For ALUMNI and FRIENDS

Volume 9 2016

Proof Reader

From the School of Mathematics, College of Sciences @ Georgia Tech

Georgia Tech

Notes from the Chair

The School of Mathematics has had many reasons to celebrate these past twelve months. We began the academic year with the School winning the campus-wide 2015 Diversity Champion Award. Four tenure-track faculty members earned NSF CAREER awards, setting an all-time record for the School for the number of CAREERs awarded in a single year, and very likely for any mathematics department in the nation. Recent hire Zaher Hani won the Sloan research fellowship and our new hire, Lutz Warnke, won the 2016 Dénes König Prize in discrete mathematics. These are just a few in a slew of Institute- and College-level awards for research, teaching and outreach won by various members of the School.

Professor Robin Thomas won Georgia Tech's highest faculty honor, the Class of 1934 Distinguished Professor Award, for his impactful contributions to research, mentoring and teaching, as well as service to the Institute as Director of the internationally recognized interdisciplinary PhD program in Algorithms, Combinatorics & Optimization. In addition to Robin's former students and postdocs, several world-renowned senior researchers provided letters expressing their endorsement in strong support of the successful nomination.

Professor Tom Morley won the CETL Faculty Award for Academic Outreach, receiving long-overdue recognition and praise for creating, teaching and tirelessly managing the high school Distance Calculus Program for a decade. Professor Ronghua Pan won the CETL Geoffrey G. Eichholz Faculty Teaching Award for his continued dedication to effective teaching of classes with large enrollments. Most impressively, over the past decade, Ronghua has taught more than twenty courses with enrollments of over one hundred students.

Late spring and early summer of 2016 saw breakthrough contributions by our discrete mathematics colleagues, Professors Ernie Croot and Xingxing Yu, on independent fronts with their collaborators.

Ernie, together with Professors Vsevolod Lev (from the University of Haifa, Israel) and Péter Pál Pach (from the Budapest University of Technology and Economics), proved ground-breaking results related to a notorious open problem concerning the largest size of subsets of numbers (elements of $\mathbf{Z}_4^n$, to be precise) that do not contain a three-term arithmetic progression. This remarkable work created quite a sensation in the world of additive combinatorics, with Fields medalists Tim Gowers and Terry Tao, among others, blogging about it.

Xingxing and his graduate students, Yan Wang and Dawei He, solved a forty-year-old conjecture, which was hypothesized independently by Paul Seymour (1977) and Alexander Kelmans (1979), concerning the characterization of 5-connected non-planar graphs. This outstanding achievement deservedly found its way to the research highlights website of the National Science Foundation.

Our postdoc program has steadily grown over the past few years, supported by various state and federal sources of funding; the School has taken the appropriate steps to initiate training and mentoring, as well as evaluating the progress and the well-being of this vital group. See page 40 for an overview of the program written by Professor Michael Lacey, Chair of the postdoc committee.

On the educational front, the Calculus Revamp has received much praise from across campus. Challenges remain, however, in part due to the spike in freshman enrollments in Fall 2015. These challenges include an insufficient number of large classrooms with suitable space to incorporate active learning and other modern teaching methodologies, and a lack of instructors to facilitate smaller class sizes.

Our recent recruitment efforts to increase the number of math majors seem successful, with 61 freshmen entering during Fall 2016, compared to 35 in 2015. At the College level, the efforts include EXPLORE events, highlighting research and training in the sciences, for the newly admitted high school students. The School-level efforts of curriculum reform, as well as the proposal to rename the mathematics degree and offer concentrations in applied, discrete and pure mathematics and probability and statistics, are also generating excitement among existing and potential math majors. I am grateful for the hard work of the undergraduate committee and the leadership of the Director of Undergraduate Studies, Matt Baker. You can learn more about the undergraduate program on page 36.

Our graduate program is also at its largest now, with 86 PhD students enrolled in Fall 2016, thanks to the hard work of the graduate committee, Director of Graduate Studies Mohammad Ghomi, his support team and various faculty members. Further news about the graduate program can be found on page 31.

Under the leadership of Professor Luca Dieci (with the support of College of Sciences Dean Paul Goldbart), the Georgia Tech Mathematics and Applications Portal (GT-MAP) program was initiated. The program is an explicit facilitator to help catalyze cross-campus research collaboration between mathematicians at SoM and scientists and engineers at Georgia Tech and beyond. See page 29 for more details on this exciting initiative that is receiving strong participation from various units on campus.

Robin Thomas and I are co-organizing a conference to be held January 9-11, 2017, in celebration of the 25th anniversary of Georgia Tech's Algorithms, Combinatorics & Optimization (ACO) PhD program, and many details are already available at http://aco25.gatech.edu. Also, it is my pleasure to introduce Dr. Dan P. Sanders (PhD 1992), the first alumnus of the ACO program, as a new member of the Friends of the School of Mathematics (FoSoM) group. See page 45 for more information on Dr. Sanders and his family.

Finally, I am grateful to all those who contributed articles to this volume, and particularly to Dr. Sneha Subramanian and Ms. Janet Ziebell for their diligence and creative work in putting it together!

Best regards,
Prasad Tetali
Professor and Interim Chair

SoM Statistics Spring 2016

Faculty	59 (tenured or tenure track)
Emeritus Faculty	17
Academic Professionals	6
Instructors	1
Research Scientist	1
Visitors	12
Postdocs	9
Staff	12
Graduate Students	67
Undergraduate Students	
Math	111
Discrete Math	17

About the Cover

Our cover features the various faces of the School of Mathematics—students (both current and former), faculty members and postdoctoral fellows. The top three rows are the new faculty and postdocs hired over the past few years, whereas the next row depicts members of the School who helped organize summer Research Experience for Undergraduates programs. As an institution, we have made significant efforts to push for a more diverse and inclusive department, as evidenced by our stellar recent hires. We have, indeed, come a long way, but we know that our work is far from over and we hope our sustained endeavors will eventually help create a truly diverse mathematical community.

Also featured on the cover is Professor Robin Thomas (center, last row), winner of the Class of 1934 Distinguished Professor Award and Director of the Algorithms, Combinatorics & Optimization (ACO) program, together with current and former students of the program. The ACO program will be celebrating its 25th anniversary in January 2017.

Faculty Profile

Doug Ulmer's Accomplishments

by John Etnyre

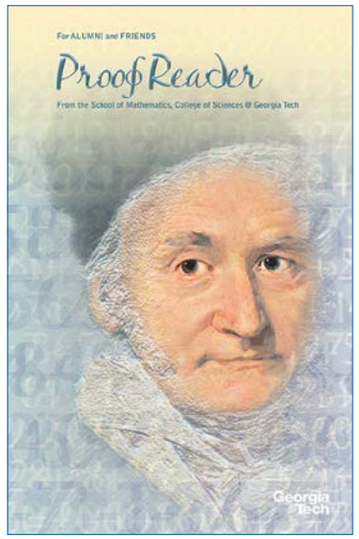
As the Chair of the School of Mathematics for six years, Professor Doug Ulmer was a tireless and creative force advocating for the School, from hiring excellent faculty and starting a postdoctoral program to expanding our presence in Skiles and engaging the alumni and friends of the School of Mathematics. "Doug did a superb job both of managing the day-to-day details of the School and in having a vision for where the School should go," recalls Associate Chair Chris Heil.

Perhaps the most visible aspect of SoM to the rest of the Institute is our teaching mission. The School has always strived to provide excellent instruction to our students at all levels, but under Professor Ulmer's guidance the faculty began a rigorous and thorough reevaluation of our classes and degree programs. This started with revamping the freshman and sophomore mathematics sequence that the majority of students take at Georgia Tech. Thanks to the hard work of many people, this new sequence is now in effect and should help students transitioning from high school to Georgia Tech as well as get students to graduation more smoothly. While pursuing these changes, Professor Ulmer also started a "pedagogy study group" to explore new ways of teaching these classes. This group considered many options from "flipped classes" to greater coordination in the freshman math sequence. While still a work in progress this process undoubtedly will lead to a better experience and better outcomes for students.

Another innovation to improve teaching started by Professor Ulmer was the use of teaching panels when interviewing potential faculty hires. These meetings between a job candidate and departmental personnel serve a dual purpose: to emphasize to job candidates the importance SoM places on teaching and to allow SoM to directly gauge a job candidate's interest in, enthusiasm for and ability in teaching.

Of course the heart of a mathematics department is its faculty, and as Chair, Professor Ulmer made many significant hires at both the junior and senior levels. Many of these hires went on to win prestigious awards such as the Sloan Fellowship and NSF CAREER awards. One particularly impressive point in the hiring is that the School of Mathematics added seven excellent women to the faculty. All the hires were outstanding, and Georgia Tech is now in the enviable position of having one of the most gender-diverse mathematics faculties among large research universities in the country.

Professor Ulmer also oversaw the hiring of several staff members and promotions of others. Sharon McDowell, who worked closely with Professor Ulmer as the Assistant to the Chair, said, "It was a pleasure working with Dr. Ulmer as his administrative assistant. He genuinely cared about the staff and always wanted to make sure that we were reaching our potential. When



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he gave me a project, it was without micromanaging and he always gave words of encouragement. He took the stress out of coming to work." These thoughts were also echoed by Professor Heil: "He was an efficient manager who knew what to delegate and what to take care of himself. He didn't micromanage; I knew what was expected of me as Associate Chair and he let me use my own judgment in dealing with those tasks. At the same time, he was always available for advice, which I often sought and which was always valuable."

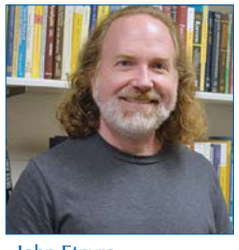
One of Professor Ulmer's most notable achievements as Chair was to initiate the Hale Postdoctoral Program, a fully funded, prestigious postdoctoral program. Such a program is a hallmark of top research mathematics departments and was long needed at Georgia Tech. The department previously only had ad hoc means to fund postdoctoral fellowships, but now has a small seed program that we hope to grow over the years.

Over the past few years, the School has grown though the addition of faculty, postdoctoral fellows and more graduate students. This has put a strain on office and seminar/classroom space, but the strain has been significantly ameliorated by Professor Ulmer's work to gain access to the ground floor of Skiles and its subsequent renovation. This provided two excellent seminar rooms and many offices that are mainly used by postdoctoral fellows. There is also a spacious atrium that has been the center of most departmental social and awards functions. These facilities are a significant upgrade to SoM's working environment and have been used and enjoyed by the vast majority of the School.

Any discussion of Professor Ulmer's accomplishments has to include his outreach and engagement with the School's alumni and other friends of the School. In particular, the School's yearly newsletter, *ProofReader*, has grown and flourished under his direction. This is one of our key ways to connect with people near and far who are interested in SoM. In addition, Professor Ulmer had started the Friends of the School of Mathematics (FoSoM). This group has allowed the School to more directly engage alumni and friends in the activities of the School and provide opportunities for our friends to interact with students and faculty on a regular basis. These initiatives have been instrumental in maintaining the visibility of the School both at Georgia Tech and beyond.

Reflecting on many of Professor Ulmer's accomplishments discussed above, Professor Presad Tetali, the interim Chair of SoM, comments, "I am confident that these initiatives will serve the School, the College and the Institute very well for very many years to come! I also want to thank him for making the transition into my interim term smooth and seamless."

This article only touches on some of Professor Ulmer's accomplishments while the Chair of SoM, but there are many others including helping the graduate program grow, securing generous gifts to the School, and partnering with faculty to run a highly successful exchange program with Jilin and Xi'an Jiaotong Universities in China. It is quite a list of accomplishments to look back on as Professor Ulmer settles back into life as a faculty member in SoM.



John Etnyre

Faculty Profile Enid Steinbart

Advising the Next Generation of Mathematicians

by Tom Trotter

Majoring in math at Georgia Tech can be challenging, but that is not because of lack of support. In fact, the undergraduate math majors here have one of the best academic advisors in the country* in Dr. Enid Steinbart.

Dr. Steinbart earned her PhD in mathematics at the University of Illinois, Urbana-Champaign, in 1989 under the direction of Steve Bank. She spent the first ten years of her academic career rising to the rank of Full Professor at the University of New Orleans, based on the strength of her continued work on ordinary differential equations in the complex plane and her outstanding teaching. She arrived at Georgia Tech in 1999, and has played an important role in the growth of our undergraduate program.

As a senior academic professional (which is a non-tenure-track rank for academic faculty), Dr. Steinbart can spend at most 50% of her time teaching. Her primary work is to help students as the Director of Advising and Assessment. She meets with prospective and incoming students, evaluates transfer credits for upper division courses, and is a valuable resource for math majors as they travel their unique paths toward their degree.

Under Dr. Steinbart's leadership, which is widely recognized across the institute, the School of Math developed specialized sections of GT1000 (an introduction to college life course for freshmen) that are specific to math majors. The school also now runs a seminar course for upperclassmen where math majors have a chance to hear from the faculty about ongoing research in an informal and accessible setting.

Some academic advisors on campus are full-time classified staff who don't teach or have advanced degrees. Since Dr. Steinbart has a PhD in mathematics and is a regular faculty member, she has a deeper understanding of the subject and can make informed decisions and give valuable advice to students.

