Notices

of the American Mathematical Society

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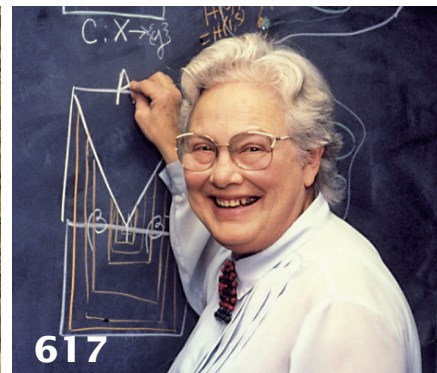
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June/July 2015

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In this double issue, we offer a fascinating snapshot of contemporary mathematical life.

First there is an article by Hyman Bass, taken from the book *I, Mathematician*, recounting his professional development as a scholar. Next, there is an article by Krishnaswami Alladi and Gabriela Asli Rino Nesin on the Nesin Mathematics Village in Turkey.

We also include an article by John Friedlander about the stunning work of Yitang Zhang on bounded gaps in the prime numbers. There is an article by Jessica Deshler et al. examining the development of graduate student teaching assistants and, finally, we include a memorial article for the distinguished topologist Mary Ellen Rudin. —*Steven G. Krantz, Editor*

Features

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From the AMS Secretary

Letters to the Editor

Misleading Mathematicians

In his article "Encryption and the NSA Role in International Standards" (February 2015 *Notices*) Dr. Michael Wertheimer works hard to leave the impression that the NSA did not place a backdoor in the DUAL_EC_DRBG algorithm. He never issues a direct denial, and indeed doing so would be difficult, in view of the overwhelming evidence of the backdoor. Instead, he misleads through selective omission of evidence, including evidence that:

- the NSA considered it a "challenge in finesse" (`tinyurl.com/n5aqlzh`) to get the standard accepted
- the NSA paid a leading industry player a large sum to make this standard (with NSA's curve points) the default option (`tinyurl.com/qc6c8qq`)
- the NSA suppressed discussion of how the curve points should be generated (`tinyurl.com/oaaava7`), and
- the standard makes no mathematical sense unless you were designing it for the backdoor.

The NSA needs to address the actual question of the backdoor, or provide an explanation of why it will not.

Dr. Wertheimer is rightly concerned that this incident may lead people to believe that "NSA has a broader agenda to 'undermine Internet encryption,'" and asks for a "fair reading of our track record." This track record includes reducing the key length of the block cipher DES in the 1970s to make it breakable (`tinyurl.com/lsfbszt`), blacklisting an inventor of DES (Horst Feistel) from cryptography jobs (`tinyurl.com/psqbsez`), advocating for control of cryptographic research in the 1980s, and, according to NSA's 2013 budget request (`tinyurl.com/n5aqlzh`), covertly influencing "commercial products' designs" and "policies, standards and specifications for commercial public key technologies" for the purposes of exploitation. Indeed, the track record speaks for itself.

Dr. Wertheimer writes that he feels "a connection to the mathematics community that goes beyond scholarship." If so, his attempt to mislead this community—the community that "encouraged and supported his studies"—is even more shameful.

A slightly different version of this letter is posted on the web at `www.cs.bu.edu/~reyzin/wertheimer-letter.html`, with thirty signatories.

—Matthew Green
Johns Hopkins University

—Ethan Heilman
Boston University

—Bruce Schneier, Fellow
Berkman Center for
Internet and Society
Harvard Law School

(Received February 9, 2015)

Getting it Right and the Shapes of India's Zero

After reading the excellent review of Mazur's book *Enlightening Symbols* (*Notices*, February 2015), I ordered it. I would have liked the book more than I did if the author's information on India had been better.

William Jones (p. 84) was the mathematician-father of the philologist-son Sir William Jones (a judge in India).

Brahmagupta's birthplace (now Bhinmal) is in Gujarat, not south India (regarded the "linguistic south").

Like the *Iliad*, the *Vedas* (all of *Rig Veda*'s 10,500 hymns) were an oral (not written, p. 35) composition, beginning about 3,000 years ago, in archaic, accented Sanskrit (now termed Vedic), and written down long after writing had evolved. Eventually, Vedic morphed into accent-less (classical) Sanskrit (the book's "Sanskrit"), still studied in India and elsewhere.

The relationship between present-day Devnagari (now just Nagari) and the extinct Brahmi script(s) (lasting for about a thousand years) baffles the author. Consulting Jensen's *Sign, Symbol and Script* and Coulmas's *The Writing Systems of the World* might help. All present-day Indian scripts have descended from some Brahmi version, which was then discarded and forgotten.

In Brahmi, the Anuswaara, a dot placed to a letter's right, imparted to it a terminal "um" sound. To secure this sound, this dot was placed above the letter for Indo-European scripts. But in the Dravidian Old-Kannada script (derived from an earlier northern Brahmi), so as not to puncture the palm leaf (the writing materials used being palm leaf and steel stylus), a small circle, instead, was placed to the letter's right. (It is still so in Modern Kannada.) I believe this was how the "dot" and "small circle" representing the Indian "zero" originated.

The present-day Hindu numerals come from Brahmi numerals. Nagari "4" is Brahmi "ma", closely resembling Brahmi "4". More could be said.

People always mention the scarcity of "hard" evidence regarding earlier Indian numerals. Could this be due to the five-century-long razing in North India of Hindu, Buddhist, and Jain temples that fell before the iconic fury of the pseudo-Islamic conquerors who demolished them wherever found? Who knows what Babylonian, Greek, Hindu, and Islamic accomplishments were lost when the pseudo-Muslim Genghis Khan invaded Mesopotamia?

Also, why couldn't the place-value notation (of which a place-holder zero is a sine qua non) have come to India from Mesopotamia? The lion-headed eagle, Imdugud (first depicted during Ur's Third Dynasty), after becoming double-headed (as seen in the thirteenth century BCE meeting of the supreme Hittite gods, Yazilikaya) did get around to several countries including India.

—Padmini Joshi
Professor Emerita
Ball State University
Muncie, Indiana

(Received February 19, 2015)

Graduate Programs: Preparing Students for the Future or for the Past?

