt).

According to Strogatz, "The Joy of X" explains some of the most elegant ideas in math and shows their surprising connections in our daily lives. We'll see how Michael Jordan's dunks help explain the fundamentals of calculus. ... We'll spot sine waves in zebra stripes and find echoes of Euclid in the Declaration of Independence."

The book, a follow-up to his popular "Elements of Math" series

of columns for *The New York Times*, explores math in a way that is accessible to the general public. Strogatz says he wrote the book because there seemed to be demand for a book about math that approaches the subject in a way most people can understand. In the book, he explains how math relates to such seemingly dissimilar topics as literature, philosophy and law. "Math is everywhere if you know where to look," Strogatz says.

His research has often involved applying mathematics to explain real-world phenomena such as "the dynamics of the human sleep-wake cycle ... [or] biological oscillators, such as swarms of synchronously flashing fireflies," Strogatz says.

He is the author of a 1998 Nature paper on "small-world" networks (commonly referred to as the six degrees of separation), which was

the most cited paper on networks across any scientific discipline for the next decade. He "loves branching out into new areas, often with students taking the lead," Strogatz writes on his website.

The Cornell Store hosted a lecture and book signing by Strogatz; he also gave a lecture on "Math for the Masses" in November. His most recent series of columns for *The New York Times*, "Me, Myself and Math," ran Sept. 10 to Oct. 15.



RESEARCH EXPERIENCE FOR UNDERGRADUATES

BY ROBERT STRICHARTZ (DIRECTOR)

During the summer of 2012, 18 undergraduates from around the world came to Cornell to work on challenging and exciting research problems in our REU program. This program has been supported by the National Science Foundation since 1994. The students worked in three areas: Analysis on Fractals, directed by Robert Strichartz (program director) with assistance from graduate students Rob Kesler and Baris Ugurcan, Locally Maximally Dense Packings, directed by Robert Connelly with assistance from graduate student Zhexiu Tu, and The Heat Equation, directed by Xiaodong Cao with assistance from graduate student Hung Tran.

The students in the Analysis on Fractals group worked on 6 different projects. Renee Bell (Berkeley) and Ching Wei Ho (Chinese University of Hong Kong) studied energy measures on the Sierpinski gasket, and were able to prove a number of interesting theorems about them, including a characterization of exactly which energy measures are positive.

Jason Bello (UCLA) and Yiran Li (Cornell) computed the spectrum of the Laplacian on differential forms on the Sierpinski carpet and a new fractal called the Magic Carpet. The Magic Carpet is constructed from a square by a process of cutting and sewing that eliminates all boundary lines, and the fractal in the limit retains many of the properties of a closed surface.

Evan Greif (Harvard) and Daniel Kaplan (Northwestern) computed the spectrum of the Laplacian on the surface of a regular polyhedron

using the finite element method. The surface is flat at the edges, where two faces of the polyhedron come together, but has singularities at the vertices of the polyhedron. For the tetrahedron, all eigenfunctions of the Laplacian are given by trigonometric functions, but for the cube, the octahedron and the icosahedron only some of the eigenfunctions have this simple form. We are working on an entertaining paper for the American Mathematical Monthly.

Weilin Li (Cornell) studied boundary value problems for harmonic functions on half of a Sierpinski gasket. He will present a talk on his work at the AMS Annual Meeting in San Diego in January 2013.

Andrew Ma (Wisconsin) studied the spectrum of the Laplacian on thick carpets using the finite element method on squares with lots of deleted square holes.

Yehonatan Sella (Berkeley), who participated in the REU program in 2010, returned to continue his work on defining Laplacians on cubic Julia sets. The Julia sets are obtained from a circle by making an infinite number of identifications of points, with an explicit algorithm giving finite numbers of identified points in a sequence of steps. Yehonatan came up with an ingenious idea that we are calling the “method of procrastination;” in constructing approximate Laplacians from the identification information you will sometimes postpone using some information obtained in one step until a later step. It works! Procrastination allows you to construct Laplacians on some Julia sets that

can't be handled if you use all the information as soon as you get it.

The Packings and Tilings group worked on two projects. Jeff Shen (MIT), Alex Smith (Princeton), and Diwakar Raisingh (Cornell) studied packings by circles of the same radius of a flat torus that are “jammed.” They found jammed packings of the triangular torus of low density (the lowest known so far), and found important ways to calculate when the packing remains jammed when the torus varies, or when the packing is lifted to a covering space.