An avid runner, Dr. Steinbart can be found in 5K races and on the streets of her hometown of Decatur many mornings of the year. "One advantage of getting older is that you advance to brackets with fewer people so your chance of a ribbon goes up," she observes. She is married to Dr. Lew Lefton, who is jointly appointed to the School of Math and the Dean's Office in the College of Sciences. They have three daughters, ages 23, 20 and 20. Hannah is a graduate of the University of Georgia and twins Natalie and Monica are currently in their third year at Georgia Tech and Emory, respectively.

Dr. Steinbart loves to travel and considers herself lucky to have been to a "majority of continents." However, the real lucky ones are the Georgia Tech students majoring in math whom Steinbart helps every day.

Tom Trotter

*** Dr. Steinbart was recognized by the National Academic Advising Association (NACADA) in 2015 with an Outstanding Advising Award in the Faculty Academic Advising category.**

Mathematics Making a Difference in Africa

by Evans Harrell

It is a remarkable time for mathematics in Africa. In the past decade, several mathematical research centers have sprung up across the sub-Saharan region, and more are being organized. How did this come about, and what does it have to do with Georgia Tech?

As first reported in the 2014 issue of *ProofReader*, the School of Mathematics has had personal ties to sub-Saharan Africa for over twenty years, beginning with the arrival of Professor Wilfrid Gangbo, a native of Benin, the Georgia-sized country immediately to the west of Nigeria. The arrival of Professor Doron Lubinsky, a native of South Africa, later deepened the connection. Wilfrid has long been passionate about promoting mathematics and science in Africa, originally through an organization he helped found, EcoAfrica, and later by recruiting several graduate students from West Africa.

My own first visit to sub-Saharan Africa in 2003 was for the West African Training School, an international meeting in Senegal, and I returned to the same event two years later with Professor Shui-Nee Chow. In 2007, Shui-Nee and I joined Wilfrid at an international meeting in Benin, and in May of last year I went back to both countries.

Africa is experiencing rapid growth economically, in population and in education, and several countries have realized that mathematics is a strategic entry point for the STEM fields. After all, mathematics research requires no expensive equipment, only talent, modest facilities and institutions, and access to scholarship, which is now easily available over the internet. With political stability and a good educational infrastructure, a country that is still emerging from poverty can provide all of these necessities.

At the same time, mathematics can have tremendous payoffs for a developing society, especially through mathematical models used to improve the understanding of climate, disease, environmental stresses, economics and urbanization; those can then inform policy choices. The cases of Senegal and Benin, where mathematics research centers are thriving, are instructive. Neither country is rich in natural resources, but they have been stable for decades. It is probably no accident that both are French-speaking, with an educational legacy emphasizing mathematics. Influential French mathematicians have been supportive of mathematics there, such as our former Georgia Tech colleague Professor Cédric Villani.

The mathematical research centers in Benin and Senegal follow somewhat different operational models. Benin's Institut de Mathématiques et de

Sciences Physiques (IMSP) was established in the 1980s with the involvement of the local Université d'Abomey-Calavi and the International Centre for Theoretical Physics (ICTP) in Trieste, Italy. Recently it built its own campus in Dangbo and obtained major funding from the World Bank to expand its program under the local leadership of Professor Joël Tossa. Georgia Tech's Wilfrid Gangbo and Tech alumnus Professor Kasso Okoudjou of the University of Maryland have close ties to IMSP and have lectured courses there. IMSP draws from the many countries in Africa, and supports both master's and doctoral programs, providing instruction and research in both theoretical and applied parts of mathematics.

Since 2011, Senegal has been the home of the second branch of the African Institute of Mathematical Sciences (AIMS), which had opened in South Africa in 2003. AIMS and its affiliated nongovernmental organization, known as the Next Einstein Initiative, were the brainchild of Professor Neil Turok. In 2001, Turok, the Director of the Perimeter Institute and a native of South Africa, believed that Africa was fertile ground for research in applied mathematics. Given the growing population of young, educated Africans, he posed this question: Why shouldn't the next Einstein be found among the new generation of Africans? The powers that be in South Africa were convinced, and Turok later won the 2008 TED Prize and made the pitch for expanding AIMS to several more countries. It now includes not only Senegal but also Ghana and Cameroon. A new branch is slated to open next year in Rwanda, and will have a focus on quantum information theory. The ambition of the Next Einstein Initiative is to set up 15 branches of AIMS across the African continent.

AIMS, which operates in English even in francophone Senegal, offers interdisciplinary master's degrees. Students arrive from across Africa and typically concentrate on mathematical economics, epidemiology or problems connected with physics. Courses are taught over three weeks by visiting international faculty in the resort city of M'bour. These faculty lecture and train teaching assistants, who continue working with the students afterward. Universities in the West African region have substantial research programs of their own, but they get additional benefits from the existence of nearby independent international research centers such as AIMS and IMSP, which host conferences and international scholars and maintain a lively level of mathematical activity.

Despite undeniable economic and infrastructure issues, the mathematics research centers are making a real difference to the intellectual capital of Africa, helping stem the brain drain of talent and helping solve problems of development. In order to learn more about this, last year I obtained a grant from Georgia Tech and the Sloan Foundation to send a small expedition to West Africa to see the new mathematics centers in operation and deepen Tech's connections to them. The focus of that grant was mathematical modeling, and after communicating with African colleagues about which societal problems offered the best chances for fruitful cooperation, I recruited mathematics

postdoc Christina Frederick and environmental engineering student Stephen Malone to travel with me. To obtain the grant, I had to make the case that it would be advantageous to Georgia Tech. I pointed out three main benefits, which were

- to find interesting research projects in mathematics and its applications;

- to inspire Georgia Tech students to study mathematics as a real-world discipline; and

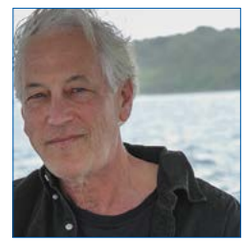
- to position Georgia Tech for better engagement in a region that will be of dramatically greater importance in the future.

Since demographic projections (mathematical modeling!) show that in twenty years the population of Africa with the educational attainment to get PhDs in STEM fields and enter the mathematical and scientific workforce will be comparable to that of China or India, Georgia Tech has a distinct strategic interest in preparing for that shift.

How did it work out? In both Senegal and Benin we participated in mathematics meetings and met with non-mathematicians who are interested in better modeling of climate and the spread of disease, and in computer-science education. In these settings we exchanged many good ideas about mathematics and applications. The Georgia Tech team has stayed in touch with climate scientists in both countries, and we have connected them with the research group of Professor Peter Webster in Tech's School of Earth and Atmospheric Sciences, which is willing to host visiting scholars from West Africa and support them in obtaining funds for that purpose from the Fulbright Foundation. Environmental scientists in Benin were put in touch with engineers who have developed inexpensive, portable air-pollution monitors and software allowing the integration of traffic data using cell phones. Among many possible diseases of concern we focused on schistosomiasis, and we have initiated research discussions with epidemiologists in Senegal and Burkina Faso, whom we have connected with Tech's Professor Howie Weiss and with Professor David Gurarie of Case Western's math department. On the personal level, I am exploring joint research with Senegalese mathematicians Professors Diaraf Seck and Mustapha Fall on the determination of optimal shapes, which has both pure mathematical aspects and potential applications.

Last May, I arranged for Associate Dean Charles Isbell of the College of Computing to meet us in Senegal, and we negotiated a contract whereby the country of Senegal will sponsor several students to enroll in Tech's Online Master of Science in Computer Science. Christina Frederick took the lead in using our experiences to inspire students by proposing related modeling projects to her Research Experience for Undergraduates students last summer. Several of them responded enthusiastically to the opportunity to think about mathematics in a global context. Christina and I followed up earlier this year at a symposium at the AAAS titled Mathematics Making a Difference in Africa, along with Kasso Okoudjou, President Thierry Zomahoun of the Next Einstein Initiative, and an audience with many other mathematicians and policymakers, focusing on the importance of mathematics to Africa and its future directions.

In conclusion, mathematics in Africa is an inspiring story. Mathematics provides a unique opportunity for Georgia Tech to engage globally, and I would be delighted to speak to any students, faculty or friends of the School of Mathematics about getting personally involved in this rewarding activity.



Evans Harrell

Fermat's Famous Margin

by Bill Green

The most famous problem in the history of mathematics is probably "Fermat's Last Theorem," which has an amazingly simple formulation for so difficult a problem:

Theorem: Consider the equation $x^n + y^n = z^n$, where x, y, z and n are required to be positive integers. If the exponent n exceeds 2, then this equation has no solution (x,y,z).

In about 1637, Pierre de Fermat, a French lawyer and mathematician living in Toulouse, encountered this equation in a copy of *Diophantus' Arithmetica* and penned in the margin his now famous notation that he had a remarkable proof of this assertion that would not fit into the space available. In 1670, about five years after Fermat's death, his son Clément-Samuel Fermat published a new edition of the *Diophantus* volume in which he included his father's annotations. In the centuries since that publication, many of the world's most talented mathematicians worked on the problem of supplying a proof, while the problem itself led to a great deal of remarkable new mathematics. Nevertheless, it resisted solution until 1994, when Andrew Wiles, a mathematics professor at the University of Oxford, building on the work of many others and with the assistance of Richard Taylor, gave a complete and correct proof of the theorem. In view of these difficulties and the length and complexity of Wiles' proof, it now seems unlikely that Fermat had a proof in 1637.

What exactly was the nature of this cryptic marginal notation? In Fermat's native French, it reads

"Au contraire, il est impossible de partager soit un cube en deux cubes, soit un bicarré en deux bicarrés, soit en général une puissance quelconque supérieure au carré en deux puissances de même degré: j'en ai découvert une démonstration véritablement merveilleuse que cette marge est trop étroite pour contenir."

which has been translated as

"It is impossible to separate a cube into two cubes, or a fourth power into two fourth powers, or in general, any power higher than the second, into two like powers. I have discovered a truly marvelous proof of this, which this margin is too narrow to contain."

But in fact, the actual annotation, as reported by Clément-Samuel Fermat, is not in French at all. The original of *Diophantus'* work was in Greek, since *Diophantus* was an Alexandrian Greek who wrote in the third century AD. In 1631, Claude Gaspard Bache de Méziriac, a French mathematician, linguist, poet and classics scholar from Bourg-en-Bresse, published his translation of the *Arithmetica* into Latin, and it was this edition that came into the hands of Fermat. Reading in Latin, Fermat also made his annotations in Latin, and so the famous marginal notation actually reads

Cubum autem in duos cubos, aut quadratoquadratum in duos quadratoquadratos & generaliter nullam in infinitum ultra quadratum potestatem in duos eiusdem nominis fas est dividere cuius rei demonstrationem mirabilem sane detexi. Hanc marginis exiguitas non caperet.

Sadly, Fermat's copy of *Diophantus*, with his handwritten annotations, has been lost. Thus much of the history of mathematics would seem to depend on the report at second hand of a short and cryptic notation by a great mathematician who may have overreached. In any event, Fermat's Last Theorem is a theorem at last. Unfortunately, this page is too narrow to contain the details.

Bill Green

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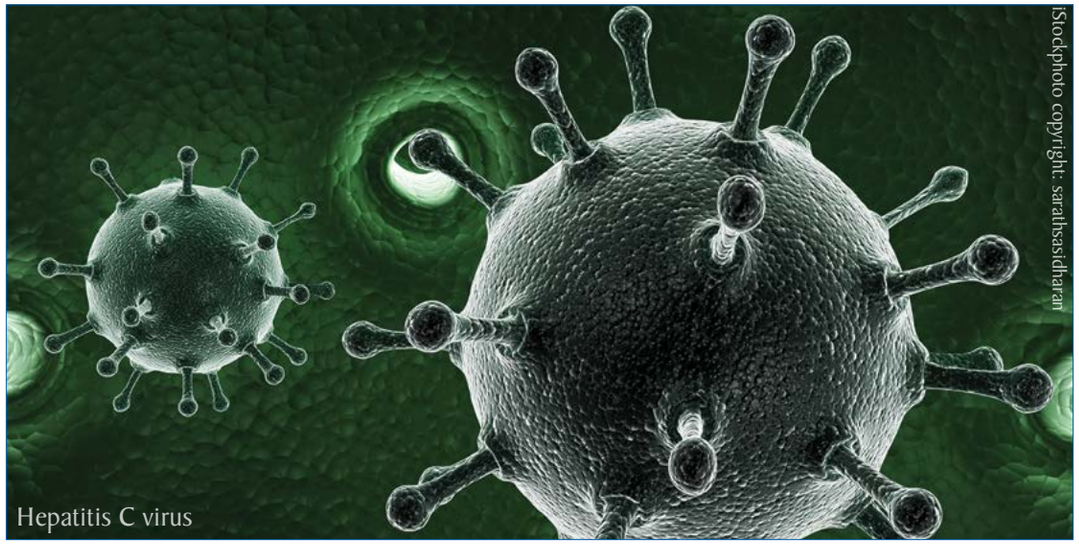
Cross-immunoreactivity

Generates Local Immunodeficiency

by Lyonia Bunimovich



Hepatitis C virus

Hepatitis C virus (HCV) affects 2.2% of the world's human population. It causes chronic liver infection in about 80% of infected individuals, and is a leading cause of liver cancer. HCV causes more deaths in US than the human immunodeficiency virus (HIV).

A natural question is why is HCV so "successful," and to answer it one must first understand how HCV evolves in the organism of the infected individual (host) and how the human immune system is fighting such invaders.