What do graduate programs look like in the mathematical sciences? Typically students take courses to prepare for qualifying exams, followed by courses to prepare for research. These activities lead to a thesis. Seminars and colloquium speakers are focused on research topics. Students are supported as research assistants or teaching assistants. The latter position might come with training for teaching. This structure points to one goal: Creating researchers and creating publishable mathematics.

An indication that this goal is not being achieved comes from [1]. Grossman looked at *Math Reviews* from 1940 to 1999. This data represents publications from 300,000 authors and included 1.6 million articles. Grossman found that 43 percent of authors had exactly one paper in *Math Reviews* and 75 percent had no more than five papers!

The research experience is invaluable. The in-depth study of mathematical ideas provides for profound understanding. Defining a research problem, developing a program of attack, writing up the solution, and giving presentations are important experiences that prove useful both for the classroom as well as for employment outside academia, as the following data show.

In 2009 the percentage of employment of new doctorates in US nonacademic positions was 23 percent, rising to 29 percent in 2013 [2]. This employment picture shows the broad utility of mathematical training. Mathematicians are in demand. If graduate programs paid more attention to these nonacademic positions, we could greatly expand the opportunities for all our graduates. Linkages between mathematics departments and industry should be increased, and summer employment at national laboratories and industry for faculty and graduate students would provide a better understanding of how mathematics is employed in the workforce. These experiences would then inform the curriculum.

Despite the increase in the number of mathematics doctorates taking jobs outside academia, most of them still make their living by teaching. And yet, with some outstanding exceptions, graduate programs in mathematics largely ignore this aspect of the profession. Once we begin teaching we have to understand how to deal with students who arrive unprepared for collegiate mathematics. Should we continue to lecture, or is there something to be learned from advances in learning theories, innovative teaching styles, and the effective use of technology? At many universities, mathematicians play a role in the training of K–12 teachers, an activity which has many challenges.

The current situation is that on-the-job training for these many responsibilities is the rule. The education graduate students obtain does not adequately prepare them for the many tasks a faculty member must address.

It is time to look at graduate programs more carefully. I suggest that all programs in the mathematical sciences perform a series of self-studies.

Employment Self-Study: Where are your graduates being employed? Though this information is difficult to obtain for bachelor's students, it is much easier to obtain for master's and PhD students. In particular, where the doctoral graduates end up after 5–10 years is important. If the graduates are going mostly to nonresearch-intensive colleges, then the graduate education should reflect this reality.

Funding agencies recognize the importance of creating a diverse scientific workforce. Given the changing demographics, it is increasingly important that underserved populations be part of this workforce, and success in mathematics is essential. Mathematics departments should take a leadership role in addressing the needs of the US workforce, and they should take seriously the responsibility of producing a mathematically literate student body. We should use the mathematics classes that we teach as a vehicle for encouraging students to take the next mathematics class and to consider adding the mathematics major to their program of study [3]. Departments that request funding from these agencies should join in the efforts to produce a diverse, mathematically literate workforce.

Demographic Self-Study: How well is the department educating the US population? A self-study should include how many mathematics majors and minors there are at the undergraduate level, broken down by US citizen-international, male-female, and underrepresented minorities. This same data should also be provided for graduate programs.

These self-studies should be part of individual research proposals to funding agencies, and the evaluation of individual proposals should be impacted by the self-studies of the department. If a department cannot provide evidence that it is producing a diverse workforce, then grants should go to other departments that more clearly support the goals of the funding agencies.

References

1. Jerrold W. Grossman, Patterns of research in mathematics, *Notices of the AMS* **52** no. 1, (2005), 35–41.
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3. William Yslas Vélez, Mathematics instruction, an enthusiastic activity, *On Teaching and Learning Mathematics*, AMS Blogs, August 1, 2014.

—William Yslas Vélez
University of Arizona
`velez@math.arizona.edu`

AMS Student Chapters

An AMS Student Chapter is designed to generate interest in the mathematical sciences and encourage students in their mathematical pursuit by providing them with new opportunities and experiences.

1 Create a petition that includes the following:

- Sponsoring University
- Faculty advisor for the chapter
- At least 5 students who will be chapter members
- Student Chapter Officers
- Rules of procedure
- An annual budget for the first year

2 Submit the signed petition to the AMS for approval

3 Receive welcome letter after AMS approval

4 Complete request for annual AMS funding

www.ams.org/studentchapters
Deadline is October 1st

5 Share your events with other chapters through the Student Chapters webpage

Memories of Mary Ellen Rudin

Georgia Benkart, Mirna Džamonja, and Judith Roitman,
Coordinating Editors

Steven G. Krantz, editor of the *Notices,* invited the editors of this article to prepare a collective remembrance celebrating Mary Ellen Rudin's life and work. In doing so, we asked several of Mary Ellen's colleagues, collaborators, and students to each contribute a short piece. The choice of contributors was not an easy one, since Mary Ellen had a very rich mathematical and social life, to which this article can only attest. Space limitations meant that we could not accommodate all who would have liked to pay tribute to her, but we hope that they will find themselves, at least to some extent, represented by the reminiscences appearing here.

This article is far from being the only initiative to celebrate Mary Ellen Rudin, and we are particularly happy to mention two additional ones: the Mary Ellen Rudin Young Researcher Award Fund established by Elsevier and an upcoming special issue of *Topology and Its Applications* edited by Gary Gruenhage, Jan van Mill, and Peter Nyikos.

Georgia Benkart

Mary Ellen Estill Rudin, Grace Chisholm Young Professor Emerita of Mathematics at the University of Wisconsin–Madison and preeminent set-theoretic topologist, died at her home in Madison, Wisconsin, on March 18, 2013. Mary Ellen was born December 7, 1924, in Hillsboro, Texas, south of Dallas–Fort Worth, a small town whose roster of notable natives also includes Madge Bellamy, a film actress of the 1920s and 1930s best known for the horror movie classic *White Zombie.*

When she was six, Mary Ellen's family moved to the even smaller town of Leakey (LAY-key) situated in the Texas hill country in a canyon carved out by the Frio and Nueces Rivers. Her mother, Irene Shook Estill, had taught high school English. Her father, Joe Jefferson Estill, was a civil engineer with

Mary Ellen's graduation from the University of Texas, 1949.