John Chiarelli (NYU) and Lisa Piccirillo (Boston College) studied the question: when can a polygon be tiled by squares and equilateral triangles with a prescribed edge length. They were able to completely answer the question for convex polygons, and found an algorithm to compute the number and orientation of the tiles in the general case.

The heat equation group, Ben Fayyazuddin Ljungberg (Cornell), Bowei Liu (Princeton), Ian Pendleton (Berkeley) and Abigail Ward (Chicago), focused on two nonlinear diffusion reaction equations. The first one is Fisher's equation; the second one contains a logarithmic growth term. They proved a number of interesting Harnack estimates for positive solutions of both nonlinear heat equations. As applications, they obtained bounds on gradient Ricci solitons and also Liouville-type theorem.

We look forward to another interesting and productive summer next year.

AMERICAN MATHEMATICAL SOCIETY FELLOWS

The Fellows of the American Mathematical Society program recognizes members who have made outstanding contributions to the creation, exposition, advancement, communication, and utilization of mathematics.

This year's inaugural class includes 20 people affiliated with Cornell, most of them from our department. It's wonderful to see that Cornell mathematics is so highly regarded.

The AMS published a book entitled, *Quasiconformal Mappings, Riemann Surfaces, and Teichmüller Spaces*. This volume contains the proceedings of the AMS Special Session on Quasiconformal Mappings, Riemann Surfaces, and Teichmüller Spaces, held in honor of Cornell Emeritus Professor Clifford J. Earle, from October 2-3, 2010, in Syracuse, New York.

CONGRATULATIONS GRADUATES

The class of 2012 had 76 graduates, many with honors.

The *Harry S. Kieval Prize* is given annually to outstanding undergraduate majors.

KIEVAL WINNERS:

Sudesh Kalyanswamy
Benjamin Philip Nachman
Thomas William Rudelius

SUMMA CUM LAUDE:

Weiyang Chen
Eli Joseph Fox
Sudesh Kalyanswamy
Benjamin Philip Nachman
Thomas William Rudelius

MAGNA CUM LAUDE:

Boris Burkov
Liang Ze Wong
Myron Zhang

CUM LAUDE:

Ethan Scott Dunn
Scott Michael Flanz
Derek Michael Lougee
Joseph David Mansky
Katherine Ellen McCulloh
Phan Nguyen
Theodore Ni
Anna M. Papush
Samuel Brewer Roland
Ivana Thng
Heyu Xiong

Keep in Touch! mathmail@cornell.edu

THE JOINT SYMPLECTIC SEMINAR

BY REYER SJAMAAR

Professor Tara Holm and I began a biannual seminar on symplectic geometry in Fall 2010. The event alternates between the mathematics departments of Cornell University in the Fall and the Pennsylvania State University in the Spring. Our co-organizers at Penn State are professors Nigel Higson, Mathieu Stiénon, Aïssa Wade, and Ping Xu. Twice a year, together with our postdocs and graduate students, we meet for a day (usually a Saturday) of talks by local and guest speakers. One or two advanced graduate students are always included among the speakers to give them an opportunity to publicize their thesis work.

Our seminar is halfway in duration between a regular research

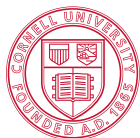
seminar and a short conference. It is relatively quick and easy to organize and serves as a brief but pleasant punctuation of the mid-semester routine. Yet, Tara and I are finding it an efficient way to strengthen our ties with a valued group of colleagues at a nearby (but not exactly next-door) major research university.

The topic of the event is symplectic geometry, which is a branch of differential geometry related to classical and quantum mechanics. One research problem that came up at our meetings is the symplectic packing problem, which is akin to Kepler's problem on the densest packing of balls in Euclidean space, but uses completely different

methods and has completely different answers. Cornell graduate student Milena Pabiniak (now a post-doctoral associate at the University of Toronto) explained her progress on the symplectic packing problem at our Penn State meeting in Spring 2012. You can get an impression of this and other topics that we have covered by visiting our website:

www.math.cornell.edu/~symplectic

We are pleased to acknowledge funding for the Cornell half of the seminar provided by the Department of Mathematics out of an annual research allocation made by the College of Arts and Sciences.



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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/.)

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:

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