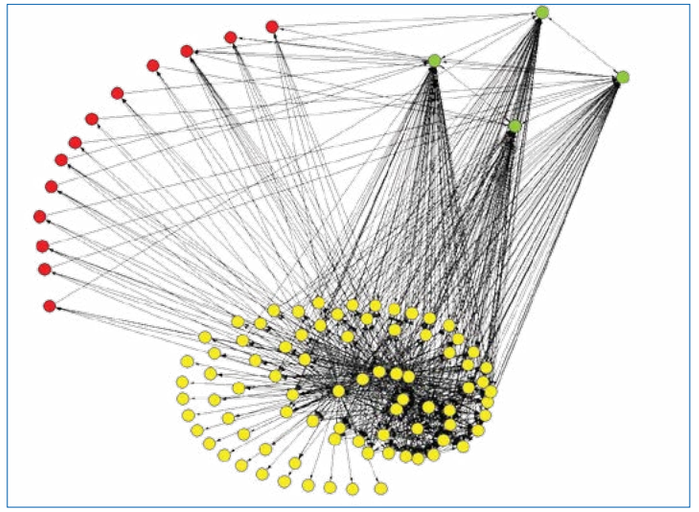
HCV is an RNA virus, which means it is a virus that has ribonucleic acid as its genetic material. It is well known that HCVs mutate very fast, and therefore, a host carries, in fact, a (large) variety of viruses. To explain the HCV dynamics, scientists developed a theory known as the "arms race" theory in theoretical biology. This theory, which for a long time was the only one to explain this, can be formulated in one sentence. The dynamics of HCV (and therefore progress of the disease) completely depend upon which action is faster—the mutation process of viruses or the production of antibodies against newer and newer viruses by the host's immune system.

However, recent advances in sequencing long (RNA-like) molecules revealed that the arms race theory does not explain quite a few clinically observed phenomena at the chronic stages of hepatitis C infection.

First, the intra-host HCV population diversifies and diverts continuously from the acute state to chronic infection, but then it starts losing heterogeneity and eventually stops diverting. Furthermore, a consistent increase in negative selection during the chronic stage of the disease was observed; that is, new HCV variants disappear under the pressure of the immune system. In fact, the late-stage HCV populations were shown to remain constant and homogeneous under the strong negative selection for years, indicating a high level of intra-host adaptation. These and other observations suggest that intra-host HCV populations can remain unaffected by the immune system over the course of infection. In other words, a stationary state appears to be reached.

Second, a complex dynamic of HCV populations was observed in infected hosts. The density of intra-host subpopulations was found to fluctuate significantly in the course of chronic HCV infection, with some subpopulations persisting at low frequency for years until becoming dominant, or reemerging at later stages of infection after being undetectable for a long time.

The earlier uniformly accepted mathematical model of the HCV dynamics/evolution, made up of simultaneous differential equations, failed to explain all these (and some other) recent observations. So, what is a standard approach in mathematical and theoretical biology in such cases? Of course, one could make a model more complicated by adding some new terms to the equations or, perhaps, even make new equations.



Cross-immunoreactivity network of 100 viral variants—the altruistic viruses are green, the persistent ones are red and the rest are yellow

I worked on this problem with Dr. Pavel Skums and Dr. Yury Khudyakov from the Molecular Epidemiology and Bioinformatics Lab at the Centers for Disease Control and Prevention (CDC) Division of Viral Hepatitis, and we took a different approach. Our results were recently published in a paper titled "Antigenic cooperation among intrahost HCV variants organized into a complex network," in the journal *Proceedings of the National Academy of Sciences* (PNAS).

Since we live in the time of BIG DATA, it is tempting to put everything in a supercomputer and, certainly, some numbers will come out.

But instead, my colleagues and I wanted to think about what is really important and fundamental in this huge collection of qualitative and quantitative data. The answer lies in the well-known biological phenomenon known as cross-immunoreactivity. Cross-immunoreactivity (CI) means that antibodies generated by the immune system to fight a specific virus can also fight (some) other types of viruses. Therefore, in each host, viruses form a cross-immunoreactivity network.

CI suggests that different viruses may interact with each other. (Do not tell this to biologists, because everybody knows that viruses do not interact! However, viruses do interact, though not directly.) Thanks to CI, they interact through the immune system and, in fact, they work like a team.

Warring armies use a variety of tactics as they struggle to gain an upper hand. One famous trick is to attack with a decoy force that occupies the defenders while an unseen force launches a separate attack that the defenders fail to notice. The hepatitis C viruses, in fact, employ exactly the same tactics. After infecting a host, HCVs evolve into many variants that include a small "altruistic" group of viruses that sacrifice themselves to protect another (slightly larger) group of "persistent" viruses that remain practically undetected by the immune system. Therefore, a new phenomenon of local immunodeficiency essentially defines the evolution of hepatitis C in a chronic stage of infection. Indeed, the persistent variants of HCVs do not overwhelm the immune system (like the HIV viruses do), but effectively fool it with the help of other HCVs. The majority of the HCVs are neither altruistic nor persistent, and the role of a given type of virus depends on its position in a cross-immunoreactivity network (see the accompanying figure).

The phenomenon of CI is well-known and observed for other diseases (like dengue, influenza etc.). A strategy for public health in fighting such diseases is to determine the "altruistic" variants of viruses and destroy them, and to do so, we need a model that better describes the dynamics of such viruses.

Our model is simpler than the older classical model that uses five types of variables. Our model uses just two types of (necessary!) variables, which are numbers of viruses of different types and numbers of the corresponding antibodies.

This is not traditional mathematics, however. No theorems have been proven (although the cases with a few variants have been studied analytically). It belongs to theoretical biology. Here the basis is, crazy for biologists, the physical idea that viruses effectively do interact. This idea opens up several directions of study, among which are the ones belonging to mathematical biology. True mathematical biology is, in fact, mathematics that addresses biological questions; that is, not questions that could be (formally mathematically) answered but the ones that are of interest to biology.

Lyonia Bunimovich

Dispersive and Wave PDE: Equations from Quantum Mechanics to General Relativity

by Zaher Hani

Soon after Newton published his *Principia Mathematica* in 1687, scientists realized that the best and most precise description of the world around us is given via mathematical equations. Newton's famous second law, $\vec{F}=m\vec{a}$ (force equals mass times acceleration), is one of the simplest evolution equations that describes how a particle's trajectory evolves when it is acted upon by a force $\vec{F}$. From a mathematical point of view, this equation is called an *ordinary differential equation* because it keeps track of the evolution of only three numbers (the particle's coordinates) that describe the position of the particle at time t. As systems become more complex and composed of a very large number of particles being acted upon by various forces, the equations of motion become more and more complicated. For example, the evolution of temperature in the atmosphere, or the shape of the surface of the ocean, cannot be completely described by a finite number of coordinates. In such cases, the equations of motion are given by *partial differential equations*, which can track the evolution of an infinite number of parameters as time passes by.

Partial differential equations (or, PDEs for short) have been studied for over 300 years now, mostly due to their fundamental importance in physics and engineering. A particular class of such differential equations that is quite ubiquitous in nature is that of dispersive and wave PDEs. Roughly speaking, those are equations that are associated with phenomena that involve waves either in an explicit or implicit way.

Of course, we interact with waves on a daily basis; for example, through ocean waves or the various electromagnetic signals on which we base our communication these days (from natural light to phone and internet signals). However, wave phenomena are much more fundamental and go way beyond things that look "wavy" at first glance. In fact, dispersive and wave equations govern physical phenomena from quantum mechanics (like the evolution of a particle according to Schrödinger's equation) all the way to Einstein's equations of general relativity. The latter can be written as a system of wave equations, and the recent groundbreaking detection of gravitational waves last year is merely a manifestation of the wave-nature of these equations.

Nonlinear dispersive PDEs. As it happens, most interactions in nature are nonlinear. Consequently, the mathematical equations describing such phenomena are nonlinear themselves (i.e., they involve products of the solution with itself or its derivatives). We are thus naturally led to studying nonlinear dispersive equations to describe wave phenomena that involve nonlinear interactions.

The study of nonlinear dispersive equations has witnessed an explosion of activity in the past thirty years, particularly after tools and developments from harmonic analysis found their way to dispersive PDEs. The field remains one of the most active areas of PDE with many open questions and directions left to pursue. Below, we briefly discuss one of those directions that is very interesting from a mathematical and physical viewpoint, although we're still at the very beginning of understanding all its complications and intricacies.

The water waves equation is a dispersive PDE that describes the shape of the surface of the ocean. Wind gives energy to the ocean by interacting with it at large scales, whereas this energy is only dissipated at much smaller scales. This transfer of energy from large scales to small scales is behind many interesting phenomena in oceanography.

Wave turbulence. After proving the existence of solutions for a nonlinear dispersive equation, the next task is to describe their long-term behavior. Usually, the starting point of this analysis is to consider initial data that are close to some special stationary solutions, typically the trivial solution $u = 0$, and ask whether those solutions stay small (equivalently close to the zero solution) or whether they exhibit some kind of non-equilibrium dynamics in which they depart far away from their original configuration. If the solutions stay small (in sufficiently strong norms), we say that the zero solution is stable. This is a typical behavior for many nonlinear dispersive equations posed on Euclidean space $\mathbf{R}^d$.

In contrast, this stability phenomenon disappears as we move to the realm of compact or bounded spatial domains. There, non-equilibrium dynamics prevails and initially small solutions can become very large if measured in appropriate norms. Constructing such solutions is far from trivial, and the first results in this direction were only proved recently. Such problems lie at the intersection of practical, physical and mathematical interest, and ultimately constitute the subject matter of the so-called ***wave turbulence theory***, which describes the non-equilibrium statistical mechanics of nonlinear dispersive systems.

Wave turbulence is a rather well-developed and quite vibrant area in engineering and physics, and it gives deep insight into the non-equilibrium dynamics of nonlinear dispersive PDEs. Unfortunately, the mathematical understanding lags far behind. The derivation of the fundamental equations in wave turbulence theory is done in the physics literature at a very formal and heuristic level, which does not allow us to make any rigorous connection between the deep conclusions of this theory and the dispersive system we start with. This is not only a mathematical problem; it is also crucial at the level of physics in terms of identifying the limits of applicability of various assumptions or conclusions.

As it turns out, questions related to turbulence are very complicated from a mathematical point of view. Renowned physicist and Nobel Laureate Richard Feynman described hydrodynamic turbulence (a close cousin of wave turbulence) as "the most important unsolved problem of classical physics." Despite that, one can still try to take some steps in the right direction in order to better understand the different aspects and shed light on this vast and tremendous problem. This was the motivation behind the recent progress my colleagues and I made in this field.

Zaher Hani

To find out more about our recent progress and about past results, please see http://people.math.gatech.edu/~zhani6/Publications--Zaher%20Hani.html

Department AWARD Diversity CHAMPION

The School of Mathematics won the **2015 Diversity Champion Award**. The Diversity Champion Awards, hosted annually by Georgia Tech's Institute for Diversity, recognize faculty, staff, students and units who actively demonstrate and positively promote the concepts of diversity, equity and inclusion within the Georgia Tech campus community. The School of Mathematics shared the award with the Division of Student Life. Here are some of the efforts put forward by several members of the faculty and the School as a whole that have been instrumental in promoting diversity and outreach.

The summers of 2015 and 2016 saw two Research Experience for Undergraduates (REU) programs organized by the Interdisciplinary Mathematics Preparation and Career Training (IMPACT) postdoctoral fellows, under the guidance of principle investigator Professor Christine Heitsch. The first one, held in 2015, was organized by postdocs Christina Frederick and Maryam Yashtini, with the help of graduate students Eric Sabo and Ben Ide, and was based on applied mathematics, numerical analysis and image processing. Professors Sung Ha Kang and Haomin Zhou also helped direct the research. The second one, held in the following year, was organized by postdocs Megan Bernstein, Torin Greenwood and Heather Smith, with the help of graduate students Anna Kirkpatrick, Thomas Prag and Peter Ralli, and was based on discrete mathematics and molecular biology. Students from Agnes Scott, Georgia State, Georgia Tech, Morehouse and Spelman participated in the programs and conducted research with many School of Mathematics faculty members.

Inspired by the Next Einstein Initiative, Professor Evans Harrell led a team (which included Christina Frederick) on a trip to West Africa with the goal of identifying possible collaborations involving faculty and students at Georgia Tech and a student exchange program. You can read more about their outreach efforts in pages 9-11.

In 2013, Professor Kirsten Wickelgren was part of a team on Women in Topology in Banff, Canada, and subsequently led a Women in Numbers team at WIN3, also in Banff. She has also taught a mini-course at the Connections for Women: MSRI algebraic topology semester and has done a faculty interview for *Girls Angle Bulletin*. Kirsten and her spouse, Professor Joseph Rabinoff, both volunteer in the Emory Math Circle, which is a math enrichment program for middle school and high school students in the Atlanta area. Plans are underway for hosting similar events at Georgia Tech.

Professor Howie Weiss and his spouse Lora Weiss (Chief Scientist at Georgia Tech Research Institute) host and mentor in their basement the Cougar Bots robotic team, which is Dekalb County Schools' first and only FIRST Tech Challenge (FTC) Robotics team. FTC teams design, build and program robots to compete against other teams. As part of the team's outreach, they help run workshops around Dekalb County to excite and teach elementary school students about programming and robotics, host a weeklong summer programming camp, help mentor new Dekalb FIRST Lego League teams, and volunteer at FIRST Lego League competitions.