Photo courtesy of the Rudin family album.

Georgia Benkart is professor emerita of mathematics at the University of Wisconsin-Madison. Her email address is benkart@math.wisc.edu.

Mirna Džamonja is professor of mathematics at the University of East Anglia, Norwich, UK. Her email address is M.Dzamonja@uea.ac.uk.

Judith Roitman is professor emerita of mathematics at the University of Kansas. Her email address is jroitman@ku.edu.

the Texas Highway Department, and the family had moved around as his projects dictated until, soon after their arrival at Leakey, the Depression hit. As there was no money to build new roads, the family stayed there throughout Mary Ellen's school years while her father did surveying work. Her brother, Joe Jefferson Estill Jr., was ten years younger; the two siblings always got along famously despite

Walter's sister, Vera Usdin, and her husband, Earl Usdin, at the wedding of Mary Ellen and Walter in 1953.

their age difference. In those days, reaching Leakey from the outside world required traveling fifty miles up a one-lane dirt road and fording the Frio River seven times. Children walked to school or rode there on horseback.

In 1941 Mary Ellen was one of five graduates in her high school class. That fall she headed off to Austin to enroll at the University of Texas and was directed to the table with the shortest line of prospective students, where Robert L. Moore sat registering students for mathematics courses. Impressed with her correct usage of "if/then" and "and/or," Moore signed Mary Ellen up for a trigonometry course. She was surprised to discover the next day that he was the professor for the class. Every single semester during her entire eight years at the University of Texas, from day one until she graduated with her doctoral degree in 1949, she attended a course taught by Moore [Ke].

Moore's method of teaching, which eschewed formal lectures, instilled in Mary Ellen a lifelong deep confidence in solving problems and conjectures, though she never used the method in her own teaching. As she later put it in an interview with Albers and Reid [AR], at the end of her freshman calculus course, "I'm not sure I knew the derivative of $\sin x$ was $\cos x$, but I could prove all sorts of theorems about continuity and differentiability and so on!" Mary Ellen often bemoaned the fact that she knew so little mathematics and felt cheated that she had not been exposed to basic subjects such as algebra and analysis.

At Texas she was a member of a terrific cohort of Moore graduate students, including Richard Anderson, Ed Burgess, R. H. Bing, and Edwin Moise, that went on to shape general topology and leave its mark on the mathematical community. In her doctoral thesis, Mary Ellen constructed a counterexample to a well-known conjecture using a technique now called "building a Pixley-Roy space" after the two mathematicians who later gave a more simplified description of it. At the time

she wrote her thesis, she had never read a single mathematics paper. She maintained an aversion to reading research papers throughout her career, loved talking about mathematics and sharing her bounty of ideas with anyone who would listen, and was an avid colloquium goer (but always with pencil and paper just in case her interest in the subject waned).

After Mary Ellen earned her PhD in 1949, Moore referred her to Duke University, which then had a women's college under pressure to hire a female mathematician. At Duke she met Walter Rudin. Walter had arrived there in 1945 from England, where he had spent the war years in the Royal Navy after fleeing Austria. Having convinced a dean that he should be admitted as a junior even though he had never finished high school, four years later, in 1949, Walter completed his PhD. He left Duke in 1950 for a two-year C. L. E. Moore Instructorship at MIT and following that for the University of Rochester, but Mary Ellen and Walter continued to see each other at the winter and summer Joint Mathematics Meetings. In August 1953 they were married at the home of her parents in Houston. While at Duke, Mary Ellen proved a conjecture of Raymond Wilder, an early Moore student, and Wilder applied for an NSF grant to enable her to visit him at the University of Michigan. When she wired Wilder that she was getting married and going to the University of Rochester, somehow he managed for the grant to be transferred from Michigan to Rochester. The University of Rochester came up with a part-time position for her on short notice, and she continued her research. Daughter Catherine arrived in July 1954, and daughter Eleanor in December 1955, so part-time teaching suited the newly expanded family.

The Rudins were on leave from Rochester visiting Yale for the academic year 1958–59 when R. H. Bing phoned Walter to invite him to give a summer course at the University of Wisconsin. Walter declined because he already had Sloan Fellowship funding for the summer but heard himself asking, "But how about a real job?" [RW]. Bing, who was mathematics department chair at the time, arranged an interview a few weeks later. In 1959 the Rudin family moved to Madison and purchased a recently built home designed by Frank Lloyd Wright that consisted of basically one large room with 14-foot ceilings and a huge number of windows (rumored to be 137). Sons Robert (Bobby)* and Charles (Charlie) were born in Madison in 1961 and 1964. Although Walter retreated to the quiet of his study to do mathematics, Mary Ellen described

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*Son Robert Rudin died in Madison, Wisconsin, October 13, 2014.

her own mode of work as "I lie on the sofa in the living room with my pencil and paper and think and draw little pictures and try this thing and that thing....It's a very easy house to work in. It has a living room two stories high, and everything else opens onto that....I have never minded doing mathematics lying on the sofa in the middle of the living room with the children climbing all over me" [AR].

Madison turned out to be exactly the right kind of place for them—the right kind of city and the right kind of mathematics department [RW]. Mary Ellen continued as a part-time lecturer who supervised graduate students and engaged in essentially full-time research until 1971, when, in Walter's words [RW], "The anti-nepotism rules, which were actually never a law, had fallen into disrepute," and she was promoted from part-time lecturer to full professor. Mary Ellen was somewhat dubious about the professorship because of the teaching and committee work it entailed, but Walter felt it was best, especially for the children, in case something should happen to him. One of my earliest recollections of Mary Ellen is sharing an elevator with her in the mid-1970s, where she showed me a printout with the small retirement sum she had accumulated since coming to Wisconsin, a reality check the ever-expanding ranks of adjuncts and part-timers teaching mathematics today are also bound to face.