Professor John Etnyre and Dr. Martin Engman, with the help of graduate students Victor Bailey and J.D. Walsh, have been active in promoting diversity by hosting a visiting day for junior and senior undergrads of local colleges to encourage pursuit of graduate math education (particularly at Georgia Tech), with special emphasis on historically black and women's colleges and universities in the area. This has continued under the direction of the new Director of Graduate Studies, Mohammad Ghomi.

Thanks to the school's hiring efforts over the past several years, we now have 16 female faculty members and eight female postdoctoral fellows, a huge improvement from even ten years ago when we had only one female tenure-track faculty. With our faculty members hailing from nearly 30 different countries and five continents, the School of Mathematics is a truly diverse bunch!

Faculty Awards
September 2015–July 2016

Professor **Luca Dieci** won the 2016 College of Sciences Faculty Mentoring Award. This award, supported by the College of Sciences ADVANCE Professorship, recognizes Luca's efforts and achievements in mentoring faculty over many years at Georgia Tech.

Klara Grodzinsky received this year's 2015 Class of 1940 Course Survey Teaching Effectiveness Award. This distinction is awarded annually by Georgia Tech's Center for the Enhancement of Teaching and Learning (CETL) to faculty members at Georgia Tech who have excelled in teaching, and only a maximum of 40 awards are given each year.

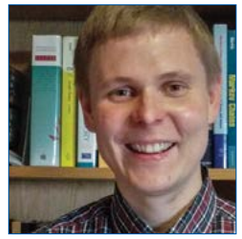
Professor **Zaher Hani** received the 2016 Sloan Foundation Research Fellowship. In the words of a Sloan Foundation press release, "the fellowships are given to early-career scientists and scholars whose achievements and potential identify them as rising stars, the next generation of scientific leaders," and "these outstanding men and women are responsible for some of the most exciting science being done today." He is one of the 20 awardees in mathematics (chosen from among all applicants in the US and Canada).

Professor **Dan Margalit** has been selected to receive the inaugural 2016 Leddy Family Faculty Fellowship. The Leddy Family Faculty Fellowship is awarded to a tenure-track faculty member in the College of Sciences. The award is made to further the goals of the College by supporting development of the research and training program and quality of instruction of a mid-career faculty member (loosely defined as a tenured Associate Professor, or one who is just before promotion to this rank or just after promotion from this rank). This award is made possible through a generous gift to the College of Sciences from Jeff ('78 Physics) and Pam Leddy.

Professor **Tom Morley** received the 2016 Faculty Academic Outreach Award. This award provides Georgia Tech with the opportunity to reward faculty members for productive academic outreach in which they go beyond their normal duties to enrich the larger educational community with their subject matter knowledge. One or two awards are granted annually depending on the number and quality of nominations.

Professor **Ronghua Pan** received the 2016 Geoffrey G. Eichholz Faculty Teaching Award. Established in 2005 through a gift from School of Mechanical Engineering Regents' Professor Emeritus Geoffrey Eichholz, the award was created to reward senior faculty members who had made a long-term contribution to introductory undergraduate education and were outstanding teachers for students taking freshman and sophomore core courses. Recently, the award has broadened to recognize faculty at any point in their careers who excel in teaching core and general education courses and who help students establish a solid foundation for their education at Georgia Tech.

Professor **Robin Thomas** is the 2016 recipient of the Class of 1934 Distinguished Professor Award in recognition of his sustained outstanding achievement in teaching, research and service. This award is the highest given to a faculty member at Georgia Tech and is presented to an active professor who has made significant, long-term contributions that have brought widespread recognition to the professor, to his or her School and to the Institute. Professor Thomas is a Regents Professor, recipient of the Neuron Award for Lifetime Achievement in Mathematics and a member of the 2012 inaugural class of American Mathematical Society Fellows. He has more than 100 papers published in top journals, and he has twice been awarded the Fulkerson Prize for outstanding papers in the area of discrete mathematics, an accomplishment that has been matched by only four other researchers in the history of the prize.



Professor **Lutz Warnke**, who is soon joining the School of Mathematics faculty, received the 2016 Dénes König Prize in recognition for his contribution to the study of random graph processes and phase transitions. This award is given biennially by the SIAM Activity Group on Discrete Mathematics (SIAG/DM) to an early career researcher or early career researchers for outstanding research, as determined by the prize committee. Awards are given for research in an area of discrete mathematics, based on a publication by the candidate(s) in a peer-reviewed journal published in the three calendar years prior to the year of the award.

Left to right: Esther Ezra, Kirsten Wickelgren, Michael Damron, Jennifer Hom

Four faculty members of the School of Mathematics won the highly competitive National Science Foundation (NSF) CAREER awards. These were Professors **Michael Damron**, **Esther Ezra**, **Jennifer Hom** and **Kirsten Wickelgren**. The CAREER awards are NSF's most prestigious grant, provided by the NSF Faculty Early Career Development (CAREER) program to support junior faculty who exemplify the role of teacher-scholars. Through five years of sustained support, the award enables promising and talented researchers to build a foundation for a lifetime of leadership in integrating education and research.

In other news, Professor **Matt Baker** has been named the 2015 Greater Atlanta Magician of the Year by the Atlanta Society of Magicians and Georgia Magic Club, a local ring of the world's largest magic organization, the International Brotherhood of Magicians. His exploits combining magic with math to enhance the teaching experience were covered in the inaugural edition of *ProofReader*.

New Faculty 2016

Mayya Zhilova received her PhD in mathematical statistics from Humboldt University of Berlin in 2015. Before joining Georgia Tech, she worked at Weierstrass Institute in Berlin in the research group Stochastic Algorithms and Nonparametric Statistics from 2011 till 2016. She did her undergraduate studies at Lomonosov Moscow State University in Moscow, Russia. Mayya's current research areas are mathematical statistics and probability theory. In particular, she works on resampling methods for statistical inference for complex high-dimensional data.

In her leisure time, Mayya enjoys listening to music and dancing. She also likes hiking and observing the sky.

Lutz Warnke did his undergraduate studies at Eidgenössische Technische Hochschule (ETH) Zürich, Switzerland. In 2012, he completed his PhD at the University of Oxford under the supervision of Dr. Oliver Riordan. Following that, he spent a few years as a Junior Research Fellow at the University of Cambridge.

Lutz's research is in the area of probabilistic combinatorics and random discrete structures, which is at the intersection of discrete mathematics and probability theory.

His particular interests include random graphs and phase transitions (with some connections to statistical physics and network science).

In his spare time, Lutz enjoys running and occasionally indulges in board and card games.

New Academic Professionals

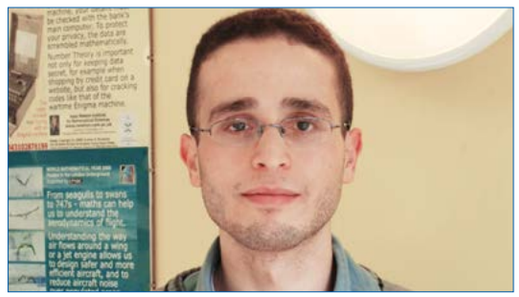
Chris Jankowski received his PhD from the University of Pennsylvania in 2009 under the supervision of Dr. Robert Powers, and he works in the field of operator algebras.

He spent time as a postdoc at Ben-Gurion University in Israel and was most recently at New York University (NYU) where he became heavily involved in teaching and coordinating undergraduate courses. He also volunteered for two summers at NYU's GSTEM program, where he served as a research mentor for high school students interested in mathematics.

Chris is a huge fan of college basketball and football. In his spare time he enjoys board games, Warhammer and pretty much anything to do with trivia.

Faculty Promotions and Transitions 2016

In Spring 2016, Associate Professors **Christine Heitsch** and **Dan Margalit** were promoted to Full Professor.



Assistant Professors **Karim Lounici** and **Ionel Popescu** received tenure and were promoted to Associate Professor.

Professors **Shui-Nee Chow** and **Tom Morley** retired after serving the School effectively for several decades.

High School Math Competition

by Gregory Mayer

Thanks to the hard work of several School of Mathematics graduate students, postdoctoral fellows, staff and faculty, the High School Mathematics competition was a huge success, with more than 400 students participating in the event.

This annual competition covers a wide range of topics, including algebra, Euclidean geometry, combinatorics, number theory and calculus. Schools from any state are welcome to compete, and schools may register up to five teams with up to five contestants per team.

We are grateful to the organizing committee for this year's event: Sharon McDowell, Annette Rohrs, Eric Sabo, Elizabeth (Betsie) Last, Chi Ho Yuen, George Kerchev and Shane Scott. Also thanks to Professor Mohammad Ghomi for an exciting presentation on the age-old Durer's problem and recent progress, and to J.D. Walsh for engaging the students, parents and school counselors with a passionate talk on professional opportunities for students majoring in math.

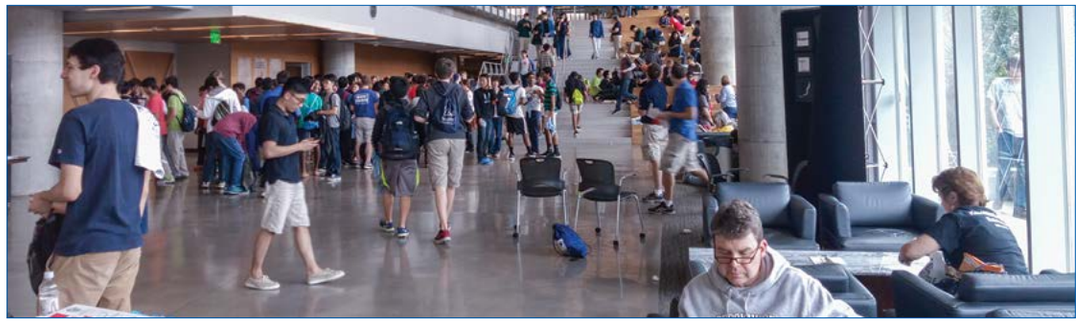
This year's winners were:

Ist Place	Henrik Boecken from Wheeler High
2nd Place	Timothy Geiseking from Gwinnett School of Math, Science and Technology
3rd Place	Kalen Patton from Chattahoochee High School
4th Place	Aaron Fishburn from Northview High School


Gregory Mayer

The teams with the top scores were:

First	Northview High School, Team A
Second	Gwinnett School of Mathematics, Science and Technology, Team A
Third	Chamblee Charter High School, Team A
Fourth	Northview High School, Team B



Conferences and Events September 2015–July 2016

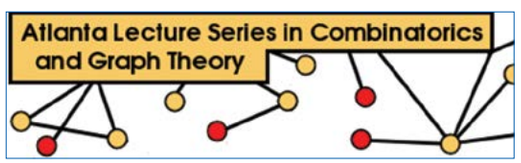
October 12-16, 2015
Ordered Algebraic Structures and Related Topics

Professor **Greg Blekherman** and postdoc **Rainer Sinn** organized a mini-symposium at the Ordered Algebraic Structures and Related Topics conference that was held at the Centre International de Rencontres Mathématiques (CIRM) in Marseille, France. The meeting marked the 30th anniversary of the conference and consisted of 30 plenary talks and contributed paper sessions.

October 26-28, 2015
Polytopal Element Methods in Mathematics and Engineering

School of Mathematics postdoc **Chunmei Wang**, together with Professors Andrew Gillette from the University of Arizona and Lourenco Beirão da Veiga from the University of Milan, Italy, organized this workshop to promote communication among the many mathematical and engineering communities currently researching polytopal discretization methods for the numerical approximation of solutions of partial differential equations. The workshop was supported by the National Science Foundation (NSF).

November 14-15, 2015
Atlanta Lecture Series in Combinatorics and Graph Theory XVI



Emory University, Georgia Tech and Georgia State University, with support from the NSF and the National Security Agency, continued the series of mini-conferences hosted between 2014 and 2017. The sixteenth of these was held at Georgia Tech and hosted by Professor **Xingxing Yu**. The conferences stress a variety of areas and feature lectures by one prominent researcher, four of five outstanding researchers, and several young researchers or graduate students. Professor Noga Alon from Tel Aviv University, Israel was this year's keynote speaker.

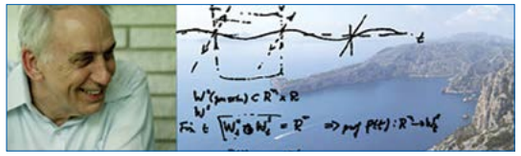
December 4-6, 2015
Tech Topology Conference

The fifth annual Tech Topology Conference again brought together established and young researchers from all around the country for a weekend of mathematics in Atlanta. The organizers were School of Mathematics Professors **John Etnyre** and **Dan Margalit**. Professor **Jen Hom** was one of the invited speakers at the conference, and our graduate student **Justin Lanier** gave a five-minute "lightning talk."

March 13-15, 2016
Southeastern Analysis Meeting

The 32nd Southeastern Analysis Meeting was hosted by the College of Arts & Sciences and Department of Mathematics & Statistics at the University of South Florida, Tampa, March 13-15, 2016. Professor **Doron Lubinsky** was an invited speaker, and Professor **Shahaf Nitzan** also presented a talk. The main goal of the conference was to disseminate and exchange the latest ideas and developments in classical analysis, complex analysis and operator theory among junior and senior researchers.