Mary Ellen was known for her extraordinary ability to construct ingenious counterexamples to outstanding conjectures, many quite complicated. She was the first to construct a Dowker space, thereby disproving a long-standing conjecture of Hugh Dowker that such spaces couldn't possibly exist. Years before this noteworthy accomplishment, in 1963 her solution to one of the Dutch Prize Problems had been recognized by the Nieuw Archief voor Wiskunde (the Mathematical Society of the Netherlands). In later years she was named a Fellow of the American Academy of Arts and Sciences and of the American Mathematical Society, became a member of the Hungarian Academy of Sciences, and received four honorary Doctor of Science degrees. She gave an invited lecture at the International Congress of Mathematicians in Vancouver in 1974 and the Noether Lecture of the Association for Women in Mathematics at the Joint Mathematics Meetings in 1984. In 1990 she was awarded the R. H. Bing Prize for significant overall contributions to mathematics. She served as vice president of the AMS 1980–81; as MAA governor 1973–75; and on a vast number of AMS, MAA, and national committees, including the editorial boards of the *Notices* and of *Topology and Its Applications*. Perhaps ironically, she chaired the AMS Committee on Academic Freedom, Tenure, and Employment

Eleanor, Charlie, Bobby, and Catherine Rudin.

Photo courtesy of the Rudin family album.

Security. In her honor, Elsevier established the Mary Ellen Rudin Young Researcher Award Fund to celebrate her achievements and to recognize her legacy in encouraging talented young researchers in topology. This award was formally announced at the 47th Spring Topology Meeting a week after her death, though she had given her approval of it earlier. The inaugural prize was awarded in September 2013 to Logan C. Hoehn of Nipissing University, Canada, a mathematical descendant of Mary Ellen.

Mary Ellen never stopped thinking about mathematics and working on problems. She was a mainstay of the Southern Wisconsin Logic Colloquium and couldn't wait to tell me about her "fabulous weekend" when the colloquium hosted the Association for Symbolic Logic meeting in April 2012. The talks were fantastic, she reported; she met lots of old friends and, of course, participated in all the social gatherings.

The Rudins welcomed mathematicians, Wright aficionados, and students from all over the world to their unique home. The door was always open—literally; it was never locked. As Mary Ellen once said to me, "People just open the door and say 'Hello, we're here.'" To which daughter Catherine quickly added, "And most of the time we know them." The Rudins entertained often and hosted everyone with a gracious, relaxed style. I remember a Thanksgiving when, with her customary cheerfulness, Mary Ellen announced to the gathering that dinner would be delayed, as the turkey, which was being cooked outside because the oven wasn't working, had been on fire.

Mary Ellen was larger than life, and her reputation for rescues almost as legendary as her

Mary Ellen on the sofa.

counterexamples. On more than one occasion she saved a child from the deep end of a pool or from crashing ocean waves. At an AMS summer mathematics institute in Colorado, a horse suddenly took off at a gallop, with the young rider who had slipped from the saddle dangling off to one side. Mary Ellen charged after them on horseback, corralled the runaway horse, and righted the girl, the daughter of the Rudins' longtime friend Yale mathematician Shizuo Kakutani, Michiko Kakutani, now a Pulitzer Prize-winning literary critic for the *New York Times.*

For well over twenty years, except for the five years that Linda Rothschild was in the department, Mary Ellen and I were the only women mathematics faculty members at Wisconsin. Mary Ellen's passion for mathematics was contagious, her support and encouragement to all extraordinary. She meant so much to so many; it was inspiring to be a part of her remarkable life. She was so accepting, so warm and welcoming, so genuine, so fiercely independent. She would never think to tell any of us that she had been taken to the hospital by ambulance in the middle of the night, except when it occurred to her she had left the house in just her nightgown with no shoes or money and no way to get back home. After Walter's death, several of us would get together regularly for dinner, and she would want to drive. "We'll pick you up," I'd tell her. "Oh, ok," she would reply. "I'll be ready". And she always was.

István Juhász

Many of us who had close personal and professional contact with Mary Ellen Rudin received with deep sorrow the news that she died on March 18 in the eighty-ninth year of her life. In this age of

István Juhász is professor emeritus at Alfréd Rényi Institute of Mathematics, Hungarian Academy of Sciences, Budapest, Hungary. His email address is juhasz@renyi.hu.

the Wikipedia and numerous other easily available public sources of information, I don't think it's necessary for me to give a detailed account of her great scientific achievements, most of which were done in the field of general and set-theoretic topology. Instead, I take this opportunity to recall a few personal memories about her.

The first of these concerns a paper of hers in which she presented an example of a first-countable and CCC regular space that is not separable and which, as a student, I presented in our topology seminar. I still remember how proud it made me that I could understand, and make more or less clear to the audience, her very complicated construction. I only much later found out the explanation of the rather nonstandard notation and terminology she used (and which made her technically very complicated ingenious construction even harder to understand): She was brought up in the (in)famous Moore school in Texas, where students were forbidden to study math books; they had to discover everything on their own. I recall a story I heard from Paul Erdős, a good friend of the Rudins, that illustrates this. On one of his visits with them he was surprised to find out that she did not know what a Hilbert space was. This was sometime in the 1950s, and, of course, she later became much more familiar with and well versed in what was going on in her field.

Our first meeting in person took place at the IMU Congress in Nice in the summer of 1970. Together with my friend and collaborator András Hajnal we were eager to meet her, and this happened right after she arrived in Nice. Her first sentence to us was "I just proved that there is a Dowker space;" i.e., a normal space whose product with the unit interval is not normal. To appreciate the weight of this sentence, one should know that this meant she solved the most important open problem of general topology of the 1960s.

The next year I made a short, basically personal, visit to North America, and she invited me to Madison to give a talk there. That was the first of many occasions when she, as a caring host, treated me so well, both mathematically and socially. Of course, she invited me to their beautiful house designed by Frank Lloyd Wright, cooked a great meal for me, and showed me around town. I was glad to be able to return some of her favors in the summer of 1973 when she came to Hungary, together with her two then-teenage daughters, for a topology conference.

She was the architect of arranging a visiting position for me at the University of Wisconsin-Madison for the academic year 1974–75. This was not a trivial thing in those Cold War times. One result of this visit was our joint paper [JKR] with

Ken Kunen, which is a very frequently cited paper in the field of set-theoretic topology. This visit was followed by many more visits to Madison, most of them organized by her. But I'd like to mention another trip of mine to the US in which she played a substantial role.