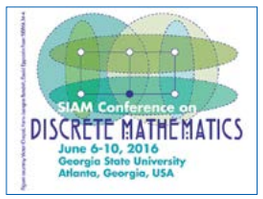
March 21-25, 2016
Dynamics of Evolution Equations



The Dynamics of Evolution Equations conference was the second in the series of conferences dedicated to the memory of School of Mathematics Professor **Jack Hale** (the first one took place at Georgia Tech in 2013). This conference, held at CIRM, was devoted to the study of dynamical systems generated by ordinary differential equations (ODEs) and partial differential equations (PDEs). Professor **Shui-Nee Chow** was a member of the Scientific Committee for the conference, while Professors **Luca Dieci** and **Rafael de la Llave** were plenary speakers.

June 6-10, 2016
SIAM Conference on Discrete Mathematics

School of Mathematics Professors **Matt Baker** and **Josephine Yu**, together with Professor Ngoc Mai Tran from the Hausdorff Center for Mathematics, Bonn, Germany, were the organizers of a mini-symposium on tropical mathematics and its applications at the SIAM Conference on Discrete Mathematics, held at Georgia State University in Atlanta. Professors **Matt Baker** and **Joe Rabinoff** also presented at the mini-symposium.



June 6-10, 2016
Topology Students Workshop

Geared toward graduate students in mathematics specializing in geometry and topology, this workshop, held at Georgia Tech and organized by Professor **Dan Margalit**, featured research talks by leading mathematicians in geometry and topology, as well as hands-on training and panel discussions on various professional development topics, such as creating and delivering research presentations, writing grants, and careers in and out of academia.

June 10-12, 2016
Benjamin Peirce Centennial Conference

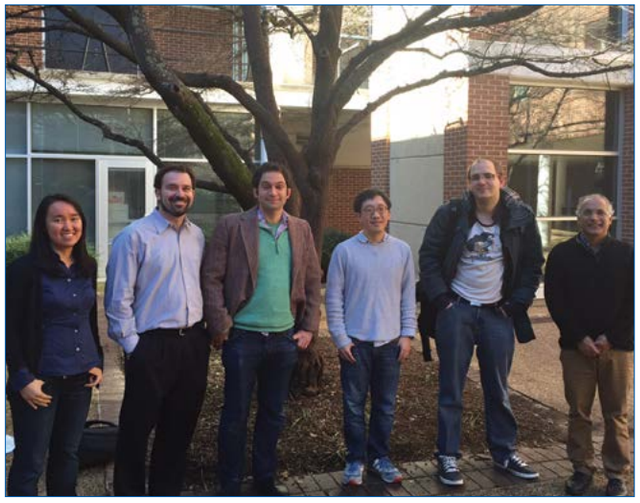
Professor **Matt Baker** was a featured speaker at the Benjamin Peirce Centennial Conference, held at Harvard University. This prestigious gathering of mathematicians included Fields Medalists and other leading researchers, and celebrated 100 years of the Benjamin Peirce fellowship.

July 11-15, 2016
Summer School on Real Algebraic Geometry and Optimization

Georgia Tech hosted the Summer School on Real Algebraic Geometry and Optimization, organized by Professor **Greg Blekherman** and postdoc **Rainer Sinn** from Georgia Tech, and Professor Mauricio Velasco from Universidad de los Andes, Bogotá, Colombia. The summer school is aimed at graduate students and recent PhD's with the goal of introducing them to the latest developments in the theory of nonnegative polynomials and sums of squares and applications. Professor **Josephine Yu** was a guest lecturer at the summer school.

Hodge Theory Conference

by Matt Baker and Josephine Yu

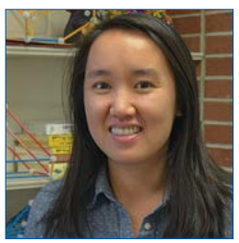


Graphs are a collection of vertices, some of which are connected by edges. If G is a finite graph (that is, if G has a finite number of vertices), a proper coloring of G with n colors is a way to color the vertices of the graph using n colors in such a manner that no two vertices that share an edge would have the same color. The celebrated four-color theorem asserts that if G is planar then there is at least one proper coloring of G with 4 colors. Hassler Whitney proved in 1932 that the number of proper colorings of G with n colors is a polynomial in n, called the chromatic polynomial of G. For example, if G is a 4-cycle graph (where four vertices are connected cyclically by four edges), the chromatic polynomial is $n^4 - 4n^3 + 6n^2 - 3n$. Ronald C. Read conjectured in 1968 that for any graph G, the sequence of (absolute values of) coefficients of the chromatic polynomial is unimodal: it goes up, hits a single peak and then goes down. (In our 4-cycle example, the sequence in question is 1,4,6,3.) Read's conjecture was proved by June Huh in a tour-de-force 2012 paper making heavy use of methods from algebraic geometry (an apparently unrelated field).

Huh's breakthrough left open the more general Rota-Welsh conjecture where graphs are generalized to matroids and unimodality is strengthened to log-concavity. It would appear that Huh's techniques are totally unworkable in the general context of matroids, since there is no underlying algebraic geometry to relate the problem to. But last year, Huh, together with Karim Adiprasito and Eric Katz, announced a proof of the Rota-Welsh conjecture based on revolutionary new techniques. The authors first proved that the Rota-Welsh conjecture would follow from combinatorial analogues of the Hard Lefschetz Theorem and Hodge-Riemann relations in algebraic geometry. For representable matroids (for example, the ones coming from graphs), this strategy can be implemented using the theory of toric varieties (a part of algebraic geometry). However, representable matroids have density zero in the set of all matroids, and in the non-representable case there is no corresponding toric variety. What Adiprasito, Huh and Katz managed to do was develop an elaborate and ingenious inductive procedure to prove the combinatorial Hard Lefschetz Theorem and Hodge-Riemann relations using the geometry of matroids and their Bergman fans.

In January 2016, Professors Matt Baker and Josephine Yu organized a weekend workshop at Georgia Tech called Hodge Theory in Combinatorics to celebrate this breakthrough and learn about the details of the proof. All three authors came and presented their new result, along with background material and motivation. There were about two dozen participants, including students and researchers from Georgia Tech, Emory and the University of Georgia, as well as mathematicians from Tennessee and Mississippi.

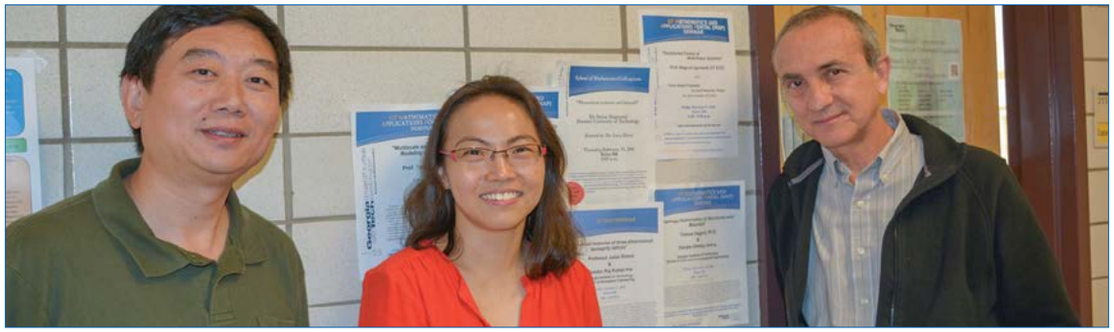
Matt Baker



Josephine Yu

GT-MAP Conference

by Luca Dieci



The School of Mathematics, with the support of the College of Sciences, launched the Georgia Tech Mathematics and Applications Portal or GT-MAP initiative in January 2016. By and large, GT-MAP has a twofold purpose. First, it will help increase collaboration between the School of Mathematics and other campus units, and make SoM a more effective research partner of the broader community at Georgia Tech. Mathematicians will become better aware of exciting research carried out in other schools across campus, while at the same time the larger campus community will become better aware of the intellectual resources, strength and diversity that SoM can offer. Second, GT-MAP will create a stable entity where researchers from the Georgia Tech community can present their work, share ideas and learn what their colleagues across the campus are doing.

Under the umbrella of GT-MAP, there are monthly seminars and a yearly workshop. Each spring and fall semester has a scientific emphasis, as described below, and there is a three-day workshop at the end of the summer semester, which serves as a prelude to the fall's scientific emphasis. You can see GT-MAP's official website **gtmap.gatech.edu** for past and future seminars.

This spring, seminars were given by distinguished faculty from the engineering units, who also provide leadership and input to GT-MAP and form the "outer core" of the GT-MAP structure.

The outer core is complemented by a large "discussion group" within the School of Mathematics, and communication and logistics are handled by the "points of contact" within the School: Professors Luca Dieci, Sung Ha Kang and Haomin Zhou.

In the summer, from August 17 till 19, we will host the first workshop under the GT-MAP umbrella, on the topic of "Materials," which will also be the emphasis of the fall semester seminars. Next spring, the emphasis will shift to "Dynamics," with an anticipated workshop next summer on the same topic, followed by a thematic semester on "Control" For 2018, we are planning thematic semesters on "Transport and Networks."

GT-MAP is a first for the School and for the Georgia Tech campus. Unlike for other initiatives, which are theme-centered, a main expectation is for GT-MAP to become an inclusive focal point of discussion and collaboration on campus in the broadest sense possible, and to eventually be the avenue by which new mathematics will be created for emerging technologies.

Our vision has thus far received the enthusiastic support of well over 40 faculty from across the campus (to which one should add more than a dozen from the School of Mathematics), half a dozen School Chairs and generous support from the Dean of the College of Sciences. More than 30 faculty have expressed their willingness to present their research, under the umbrella of GT-MAP, from just about every unit in the Colleges of Sciences, Computing, Engineering and Architecture.

We expect that in a few years GT-MAP seminars and workshops will be the most established permanent appointment for the Georgia Tech scientific community. In short order, we expect to be able to also attract funds to sponsor graduate students and postdoctoral fellows working on GT-MAP initiatives.

For further information or details, please feel free to email or call Luca, Haomin or Sung Ha.

Staff Profile Matt Hanes

by Lew Lefton

There's a connection between one of the best burgers in Atlanta and the Georgia Tech School of Mathematics. The Imperial, a popular local pub in Decatur, was recently selected by Zagat's as serving one of "Atlanta's 10 Best Burgers Under $10." When you go there, you may see one of our IT support staff members, Matt Hanes, who is a co-owner of the restaurant and bar.

For the past ten years, Hanes has been helping the faculty, staff, students and guests of the School of Mathematics with all manner of technical support. His strong technology skills, friendly personality and commitment to providing the highest level of support have made him an important part of our computer support group, which is widely respected across the campus for excellence and leadership. Hanes doesn't just do desktop support. He is also very knowledgeable about networking, server and storage architectures, and advanced collaboration tools including our increasingly popular video conferencing facilities.

Hanes grew up as the son of a mathematician and a librarian in Richmond, Indiana. In 1985, he graduated from Earlham College, where his father taught, with a degree in art. After a stint in New York City, Matt came to Atlanta in 1987. He worked at a wide variety of jobs, ranging from rock band musician and bartender at the Euclid Avenue Yacht Club in Little Five Points to the technical manager of a team of software developers. He was also part of two startups before joining the School of Mathematics in 2005.

Hanes' many interests include cooking, music and baseball. Incidentally, he and his wife were at the stadium for many of the important Braves events in the early '90s, including Otis Nixon's 1992 centerfield catch, the 1991 Mercker/Wohlers/Pena no-hitter and Sid Bream scoring from second to clinch the 1992 National League Championship Series. He also cost his wife, Jeanne Canavan, a foul ball during the 1991 playoffs—this is not discussed at their house.

In 2012, Hanes teamed up with three longtime friends to open the Imperial. The Oakhurst neighborhood embraced the venue with its comfortable ambiance and patio. For Hanes, it was a great opportunity to develop his already significant skill in creating delicious food. He sometimes even spends weekends baking cakes for the restaurant.

Hanes and his wife are raising two teenagers. Jenna will be starting her second year at the University of Georgia and Stephen is a junior at Decatur High School. Their family is rounded out by two pug mixes, Charlie and Lily.

So the next time someone in the School of Mathematics needs help on a problem with email or advanced mathematical software support, he or she will find that the person helping out makes the complex job look like a piece of cake!

Lew Lefton

Graduate Program News 2016

by Mohammad Ghomi, Director of Graduate Studies

It has been an eventful and exciting year in the life of the graduate program. Since I assumed the position of graduate director in the summer of 2015, ten graduate students have successfully defended their PhD dissertations through the spring of 2016. Of these, six have secured postdoctoral positions at UC Berkeley, UCLA (two students), Georgia State University, Queen's University and the University of Minnesota, while the rest have started jobs at JP Morgan and NCR Corporation, among other companies. Furthermore, two first-year PhD students, Samantha Petti and Justin Lanier, were awarded National Science Foundation (NSF) graduate fellowships, which account for two of the three such fellowships awarded to the entire College of Sciences last year.

Mohammad Ghomi

As always, a large part of our energies is devoted to the recruitment of promising and outstanding students. Last year, we received a record 240 applications for our PhD programs, a 13% increase over the previous year. The graduate committee, composed of Greg Blekherman, Ernie Croot, Plamen Illiev, Ionel Popescu and Andrzej Swiech, worked diligently to admit 30% of these applicants, a quarter of whom accepted us in return, resulting in an incoming class of 19 students, which matches the largest incoming PhD class we have ever had. A total of 27 admitted students visited the school in February and March and met with at least four faculty members each, as well as several graduate students. Many thanks to all the faculty and students, including the graduate committee's student representative, Shane Scott, who helped host these visitors.

Out of the 19 students in the incoming PhD class, ten will be Mathematics students, six will be in the Algorithms, Combinatorics & Optimization (ACO) program, two will be Computational Science and Engineering (CSE) students, and one will be a Quantitative Biosciences (QBios) student. Five among the 19 are female students. This class includes one of our own master's students, Cvetelina Hill, who was promoted to the PhD program after passing a qualifying exam in her first year. The international students in this group hail from China, South Korea, Mexico and Columbia. Two students are from Jilin University, China, who had visited the School the previous year, and four others had completed their undergraduate or master's degrees here in the US. We also expect nine new master's students in the fall: four mathematics, two statistics, and three CSE students who were chosen from a total of 123 master's applications.

We expect to have a total of 86 PhD students enrolled in fall 2016, which marks the largest our PhD program has ever been. Despite that, with 61 permanent faculty members, our student-to-faculty ratio remains quite low compared to those of our peer institutions, thus ensuring that our students continue to receive plenty of individual attention during the course of their studies. Given the size of our faculty, we are well positioned to grow the PhD program even further by increasing our admissions yield rate, especially among domestic students. To this end, we will need to increase the stipends, which have not kept pace with the rise in fees and living costs in Atlanta. More important, we need to significantly reduce our teaching loads in order to compete for the best students. Securing the resources needed to achieve these goals is our highest priority.

In other news, Mitchell Everett has joined Marty Engman and me as a member of the graduate staff, replacing Kenya Payton, who left the School last spring after two years of service. Mitchell brings extensive experience from his former position as academic advisor to students at the University of Maryland and will help us become more effective and efficient.

It has been a fulfilling and highly instructive experience to serve the School as the graduate director for the past year, and I have enjoyed my interactions with students and faculty in that capacity. I look forward to utilizing these experiences to further grow and strengthen the graduate program in the coming year.

Graduate Profiles

Justin Lanier and Samantha Petti

by Sneha Subramanian

Justin Lanier and **Samantha Petti** have more in common than being first-year graduate students at the School of Mathematics. First, they have both done us proud by winning the immensely competitive National Science Foundation (NSF) Graduate Research Fellowship. Second, the summer before starting their PhD studies, both worked at Bridge to Enter Advanced Mathematics (BEAM) in Upstate New York. BEAM is a math program for talented but underserved middle schoolers who live in New York City. Justin was an instructor and Samantha was a counselor and teaching assistant.

After graduating from St. John's College, Maryland, with his bachelor's degree in liberal arts, **Justin** spent ten years teaching mathematics in middle and high school before he decided to pursue a PhD in math. He says, "Over the course of those years, I met a number of PhD mathematicians who were pursuing all kinds of professional paths—professors at research universities and liberal arts colleges, high school teachers, curriculum developers, and people involved in math outreach. And I really liked these people! That is how going to grad school for math became an attractive path for me."

Justin began his PhD here in Fall 2015 and has been working with Professor Dan Margalit. His areas of interest lie in geometry and topology, as he is attracted to topics in mathematics that have a strong visual component. "I spend a lot of time thinking about the shape that is the surface of a doughnut, or a doughnut that has many holes instead of just one. Surfaces like these have many symmetries, and they interact in intricate ways. You could compare it to the moves of a Rubik's Cube. Some of the symmetries of surfaces have infinite order, the same way that you can translate a number line endlessly. Other symmetries have finite order, the same way that rotating a square four times brings you back to start. A research project that I pursued this year answered some questions about whether you can build every symmetry of a surface—its entire mapping class group—out of just a few finite-order symmetries." He describes the said research question as akin to trying to solve a Rubik's Cube where one is only allowed to use a handful of moves.

Samantha had always been interested in mathematics and enjoyed the idea of being able to solve open problems in mathematics as a career. Her experience in Budapest, where she spent a semester in 2013 taking advanced courses in discrete mathematics and combinatorics, and her involvement in various undergraduate math programs, summer schools and labs only cemented her desire to learn and discover more in this field. After earning her bachelor's degree in mathematics from Williams College, Williamstown, Massachusetts, Samantha started her PhD studies at School of Mathematics' ACO (Algorithms, Combinatorics, & Optimization) program at Georgia Tech, which is ranked as one of the best in the country.

Samantha has already worked on several projects at Georgia Tech, including one about neurally plausible computation. She describes her project here. "Neurons in the brain form a highly distributed network. This architecture suggests that the algorithms neurons use to achieve cognitive functions must be very localized. In other words, each neuron only communicates with a relatively small set of nearby neurons. Inspired by this local restriction, we asked the following question: Using only the boolean AND and OR operations, what functions can we compute in such a local manner?"

Professor Santosh Vempala, who is Samantha's PhD advisor, says, "Samantha Petti is an exceptionally gifted student, in terms of both technical and creative abilities. It has been a delight to work with her over the past year. I look forward to her achievements and discoveries in coming years, and to learning much from her."

If you think the life of a mathematics graduate student is all work and no play, think again! Justin has continued his passion for math education, and during his spare time writes a math blog called Math Munch. Likewise, Samantha enjoys sculpture, hiking and water polo.

The School of Mathematics is proud to have Justin and Samantha in our program, and we are excited to see these two gifted and hardworking students grow and evolve as mathematicians.

Sneha Subramanian

Graduate Awards
September 2015–July 2016

Justin Lanier and **Samantha Petti**, both first-year graduate students at the School of Mathematics, have been awarded the highly competitive **National Science Foundation (NSF) Graduate Research Fellowship**. The NSF Graduate Research Fellowship Program provides support to outstanding graduate students in STEM fields.

Scott Shane was nominated for the **CETL/BP Outstanding Graduate TA**, and **Ishwari Kumar** was nominated for the **CETL/BP Outstanding Graduate Instructor**.

The School of Mathematics Graduate Student Awards: Spring 2016

Festa Fellowship: **Justin Lanier**
The award includes a cash stipend to the student who shows superior academic and leadership skills.

Outstanding Student Evaluations: **Betsie Last**, **Haiyu Zou**, **Alex Hoyer** and **Joseph Moravitz**

These students received certificates honoring the exceptional student survey responses on their recitations.

SoM Best PhD Thesis: "Symmetric Ideals and Numerical Primary Decomposition" by **Robert Krone**.

SoM Top Graduate Student: **Chenchen Mou**
Awarded for evidence of superior academics and achievement.

SoM Outstanding Graduate Teaching Assistant: **Hagop Tossounian.**

Undergraduate Program News Fall 2016

by Matt Baker, Director of Undergraduate Studies

The undergraduate program in the School of Mathematics is undergoing a number of changes right now as a result of detailed planning and discussions by the undergraduate committee. I would like to highlight some of these changes, with the caveat that they have been endorsed by the faculty of the School of Mathematics but have not yet received Institute approval.

The first, and perhaps biggest, change is that we plan to introduce a new undergraduate degree in mathematics, which will replace the current degrees in applied mathematics and discrete mathematics. The School of Mathematics has changed dramatically over the past 20 years, and we feel that the name of our degree should reflect the broad range of interests of our faculty and students. The new degree will feature optional concentrations in applied mathematics, probability and statistics, discrete mathematics, and pure mathematics. Course requirements will be updated to reflect changes in our curriculum over the past several years. We hope that the new degree will not only provide more flexibility and a better education for students, but also attract more students to major in mathematics. The changes to the major will be accompanied by corresponding changes to the math minor, which we also hope will result in increased student participation.

Matt Baker

The School of Mathematics has also responded favorably to a recent proposal from the School of Economics to introduce a new degree program in economics and applied math.

There are plenty of other changes in the works as well:

- We plan to offer two new undergraduate courses in probability and statistics, which will be more mathematically rigorous than the current offerings.
- An effort has been underway over the past year or so to develop new repositories for material related to our lower-division undergraduate mathematics courses.
- We are piloting WebWork-based online homework for select classes.
- We are planning a Career Day during the 2016-2017 academic year to highlight the plethora of career options available to undergraduate math majors.

Stay tuned for more details on all of these developments! Many thanks to Igor Belegradek, Klara Grodzinsky, Michael Lacey, Karim Lounici, Joe Rabinoff, Martin Short, Enid Steinbart and Josephine Yu for their active participation in the undergraduate committee over the past year.

Several undergraduate math majors have won awards in the past year, including Wendy Jiang, who won the prestigious Nickelson-Sutherland Award from the Georgia Tech College of Sciences. Congratulations, Wendy!

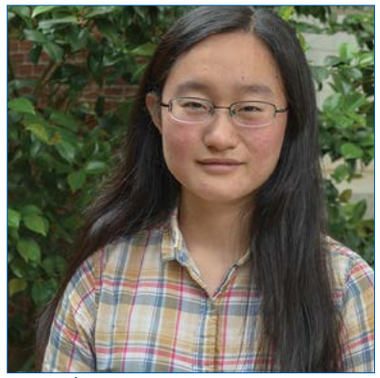
The School of Mathematics continues to be a leader in outreach efforts, running an REU (Research Experience for Undergraduates) program in Summer 2016 and a highly acclaimed Distance Calculus program throughout the year (as well as a post-Distance Calculus program), and organizing the annual Georgia Tech High School Math Competition, which as always attracted hundreds of students in Spring 2016. Our Club Math meets every week to discuss exciting undergraduate-level mathematics and puzzles, and almost 40 undergraduate students took the notoriously difficult Putnam Examination in December 2015.

There's a tremendous amount happening in the Georgia Tech School of Mathematics, and it's about to get even more exciting!

Undergraduate Profiles

Zixin (Wendy) Jiang and Riesling Meyer

Wendy Jiang graduated from Georgia Tech in Spring 2016. She came to Tech with a strong physics background, having participated in physics competitions in high school, and so it was quite natural for her to select physics as her major. After working on her first astrophysics research project with Professor Tamara Bogdanovic and on single atom trapping with Professor Michael Chapman, she realized in her junior year that she would need more knowledge in mathematics in order to go deeper into physics. This led her to declare applied mathematics as her second major. She says that the rigor and subtlety she found in her math classes made her fall in love with math.



Wendy Jiang

Soon, Wendy began taking advanced math classes, such as abstract algebra and algebraic number theory with Professor Joseph Rabinoff, graduate-level real analysis with Professor Wilfrid Gangbo, and complex analysis with Professor Kirstin Wickelgren. In the summer of her junior year, Wendy started working with Professor Igor Belegradek on the smoothness of the Minkowski sum, which was the first time she engaged in mathematical research. This experience taught her that, as much as she enjoyed working in a physics lab, mathematical research was what she truly wanted to do! This fall, Wendy will be starting a PhD in mathematics at the University of California, Berkeley.

Riesling Meyer graduated from Georgia Tech with high honors in Spring 2016 with a bachelor's degree in discrete mathematics. Her parents knew she was interested in math when in elementary school she starting calculating probabilities in backgammon, but Riesling really started pursuing math as a major after her math teacher, Mr. Kaczmar, from Lower Merion High School, encouraged her to attend the Rutgers Youth Scholars Program in Discrete Math.

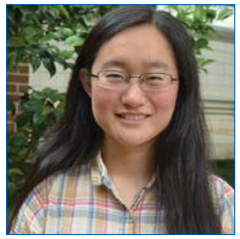
Riesling Meyer

While at Georgia Tech, Riesling worked as a teaching assistant in the College of Computing as well as a tutor in the GT athletics department. She was awarded the Mentoring through Critical Transition Points (MCTP) scholarship in 2012, and for her thesis, she worked on research in the quantitative psychology program with Professor James Roberts on misspecifications of data fitting to the multidimensional generalized graded unfolding item response theory model. In addition to her academics, Riesling has been a GT tour guide, the publicity manager of Club Math and a mentor with Money Think. She chaired the GT high school math competition, danced with DanceTech and started a charity knitting club.

Riesling will now be working as a business analyst at Capital One where she previously interned and competed in a case competition. She is passionate about teaching math and plans to continue that passion through community service.

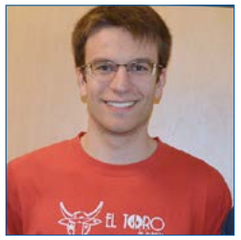
Undergraduate Awards

September 2015–June 2016



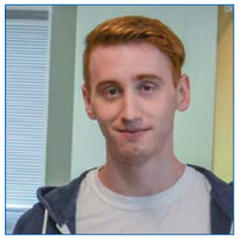
Zixin (Wendy) Jiang, who received bachelor's degrees in mathematics and physics, won the 2015 **A. Joyce Nickelson and John C. Sutherland Undergraduate Research Award**, which includes a $3,000 scholarship and a certificate. The scholarship recognizes excellence at the interface of mathematics and physics.

The award was created by a donation by Joyce E. Nickelson and John C. Sutherland to honor Joyce's late mother, A. Joyce Nickelson (MATH 1962), and the Nickelson's longtime friend, John C. Sutherland (PHYS B.S. 1962, M.S. 1964, PhD 1967). It is awarded to an undergraduate student who has jointly studied mathematics and physics, and who has engaged in scientific research.