This took place in 1983 when my friend Endre Szemerédi had been diagnosed with a serious case of cancer while on a visit in the US. Of course, after having found this out, I turned to Mary Ellen to ask if she could arrange a visit to Madison for me so that I could see my ailing friend. It turned out that this was not possible because of some financial problems at UW Madison. Still, she managed to convince the head of another math department in the US—as I later found out, not without some arm twisting—to invite me, thus making it possible for me to visit my friend right after he had a very serious operation. This story has a very happy ending: My friend has completely recovered, and, as is well known, in 2012 he was awarded the Abel Prize.

I was fortunate to be present at Mary Ellen's retirement meeting in Madison in 1991, where I could witness her efforts trying to help Boris Shapirovskii, another great mathematician fighting cancer, unfortunately in his case with no success.

I was very happy and proud when in 1995, mainly thanks to the strong recommendation of András Hajnal, she was elected to be an honorary member of the Hungarian Academy of Sciences. Moreover, the next year she and her husband, Walter, after visiting Prague and Vienna, Walter's hometown, managed to come to Budapest so that she could deliver her acceptance address at the academy. A high point of this trip was that my family had the good fortune to host a meal in our home for the Rudins, the Shelahs, the Hajnals, and Paul Erdős, who, sadly, died just a few weeks later.

I last saw Mary Ellen in person in 2009 at the Kunen Fest, Ken Kunen's retirement celebration. Although quite fragile physically, she was as cheerful as ever. And the last email I got from her was sent in November of 2010, congratulating us on the occasion of the birth of our grandson.

William Fleissner

Mary Ellen Rudin was an inspiration to me and other graduate students. Intellectually, she was enthusiastic about set-theoretic topology. Emotionally, she was warm and kind not only to mathematicians but also to their spouses.

I remember seminars on the ninth floor of Van Vleck Hall, with large windows overlooking

William Fleissner is professor emeritus of mathematics at the University of Kansas. His email address is `fleissn@ku.edu`*.*

Alex Nagel, Mary Ellen and Walter.

Photo courtesy of Yvonne Nagel.

Lake Mendota and the city of Madison. Once she presented the Reed-Zenor proof that locally compact, locally connected normal Moore spaces are metrizable. She drew a Cantor tree, put a unit interval at the top of each branch, sketched a red circle about the 0's and a blue circle about the 1's. It was not a proof of the theorem. It was more an explanation why a counterexample cannot be constructed from Martin's Axiom. Even that was not rigorously proved. But she conveyed the ideas with great enthusiasm. In the audience, I thought, "I want to do mathematics like that!"

There were memorable evenings at their Frank Lloyd Wright-designed house on Marinette Trail. (Occasionally, tourists would look in the windows, and Walter would stick out his tongue.) There would be food and drink in the kitchen, and a circle of chairs in the living room, which was large in width and length and two stories high. The winters in Wisconsin can be bitterly cold, but then there would be a fire in the fireplace, making the gathering warm and cheery. The conversation was varied, and everyone was welcome to talk, not just the distinguished professors. The research group at Wisconsin felt like a big family.

Judith Roitman

She claimed that she did most of her work on what she called her theorem-proving couch, and other mathematicians joked about how they wished they had couches which could prove theorems, but it wasn't just theorems. She created examples— some easy, some difficult, and some which were breathtaking, almost audacious. Her theorems and examples cut a wide swath through a world that, when she began, was known as point-set topology and which relatively soon, in large part because

Mary Ellen and Paul Erdős when he received an Honorary Doctor of Science degree from the University of Wisconsin in 1973 (her Erdős number is 1).

of the kind of work she did and the kind of influence she had on others, came to be known as set-theoretic topology.

The difficult, breathtaking, audacious examples came about because, to her, complexity, intrinsic complexity, came easily. Her work is, as Steve Watson [W] wrote in the 1993 Festschrift to honor her seventieth birthday, "just hard mathematics, that's all." To pick one example: She looked at an arbitrary Suslin tree T and saw not just an L-space out of its branches, which everyone else saw, but an S-space constructed out of triples in $\omega \times \omega_1 \times T$ whose neighborhoods came from not quite subtrees related to each other in an intertwined fashion so complex that, working through it, you think, "This can't possibly work." But it does [R72a]. Yet, as is evident in the brief description of this construction in her 1975 CBMS notes [R75], she did not see her S-space from a Suslin tree as particularly difficult. That is what I mean by breathtaking and audacious.

Aside from her results, there was her influence. There were three aspects to this: she brought people together, she encouraged anyone who was interested, and she knew where we should be looking: in particular, her 1975 *Lectures on Set Theoretic Topology* [R75], from the 1974 CBMS Regional Conference in Laramie, set the agenda for decades.

Her hospitality and warm presence were both legendary and a major part of her influence. Consider how I met her. I was a graduate student at Berkeley wanting to use set theory to do topology and thus wanting to spend time in Madison. Arrangements were made. As soon as I arrived, I called Mary Ellen, per her instructions. She apologized that she could not help me get settled right away because her father had just died and she had to leave town for his funeral. Would I be okay for the next couple of days until she could get back? I am still astonished at the kindness of this gesture from a major mathematician to a very new graduate student barely past quals.

There were so many gestures like that to so many people, helping to form and nurture a community, a floating crew which would meet up in Prague, Warsaw, the Winter School, the Spring Topology Conference....It was an extraordinarily fertile time. I remember one summer in the mid-1970s when a number of us converged simultaneously on Madison for an impromptu summer-long seminar that met several times a week. Every meeting began with Mary Ellen asking, "Who proved a theorem last night?" and at every meeting several hands were raised.

Along with her warmth was an immense good cheer born of deep integrity and an unblinking sense of reality. When my first baby died of meningitis, Mary Ellen wrote the words that I turned to again and again, telling me how it was for her when her son Bobby was born with Down syndrome, and the doctors laid out a hopeless future for him (the hopelessness of which—Mary Ellen and Walter being who they were, refusing to pay attention to what was then accepted wisdom—did not come to pass): "Your life will never be quite the same again." There was tremendous comfort in those words.

Much about Mary Ellen was symbolized to me by the kitchen radio, an AM radio, already very old when I first noticed it. I asked Mary Ellen years later why they didn't have a newer, better model, and she said, "Because it still works." A few years ago I noticed that the radio was gone. What happened to it? "It stopped working." This radio was, for me, a symbol of Mary Ellen's and Walter's basic decency and solid values: no matter how many features the new radios have, you don't get rid of your old one if it's still working.

Mary Ellen was, of course, a woman mathematician at a time when there were few women mathematicians. She belonged, with Julia Robinson, Emma Lehmer and others, to what she called the housewives' generation: women who did substantial mathematics outside the academy, with only occasional ad hoc positions. I think of those women as exhibiting enormous strength of character. I think they thought of themselves as simply doing mathematics. As F. Burton Jones wrote in the Festschrift volume [J], "Wherever Mary Ellen was there was some mathematics."

Feminist that I was, I would try to engage Mary Ellen about how the mathematical community treated women, with her as exhibit, if not A, then at least E or F. She was not interested. "The best way to help women in mathematics is to do mathematics!" she roared at me, pounding the breakfast table at the 1974 Vancouver ICM. Yet she went out of her way to meet with young women and encourage them, and she told me many years after Vancouver that she had come to realize that when young she had protective blinders: she simply didn't notice the differences in how she was treated, so she wasn't hurt by them.

The last time I saw Mary Ellen was about a year after Walter died. By then she was using a walker and had moved into the guest bedroom off the living room to avoid the stairs. But she was still spending time every day thinking about mathematics simply because she loved it so much, working in Walter's old office on a huge table that I think was made out of a door plank. We went through the photos and reminiscences that people had sent her in homage to Walter, and her great no-nonsense good cheerfulness was still there, remembering all the times they had shared. There was a call about Bobby's care, and she excused herself to deal with it. She was going to meet with friends for lunch. Her life was full, her affect was vital, and I could not imagine that this would be the last time I would see her. But it was.

Mirna Džamonja

Much has already been said about Mary Ellen's outstanding personality and human quality. In this respect it is impossible for me to separate Mary Ellen from her alter ego and husband, Walter Rudin, as this is how I met them and perceived them one sunny day in the summer of 1986, when I was finishing the second year of my undergraduate degree at the University of Sarajevo in Yugoslavia (now Bosnia). They had come to see the university from which Amer Bešlagić, one of Mary Ellen's best students, had graduated; their visit was a major event in the mathematical life of the city. They each gave an excellent talk, and after Mary Ellen's talk, I knew I had found myself mathematically: the subject fascinated me, and the speaker perhaps even more so. I was invited to several social occasions with them then, and I was absolutely mesmerized by this couple, so different from each other, but so inseparable and complementary, the Old World and the New coming together in a unique mixture, which I had the honour to follow and know from that moment to the end of their lives. I could not have imagined then that we would become such close friends and that it is with Walter Rudin that I would dance at my wedding some years later
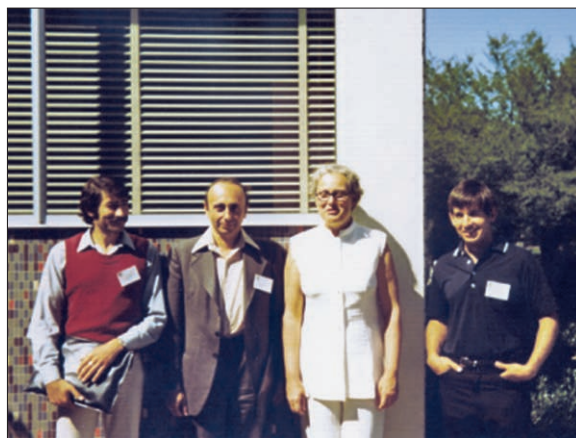
István Juhász, A. Hajnal, Mary Ellen, and Michael Starbird at the ICM in Vancouver in 1974.

and with Mary Ellen that I would discuss everything from mathematics to cooking. Mary Ellen was a brilliant mathematician, and even though it is hard to stop talking about her as a person, let me stop now and try to say something about her mathematical contribution. This is enormous and I have decided to concentrate on one aspect of it which I know the best, Dowker spaces.

The story of Dowker spaces starts with J. Dieudonné, who in his 1944 article [Di] considered sufficient conditions for a Hausdorff topological space X to satisfy that for every pair (h, g) of real functions on X with $h < g$, if h is upper semicontinuous and g is lower semicontinuous, then there is a continuous $f : X \to \mathbb{R}$ such that $h < f < g$. C. H. Dowker in his 1951 article [Do] showed that this property is equivalent to the product $X \times [0, 1]$ being normal (answering a conjecture of S. Eilenberg) and left open the possibility that this was simply equivalent to X being normal. A possible counterexample, so a normal space X for which $X \times [0, 1]$ is not normal, became known as a Dowker space. In 1955, Mary Ellen Rudin [R55] showed that one can obtain a Dowker space from a Suslin line. At the time, the consistency of the existence or nonexistence of a Suslin line, of course, had not yet been known. M. E. Rudin returned to the problem in 1970 [R71b] when she gave an ingenious ZFC construction of a Dowker space as a subspace of the product $\prod_{n \geq 1}(\omega_n + 1)$ in the box topology. This space has cardinality $2^{\aleph_\omega}$. This construction of Mary Ellen inspired a large amount of research, out of which I mention the two directions that are most interesting to me.

The first one is Z. Balogh's construction [B1] of a "small Dowker space," which was in this context taken to mean a Dowker space of cardinality $2^{\aleph_0}$ (which, of course, in some universes of set

Alan Dow, Mary Ellen, and Ivan Reilly at Oxford University.

theory is as large as $2^{\aleph_\omega}$ but in others it is not). Balogh's method is a very intricate use of certain sequences of functions and elementary submodels, and reading it even today, one feels that its full limits have not yet been reached. The other direction was taken by M. Kojman and S. Shelah in [KS], where they used pcf theory to find a subspace of M. E. Rudin's space which is still Dowker, but has size $\aleph_{\omega+1}$. This construction rounds up the long list of set-theoretic techniques (forcing, large cardinals, pcf, . . .) that were used in Mary Ellen's work and the work she inspired, carrying the field of general topology to what has since become known as set-theoretic topology. The interaction between set theory and set-theoretic topology has been most fruitful and has carried both subjects forward. Mary Ellen was the mother of it all. Let us hope that the unruly children that we are, we shall be able to carry forward not only Mary Ellen's mathematical legacy but also the legacy of the spirit of collaboration, inspiration, mutual respect and joy for all which she was able to create and live up to.