Derek Kielty was the School of Mathematics nominee for the Institute-wide **CETL/BP Outstanding TA award in the Undergraduate TA category**.

Every year, the SoM undergraduate committee recognizes the achievements of our exceptional undergraduate math majors and the efforts of our excellent undergraduate teaching assistants (TAs).



Brandon Boggess and **Andrew McRae** each won a **2016 Outstanding Undergraduate Award** with stipend in recognition of their outstanding academic accomplishments as math majors. Both Brandon and Andrew graduated in the fall of 2015 with a perfect 4.0 GPA. Brandon received a BS in applied mathematics and will be pursuing a PhD in mathematics at the University of Wisconsin-Madison. Andrew received two bachelor's degrees—in applied mathematics and in electrical engineering—and is currently a master's student of electrical and computer engineering at Georgia Tech.

The **2016 SoM Outstanding Junior Award** with stipend was given to undergraduate **Kumbit Hwang**. Kumbit is currently finishing her degree requirements and conducting undergraduate research with Professor Sung Ha Kang. She is planning to graduate with a BS in applied mathematics in the fall of 2016.

The **2016 Outstanding Undergraduate TAs** were **Kabir Nakra** and **Thomas Ng** (not pictured). This award goes to graduating seniors who have excellent evaluations from students and faculty and have been good departmental citizens.

Based on 2015-2016 student survey responses on their recitations, the following undergraduate students received certificates honoring them as having **Outstanding Student Evaluations**: **Ross Schlegel**, **Markace Rainey**, **Frazier Woodruff**, **Aditya Ragunathan** and **Jared Kleinwaechter**.

Postdoc Program News 2016

by Michael Lacey, Chair of the Postdoc Committee

For the past several years, the School of Mathematics has seen a marvelous growth in our postdoc program. During the 2015-2016 academic year, we had fifteen postdocs. Their contribution to the School, and the School's efforts to train them, form a large component of the School's twin ambitions in advancing research and training the next generations of mathematicians and scientists.

Postdoctoral positions are very common in mathematics and other sciences. In brief, they are faculty-level appointments held by someone who is less than two years from receiving his or her PhD degree. For the postdoc, this comes after four years of undergraduate study and five years of graduate study, typically at a new university.

Usually, postdoctoral positions last for up to three years, during which the postdocs are expected to advance their standing in the field in both research and teaching. Recruited from a leading institution on the strength and ingenuity displayed in their PhD work, they should advance the research started in their PhD work by publishing results and approaching related problems. But they can also make new research connections with faculty and graduate students at Georgia Tech. Indeed, this sharing of information and perspective frequently has many interesting consequences. They also publish papers, present at conferences and engage in the School's very active seminar schedule.

Michael Lacey

All of the postdocs contribute to the School's teaching mission as well. Beginning with classes that are highly structured, they typically teach one class per semester, with the assignments growing in sophistication over their time at Georgia Tech. Our instruction covers both an enormous number of students and an enormous offering of courses, so postdocs have plenty of opportunities to teach a wide variety of courses, with a range of teaching methods.

The goals of the postdocs during their three-year appointment are broad, and there are several mechanisms that the School uses to ensure a successful tenure in the position. An initial orientation at the beginning of the appointment introduces the postdocs to the School, its activities and the expectations of the position. Initial teaching assignments are made to highly organized classes, with detailed syllabi, sample exams and course coordinators. The postdoc has a teaching mentor as well as a research mentor. The latter has research interests closely aligned with those of the postdoc and guides the postdoc in a wide set of important issues: which journal to publish a paper in; which conferences to attend; finding the appropriate mixture of research goals and objectives; how to write a grant; and how to manage the many competing demands for time. The School also organizes an annual review of each postdoc, overseen by the mentors and the School's postdoc committee.

The School has a large number of postdocs, and also a wide range of ways that they are supported. The School has only recently had budgetary lines devoted to postdoctoral researchers. These positions are called Hale Professorships, in memory of Professor Jack Hale, a distinguished member of the School's faculty from 1988 to 1998. To date, there have been 14 named Hale Professors. A second source of funds is grants awarded to the School's faculty that support postdoctoral positions. These grants can be standard research grants, or awards like a Sloan Fellowship or an NSF-CAREER grant. A third source of funds is grants that are specifically designed to recruit and train mathematicians. The School has one such current grant, the NSF-funded IMPACT award, which has recruited postdocs who are exposed to applications of mathematics, like combinatorics and mathematical biology, or analysis and signal processing.

The reward for all the postdocs' efforts is the satisfaction of establishing a presence in the international field of researchers and obtaining a tenure-track position. The last point again requires a move—to a fourth university—and another period of intense work and growth to obtain tenure there.

Postdoc Profile

Irina Holmes

by Sneha Subramanian

Hale Postdoctoral Fellow **Irina Holmes** faced an uncommon challenge when she arrived at Georgia Tech after completing her PhD two years ago. Coming from a probability background, she decided to change fields to harmonic analysis when she got here. This change was never going to be easy, as Irina describes. "It was very terrifying because I had never even taken a class in harmonic analysis while I was in graduate school. Basically I didn't sleep for a year and had to learn everything from the bottom up."

Irina's PhD thesis was based on Radon transform on infinite-dimensional spaces, which studies the cross-sections formed by cutting spaces with hyperplanes. This and the inverse Radon transform (which is essentially reconstruction of the space back from the cross-sections) form the basis behind CT and MRI scans as well as topography.

When Irina started her position at Georgia Tech, she was expected to work with the probability group on problems related to her PhD thesis. Instead, conversations with Professor Brett Wick, who was her teaching mentor at that time, steered her interest toward dyadic harmonic analysis. In harmonic analysis, wave signals are studied using complicated continuous operators such as Hilbert transform, Riesz transform and others, which are usually difficult to work with by themselves. Dyadic harmonic analysis uses approximations of such operators by what is known as the Haar function, which is discrete and a lot easier to work with.

Despite the hugely daunting task, Irina's diligence and hard work in learning this new field truly paid off. By the end of her first year at Georgia Tech, she had already submitted four papers on the new subject. She also won the extremely competitive National Science Foundation (NSF) postdoctoral fellowship for three more years of postdoctoral work. She says, "If you had told me when I first started this craziness, this changing fields thing, that it would have worked out so well, I wouldn't have believed it!"

Irina's phenomenal research work was by no means her only contribution during her time here. She also taught four courses over the past two years. Regarding her teaching experience, she says, "On one hand it has been very stressful, and a lot of work, but that is partly my fault because I put a lot of myself into teaching and can't help myself. However, the students here are the best part and they make it all worth it! The students at Georgia Tech have been absolutely amazing. There is always a small percentage of every class that is very good or exceptional, but in my experience, at Tech, the percentage of students that were just exceptional was unbelievably high. It is incredible how hard-working and curious they are."

This summer, Irina begins her NSF postdoctoral work with Professor Brett Wick at Washington University, St. Louis. We are sure that this young mathematician has a bright, promising future in front of her.

Sneha Subramanian

Postdoc Profile

Chunmei Wang

by Morag Burke

Dr. Chunmei Wang came to the School of Mathematics at Georgia Tech in the fall of 2014 as a new Visiting Assistant Professor, with Professor Haomin Zhou as her postdoc advisor. Before coming to Georgia Tech, Chunmei was working as an Assistant Professor at Nanjing Normal University Taizhou College, in her hometown of Taizhou, China. She received her PhD from Nanjing Normal University in Nanjing in 2014 under the supervision of Dr. Junping Wang and Dr. Jinru Chen.

Dr. Junping Wang, with whom she has collaborated many times even after receiving her degree, had developed a new numerical method called the weak Galerkin finite element method (WGFEM) that can be used to solve partial differential equations (PDEs) efficiently. Chunmei worked with him to develop an improvement to WGFEM, called the primal-dual weak Galerkin finite element method.

When she started working with Professor Zhou at Georgia Tech, she discovered that she could actually use these methods to solve problems in their first project. By the end of September 2014, she had achieved good preliminary theory results. Encouraged by these and further numerical tests, she decided to apply for her first National Science Foundation (NSF) research grant. Her grant application was successful and she was awarded the grant in 2015.

Later that year, Chunmei received a second NSF grant, this time to support a conference she organized together with Dr. Andrew Gillette from the University of Arizona. The conference was called "Polytopal Element Methods in Mathematics and Engineering," and was based on three methods, including WGFEM. The purpose of this conference was to promote communication among the many mathematical and engineering communities currently researching polytopal discretization methods for the numerical approximation of solutions of PDEs.

The workshop-type environment at the conference aimed to foster a community-wide understanding of the comparative advantages of each technique, and assist in the development of a set of "best practices" in regards to implementation. For more information about the conference, you can visit the conference website: **http://poems15.gatech.edu/**.

To say that the conference was successful would be an understatement. There were 54 participants, affiliated with 28 universities, from six countries and four national laboratories. The attendees were academics who proposed and developed the methods. There were four plenary talks, 20 invited talks and 16 posters by students and postdocs. While the NSF grant provided travel support for most of the participants, the School of Mathematics supplied space, catering and supplies.

Chunmei accepted a tenure-track position at Texas State University, beginning in Summer 2016. Her new position, she says, brings new challenges in teaching, research, applying for the NSF career grant and other research grants, organizing seminars and conferences, and finding new collaborations. Given her achievements so far, we have no doubt that she will succeed in each and every challenge!

Morag Burke

Life After Retirement: Rena Brakebill

by Cathy Jacobson

When we enter the foyer of the Peachtree Branch of the Atlanta-Fulton Public Library System located opposite the High Museum, a beautiful origami art installation titled "Tale of the Phoenix" by Rena Brakebill pops from the wall. Looking more closely, we see that the installation, a colorful phoenix rising out of an open book, is composed of approximately 1,300 individually folded origami pieces. There are butterflies, beetles, bats, flapping cranes, ducks, peacocks, pheasants and doves, each species with its own color and each folded from a single sheet of paper. What an amazing paper mosaic!

In addition to her mathematical skills, our former colleague, Rena, has had many craft and art interests, and members of the School of Mathematics were often the lucky recipients of her creations. After her retirement, Rena began exploring origami in 2010 when our *ProofReader* graphic designer, Janet Ziebell, asked her to help create a pentagonal-base twisted star for a College of Sciences card, and she did so using origami.

She continued to research and learn more about the topic, and by 2011, Rena had checked out so many books on the subject that it prompted the Children's Librarian, Ken Vesey, to ask her to conduct a summer origami workshop for elementary and middle school students at the Peachtree branch. Its success led to the formation of an origami club in 2012 that is supported by the Friends of the Library who supply the paper. See the club schedule listed under Events and Classes at **http://www.afpls.org/peachtree-branch6**.

Word spread, and the monthly Saturday sessions have been attended by Georgia Tech faculty and Chinese visiting research scientist families, as well as others living nearby and some driving in from Dunwoody and Peachtree City. Currently, the club has expanded to include three origami teachers, Lolita D'Souza, Mary Jane Kettler

and Rena, who meet with 15 - 25 children, parents and grandparents at each Saturday session.

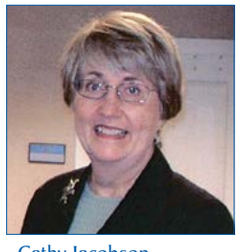
Cal Gaugh, the former Peachtree Branch manager, had also noticed Rena's interest and linked her to Origami Graffiti, being practiced by an artist in Paris. See https://www.visualnews.com/2012/05/25/origami-graffiti/. He suggested that she might create something similar for the entrance lobby, and thus the installation "Wings of Paradise" (2012) was born.

Rena found the design on a tattoo web site, and translated it into around 1,000 origami pieces, and then folded each one. (Her second installation in 2014, "Tale of the Phoenix," required even more pieces, and her eighth-grade former neighbor and accomplished folder, Dhruv Mehra, helped out.) The project involved submitting a proposal using eight colors, one color per winged creature shape, and after its approval, creating a full-sized model by laying out the pieces, cutting sheets of plastic to back the model, gluing each piece to the backing and transporting it to the Library in sections that were then joined and hung on the wall with the help of her husband, Ken.

What do you give a person who has everything? Perhaps an origami holiday ornament, card or earrings that Rena folds and then sells at the Paideia Art Visions show each November, or perhaps one of Rena's shadow box framed dioramas featuring folded origami pieces. Some of her favorite commissions are a diorama of a lady's garden in Provence featuring all five of her pet dogs and a six-month anniversary celebration diorama that featured hearts, flowers and a dress, folded using two-dollar bills and arranged in the shape of a 6!

Rena noted that origami was once thought of as just a traditional Japanese craft or kid's project. (In fact, the Japanese word "origami" comes from "ori" meaning to fold and "kami" meaning paper.) However, origami appeals to a wide range of professionals such as research scientists, mathematicians, engineers, computer scientists, educators and artists. She noted that interesting applications are being made in medicine, such as the origami-designed collapsible heart stent. (See http://www.popsci.com/article/science/robots-retinas-9-amazing-origami-applications and be sure to watch Robert Lang's TED Talk about origami in math and science.)