Franklin Tall

Set-theoretic topology was inspired by Mary Ellen Rudin for three decades. Her influence and leadership in North America and worldwide were central to the development of the field.

Mary Ellen grew up in a small town in Texas with no idea that she might become a mathematician. When R. L. Moore was trawling for prospects at registration at the University of Texas, he sensed she was a good one and began reeling her in. In classic Moore fashion, he created a confident, powerful researcher who didn't know

Franklin Tall is professor emeritus of mathematics at the University of Toronto, Toronto, Ontario, Canada. His email address is tall@math.utoronto.ca.

any mathematics other than what he led her to discover. Her thesis and first few papers are written in Moore's antiquated language, but Steve Watson [W] has demonstrated that they are still well worth reading. In her thesis [R49], she gave the first example of a nonseparable Moore space satisfying the countable chain condition.

After positions at Duke (where she met her husband, Walter Rudin) and Rochester, the Rudins moved to the University of Wisconsin at Madison. The UW system had a nepotism regulation that prevented Mary Ellen from having a regular position because Walter had one. As a result, she stayed a "lecturer," which had one advantage: she was free of committee work. In 1971 the regulation was finally abolished, and she was promoted directly to full professor.

I first met Mary Ellen in the summer of 1967. I was casting around for a supervisor and Mary Ellen was very approachable, helpful, and encouraging—qualities that supported a long line of students thereafter. I was her first PhD student, and in 1969 I had to have the department chair cosign my thesis because, as a lecturer, Mary Ellen was not allowed to be a full-fledged supervisor.

The first paper of Mary Ellen that most set-theoretic topologists have heard of is [R55], in which she used a Suslin tree to construct a Dowker space. Such a construction would be quite interesting if done for the first time now, but in 1955, before the consistency of the existence of such trees was known, this was quite extraordinary. She constructed a "real" Dowker space in [R71b], leading to an invitation to address the ICM.

The students of Moore such as Mary Ellen and R. H. Bing were familiar with both elementary set-theoretic techniques and geometric ones, especially dealing with connected spaces. Mary Ellen's geometric abilities proved invaluable in her work on pathological manifolds. Her most noteworthy result in this area is the consistency (with P. Zenor) and independence of the existence of perfectly normal nonmetrizable manifolds [R76], [R79].

Some other areas wherein she produced significant results are: classifying ultrafilters on the natural numbers (the Rudin-Keisler and Rudin-Frolik orders), showing (with Y. Benyamini and her student Mike Wage) that continuous images of Eberlein compacts (weakly compact subspaces of Banach spaces) are also Eberlein [BRW], and establishing many theorems about normality of products and box products. Let me give just one example of a normality theorem, consistently solving a problem of K. Morita. Mary Ellen, with her student Amer Bešlagić, proved in [BR]: Gödel's Axiom of Constructibility implies that for a space X whose product with every metrizable space is normal, X is metrizable if and only if $X \times Z$ is

normal, for every space Z such that Z's products with metrizable spaces are all normal. Amazingly, they proved this by constructing an example!

Mary Ellen's fame was largely as a producer of weird and wonderful topological spaces—examples and counterexamples. She had an uncanny ability to start off with a space that had some of the properties she wanted and then push it and pull it until she got exactly what she wanted. In her heyday, several times a week she would receive inquiries from mathematicians around the world—often nontopologists—asking for an example of something or other. She would answer these by writing back on the back of the same letter, not from "green" sentiments, but to avoid clutter. I am convinced that her avoidance of clutter, especially mentally, was one of the secrets of her mathematical power. By not filling up her memory, she maximized processing capability in her brain.

Mary Ellen's papers became (and stayed) more set-theoretic, starting in the late 1960s. There were a variety of reasons for this in addition to what Marxists might call "historical necessity." The most important reason was that set theory was being done at Wisconsin, most notably by Ken Kunen, who arrived in 1968. David Booth and I were both students in logic who had begun thinking about applications of set theory to topology; we frequently went back and forth between Ken and Mary Ellen, and that accelerated the collaboration that made Madison such an exciting place for set-theoretic topology in the 1970s. During the summers I and many other set-theoretic topologists would come to visit and interact with Mary Ellen and Ken. The most memorable summer, though, was the one of 1974, when we all went off to the CBMS Regional Conference in Laramie, Wyoming, for Mary Ellen's lectures on set-theoretic topology [R75]. I remember the sense of excitement we felt at Mary Ellen's lectures, which set the course of the field for the next decade. The resulting book, with chapters on cardinal functions, hereditary separability versus hereditary Lindelöfness, box products, and so forth, established a framework for the new field of set-theoretic topology, which grew out of general topology but employed new methods, which led to new questions. It was an exciting time. It was a noteworthy challenge to try to solve a problem on her problem list.

We celebrated Mary Ellen in 1991 on the occasion of her retirement with a conference in Madison. The proceedings were published in [T1]; much of this note is drawn from my contribution [T2] in [T1], where more details of her mathematics can be found. There is also the excellent biographical article [AR]. Mary Ellen's research certainly did not stop with her retirement. Particularly impressive was her complex proof of Nikiel's Conjecture,

Mary Ellen and Walter with daughter Catherine's family: Ali Eminov, Catherine, and their sons, Deniz and Adem Rudin.

characterizing the continuous images of compact ordered spaces as the compact monotonically normal spaces [R01]. As Steve Watson wrote in [W] (quoted by Todd Eisworth in his review [E] of [R01]), "Reading the articles of Mary Ellen Rudin, studying them until there is no mystery takes hours and hours; but those hours are rewarded, the student obtains power to which few have access. They are not hard to read, they are just hard mathematics, that's all."