Since 2013, Rena has attended regional and national origami conventions where she continues to learn, create and share the art of origami. She has volunteered as an origami instructor at the Global Village Project, a middle school for refugee girls in Decatur, been a visiting "math folder" for grades K-2 in Gwinnett County and a resource origami artist leading high school students in Clayton County. In addition, Rena has developed an "origametry" (origami and geometry) workshop for elementary and middle school students. To date, she has presented it at the Peachtree Branch Library, the Ponce de Leon Branch Library and the Paideia School.



Cathy Jacobson

When folding origami, Rena finds pleasure in the beauty of the individual product and the joy in mastering a technique that takes a lot of effort. She looks forward to seeing the model come to life, but most of all she enjoys the excited reactions of children when she arrives for a special folding project. Perhaps one of those students will become the next mathematical origamist!

Here are Rena's favorite origami sites:

https://origamiusa.org
http://www.happyfolding.com
http://www.origamispirit.com
http://langorigami.com

Friends of School of Mathematics (FoSoM)—Dan Sanders

Dan and Phaleiny Sanders

After completing his undergraduate studies at Mercer University, the small Baptist college in Macon, Georgia, and after his marriage to fellow Mercer student Phaleiny, Daniel P. Sanders arrived at Georgia Tech in the fall of 1990, supremely confident of brilliant success, but not having any real idea of what was actually involved in achieving his goal of a PhD from the School of Mathematics.

After all, research was not present at Mercer.

The Chair of the Department of Mathematics at Mercer, Professor Emory Whitaker, was a wonderful teacher, but also acted in the college plays at Mercer and won many local bridge tournaments. And so it was a big change for Sanders as part of his Presidential Fellowship to get involved immediately in a graph theory research project with Professor Robin Thomas.

While most of the research at the School of Mathematics was in applied fields, Sanders was happy to stay in pure mathematics. His favorite math classes at Mercer had been symbolic logic and non-euclidean geometry. In fact, when an elder SoM professor found out that Sanders had never taken a class in differential equations, he insisted that Sanders teach one (but that never happened). Since he had also majored in computer science at Mercer, the new Algorithms, Combinatorics & Optimization (ACO) program just set up by Professor Richard Duke seemed a perfect fit. Through the guidance of Duke, his advisor Thomas and Professor Xingxing Yu, Sanders was able to be the first graduate of the ACO program. Although his thesis was on a graph algorithm, his subsequent math research was mainly in graph coloring. His favorite result was a new lower bound on the number of edges of graphs critical for edge coloring.

Sanders was happy to continue doing math research in academia, and had temporary positions at the math departments of Ohio State and Princeton, but a permanent job was not forthcoming. So in 1998, he decided for the first time to try applying to jobs in industry.

These included a software company that produced war games for the military, a think tank in Washington, DC, and a hedge fund on Long Island. The last of these is where he is still working today—Renaissance Technologies, founded by mathematician James H. Simons. No longer could Sanders spurn applied mathematics, for graph theory isn't that useful in finance. Although his first projects were mainly in computer science, he quickly switched over to becoming an applied mathematician. This involved begrudgingly ignoring details and approximating. This was a new world where being simpler could be better than being more correct.

Daniel and Phaleiny split time between Long Island and Charlotte. Their daughter just graduated from Massachusetts Institute of Technology (MIT) with a degree in mathematics. She will enter Georgia Tech in the fall, to pursue a PhD in industrial and systems engineering. Their two teenage sons are interested in video game art and design. Sanders enjoys reading comics, running and watching NCAA football. He is excited for the Mercer-Tech game in the fall and has decided to wear orange and black to Bobby Dodd Stadium.

Alumni News

Daniel Connelly (BS Applied Mathematics, 2009, and MS Computer Science, 2012)

I have been working at Google as a software engineer for a while now. After having worked on Chrome for a few years in Germany, I currently lead a small team in New York working on Maps. The other day I had to use the inclusion-exclusion principle for something at work, so I guess things are pretty okay. My wife is doing a PhD in political science at the City University of New York, and we live in Brooklyn, New York.

Blacki Li Rudi Migliozzi (BS Discrete Mathematics, 2009, and MS Human-Computer Interaction, 2012)

Blacki Migliozzi is a data visualization developer for Bloomberg Graphics. He had previously spent time designing and prototyping small-scale agricultural technologies. His interest in the intersection of biotech and agrarian practices made him an ideal member of the team Genspace which won the gold medal for their project "SuperFUNd Gowanus!" at the International Genetically Engineered Machines Competition (iGEM) in Boston, Massachusetts, on September 24-28, 2015. According to the RiverKeeper website, the Gowanus Canal in Brooklyn, New York, is one of the most heavily contaminated water bodies in the country. The team built a working biosensor of sewage contamination to alert the surrounding community of water contamination once the canal undergoes its scheduledSuperFund-mandated cleanup.

In March 2016, Blacki co-developed and designed for *Bloomberg News* an interactive infographic piece, "What's Really Warming the World?" The piece won the special Malofiej prize for the best online publication in the Climate Change and Environmental Commitment category.

Michelle Delcourt (BS Discrete Mathematics, 2011)

Michelle Delcourt is currently a National Science Foundation (NSF) Graduate Research Fellow at the University of Illinois at Urbana-Champaign, working with Professor Jozsef Balogh in combinatorics. In the Association for Women in Mathematics, she served as Vice President (2012-2014), President (2014-2015) and Outreach Director (2015-present). In the Illinois Geometry Lab, she served as Associate Manager (2013-2014) and Outreach Manager (2014-present). In these positions, Michelle has organized three four-day Girls Engaged in Math and Science Workshops for middle school girls, six day-long Sonia Math Days for high school girls, over thirty field trips with local schools (reaching over a thousand participants) and five training sessions for local teachers. Michelle received the Graduate Student Leadership Award from the Graduate College in April 2016. As part of her graduate studies, Michelle also studied abroad in Hungary for six months; her research accomplishments have earned her invitations to speak at research seminars, conferences and workshops in the US, Canada, Hungary, Switzerland, Germany and France.

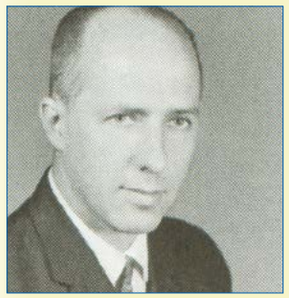
We owe a particular debt of gratitude to Rena Brakebill, who helped us track down some of our far-flung alumni and shared their good news with us. Many thanks, Rena, for staying in touch!

Ricardo Restrepo (PhD Mathematics, 2011)

After graduating from Georgia Tech, under the direction of Prasad Tetali, I had a postdoctoral position at the University of Toronto under Michael Molloy. Currently I work as an Assistant Professor at Universidad de Antioquia (Medellín, Colombia) and as a "math scientist" for the quantitative modelling company Math Decision. Since I joined Math Decision two years ago, it's been a challenge to be involved jointly in academia and industry, but it is certainly a great experience and I am getting the best of both worlds. It is especially gratifying to construct practical tools that are used day to day. In particular, I've had the opportunity to lead development teams to build actuarial software tools for pricing and reserving, as well as statistical learning tools used to identify fraudulent transactions, money laundering activities, energy fraud, etc. On the other hand, I stay active in academia, having the opportunity to interact with talented undergraduate and graduate students. My research area is probability and its applications (especially to discrete math and algorithms), and certainly, given my industry experience, I've added several statistical problems originated from real-world applications to my research repertoire.

Obituary for Roger D. Johnson

Professor Emeritus Roger D. Johnson Jr. passed away on April 22 in his hometown of Atlanta. Roger's early interest in mathematics led him to major in the subject at Dartmouth College and to pursue a doctorate at the University of Virginia. He was hired by Georgia Tech immediately after receiving his degree and spent the next 38 years in the School of Mathematics until his retirement in 1994. He was a lifelong Unitarian and one of the founders of an environmental outdoors group, Ens and Outs, within his church. Ens and Outs collaborated with other environmental organizations to help protect Georgia's mountains and parks. Roger had a special interest in the state's water resources, serving as a member of the Georgia Water Coalition. Other environmental groups to which he actively contributed were Earth Ministry and the Northwest Endowment Committee. Friends described him as an "earth champion" and "the mainstay of his church's earth ministry." Roger is survived by his wife, Jean, two daughters, three grandchildren and a great-grandchild.



Source: *Dartmouth Alumni Magazine*

Obituary for Timo Eirola

It is with great sorrow that we give you the sad news that our friend and colleague Timo Eirola passed away on May 15, 2016. Timo was just shy of his 65th birthday, and had recently retired from Aalto University (formerly Helsinki University of Technology).

During the past 20 years, Timo visited the School quite often, including a long sabbatical in the academic year of 1996-97. Timo's career spanned more than 30 years, with professor positions at Helsinki University of Technology, Joensuu University and Aalto University. He had long-term visiting positions at Leningrad State University, the Banach Center, Mittag-Leffler Institute, University of Geneva, the MSRI and Georgia Tech. He authored influential works on several different problems in numerical dynamical systems, methods for differential equations, numerical linear algebra and smoothness of wavelets.

Those of us who have had the fortune to know him well for more than 30 years will badly miss him, his quick wit, beautiful mind and friendship. He is survived by his wife, three sons and several grandchildren. Please keep him and his family in your thoughts.

by Luca Dieci

Notes from the ProofWriters

Dear Reader,

The ninth volume of our beloved newsletter has attempted to give you yet another glimpse into life at the School of Mathematics at Georgia Tech. While every new academic year brings new excitements and new challenges, the past couple of years could not have been more eventful for the School. We have completely revamped our calculus curriculum, remodeled our bachelor's degree and expanded our PhD program. We have initiated programs to facilitate cross-campus research collaborations in the form of GT-MAP and conducted important research in a wide variety of mathematical fields, including solving famous longstanding conjectures. We have continued with and built upon our efforts to improve diversity in the mathematical sciences. And as in every year, we have taught thousands of students various topics of a subject that we hold dear to our hearts.

This ninth volume also brings a new Editor-in-Chief, Dr. Sneha Subramanian, following Ms. Cathy Jacobson's retirement last year. We are incredibly grateful to Cathy, who is a founder of *ProofReader* and served as its Editor-in-Chief for eight straight years since its inception. Despite having the option of enjoying a pleasant life after retirement, she has continued to stay involved in the creation of the newsletter by writing a beautiful article, editing many others, and regularly providing inputs and suggestions along the way.

We are also thankful to Ms. Rena Brakebill for the invaluable help she gave with regards to tracking alumni information and writing alumni blurbs. College of Sciences Assistant Dean Dr. Lew Lefton has been very kind to let us continue sharing his office space. A special thanks to all the writers and contributors and to the members of the Communication, Development and Outreach (CDO) Committee. Professor Prasad Tetali, our interim Chair, has been enormously patient and highly responsive; without him there would be no *ProofReader* this year. And last, but in no way least, we thank our graphic designer Ms. Janet Ziebell for yet again creating a beautiful finished piece that is pleasing to the eye.

We hope you enjoyed reading our newsletter. We look forward to hearing your feedback on the stories that appeared in this edition or anything else you wish to share with us. You can reach us at **editors@math.gatech.edu.** —Sneha Subramanian, for the Editorial Team

Why Make a Gift?

The short answer is this: your gift can have a large impact on the education and research efforts of the School of Mathematics. Below are some of the many ways this can happen.

A longstanding goal of the School is to have a program of named postdoctoral fellows. These positions are the route to a permanent appointment at a top institution (such as Georgia Tech). Securing sufficient funds to sponsor a permanent postdoc program is a long-term project requiring significant effort, but it promises to contribute greatly to the School's progress into the top ranks worldwide.

A central part of the mission of the School of Mathematics is teaching, and we have a very talented and dedicated teaching faculty. Recognizing the best of them through awards for excellent teaching and mentoring underlines the importance of these efforts and encourages even more excellence. A named award would be a great way to remember an alumnus or former faculty member who had a big impact on your life.

Our graduate students are integral to all of the efforts of the School—from teaching to research to outreach. They are also the future of the discipline. Supporting them with scholarships, thesis prizes, travel-and-professional-expense funds or other small gifts has a large impact on the School and the discipline.

Everyone knows that college affordability is a serious issue for many families. Funds for undergraduate scholarships help support deserving students as they work toward a very valuable degree.

The High School Mathematics Competition is an inspiring event where students gather with others interested in mathematics and compete for scholarships. It is run entirely by undergraduate and graduate student volunteers, with scholarships supported by corporate and private donations as well as a federal grant. Contributions toward prize money or operating expenses help ensure that this event continues and inspires the next generation. See **http://hsmc.gatech.edu.**

We're very grateful for help in all forms, large and small, from our friends. If you would like to contribute to any of the efforts mentioned above or discuss other possibilities, please get in touch.

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Share Your Story with *ProofReader*!

Dear Alumni,

We need your news!

What's going on in your professional or personal life?

Please go to **www.math.gatech.edu/shareyourstory** and send the following updated contact information along with your news.

Name:

Degree and Class:

Email Address:

Snail Mail Address (new?):

Your News:

Or you can email the same to **editors@math.gatech.edu**.

We need your photos too.

You can upload a recent high-resolution (300 dpi minimum) photo of yourself at the website or attach it to your email. If the photo was taken on a cell phone, send the "full" size or largest size available.

When your submission is accepted, we reserve the right to edit it for length and style. Be sure to check the box on the website giving us permission to use the material in the next issue of *ProofReader*.

We hope to hear from you soon!

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