Although her body failed her, her mind remained sharp as she aged. She stopped traveling, and I was busy with family responsibilities, so I saw little of her in recent years, but she remained and remains an inspiration for all of us in the field.

Peter Nyikos

I had the honor of delivering a short eulogy for Mary Ellen at this year's Spring Topology and Dynamics Conferences (STDC) in Connecticut. It said: "Mary Ellen was a great mathematician. But she was much more than that: she was what Prabir Roy called a guru—someone you could turn to for advice and comfort on all kinds of matters…To those of us who knew her well, she was simply 'Mary Ellen.' Whenever set-theoretic topologists got together for a chat, and someone said 'Mary Ellen,' 99 times out of a hundred, everyone would know who was being talked about."

I briefly listed some of her main accomplishments, including of course the writing of "Mary Ellen's booklet" [R75], another expression that usually gets instant recognition. Among her research accomplishments is a beautiful generalization of

Peter Nyikos is professor of mathematics at the University of South Carolina. His email address is nyikos@math.sc.edu.

Photo courtesy of the Rudin family album.

Mary Ellen and and co-author Keiko Chiba in Kyoto for the ICM in 1990.

the Hahn-Mazurkiewicz theorem. It is an immediate corollary of her solution to Nikiel's Conjecture [R01] and of a 1988 theorem of Nikiel [Ni]. The Hahn-Mazurkiewicz theorem states that, if a metrizable space is a locally connected continuum (compact, connected space), then it is a continuous image of $[0, 1]$. (The converse is elementary.) These spaces are called "Peano continua" in recognition of Peano's space-filling curve. Back in 1966 [M], Sibe Mardešić wrote: "It is natural to ask for a nonmetric analogue of this theorem....Recently the interest in this and related problems has been revived...." Mary Ellen's solution to Nikiel's Conjecture allows one to substitute "monotonically normal" for "metrizable" in the Hahn-Mazurkiewicz theorem. And the proof that every metric space is monotonically normal is essentially identical to the usual proof that every metric space is normal. The search for a natural extension of the Hahn-Mazurkiewicz theorem to compact connected, linearly ordered spaces was akin to the search for a metrization theorem generalizing the Urysohn metrization theorem, and it lasted even longer. (The Bing-Nagata-Smirnov theorem was hailed as the solution to this metrization problem after a search of over three decades.)

I closed my eulogy by expressing the hope that there would be some publications in remembrance of Mary Ellen that would do justice to her greatness, and I am very happy to be able to contribute both to the special issue of *Topology and its Applications* dedicated to Mary Ellen and to this remembrance.

I got a unique taste of Mary Ellen's graciousness and hospitality in early 1974, when I was a postdoctoral student at the University of Chicago. She invited me up to Madison, where I arrived with a bad cold (I naïvely decided not to postpone the visit, which had already been delayed a number of times), but although it was obvious to everyone, she never mentioned it once and had me stay overnight at her house, where I met her two sons and played board games with them. The same evening she introduced me to the axioms ◊ and ♣ and to Ostaszewski's S-space, all of which were totally new to me at the time.

The next two years I saw her at the two STDC conferences, where I became impressed first by her lecturing style and then by the high regard in which she was held. There was a panel discussion in Memphis about the future of point-set topology, and the panel included Mary Ellen and other leading figures such as R. H. Bing, R. D. Anderson, A. H. Stone, and E. Michael.

Her paper on her screenable Dowker space [R83] solved a 1955 problem of Nagami whether every normal, screenable space is paracompact [Na]. The proof of normality was a tour de force, amazing in its originality. I had never seen anything remotely like it, nor the way she was able to use the intricate set-theoretic axiom $◊^{++}$ to define the space itself. To this day I have no idea how it entered into her mind that a peculiar space like this would have all the properties required to solve Nagami's problem nor how she was able to decide on the way to use $◊^{++}$ in the definition. One part of her paper reminded me of an anecdote that was told about a session in the Laramie workshop. She had been going over a particularly intricate construction when F. Burton Jones interrupted: "What allows you to say that?" Mary Ellen replied, "Why that's—that's just God-given." "Yes," Jones is supposed to have said, "but what did God say when he gave it to you?"

There were some problems in set-theoretic topology which Mary Ellen could not solve but on which she did obtain large "consolation prizes." One such prize was her screenable Dowker space, an offshoot of her unsuccessful attempts to solve a problem for which we still have no consistency results: is there a normal space with a σ-disjoint base that is not paracompact? Zoltán Balogh later [B2] came up with one of his "greatest hits": a ZFC example of a screenable Dowker space. Mary Ellen's consistent example is, however, the only one known to be collectionwise normal. A recurring theme in Mary Ellen's research, up to the very end of her life, were two further problems about Dowker spaces: the problem of whether there is a

Mary Ellen and Walter when they retired in 1991.

normal, linearly Lindelöf space that is not Lindelöf and the problem of whether there is a normal space with a σ-disjoint base that is not paracompact.

Kenneth Kunen and Arnold Miller

There is an excellent biographical interview of Mary Ellen published in [AR]. Also, there is an entire volume [T1] devoted to articles describing her mathematics. All quotations below are taken from [T1].

Mary Ellen Rudin was one of the leading topologists of our time. Besides solving a number of well-known outstanding open problems, she was a pioneer in the use of set-theoretic tools. She was one of the first to apply the independence methods of Cohen and others to produce independence results in topology. She did not do forcing arguments herself, but many of her papers make use of set-theoretic statements, such as Martin's Axiom, Suslin's Hypothesis, and $\diamond$, that other researchers have shown to be true in some models of set theory and not in others.

In her thesis [R49] she gave an example of a nonseparable Moore space that satisfies the countable chain condition. She published the results of her thesis in three papers in the *Duke Math Journal* [R50], [R51], [R52].

To quote Steve Watson, "This cycle represents one of the greatest accomplishments in set-theoretic topology. However the mathematics in these papers is of such depth that, even forty

Kenneth Kunen is professor emeritus of mathematics at the University of Wisconsin at Madison. His email address is kunen@math.wisc.edu.

Arnold Miller is professor of mathematics at the University of Wisconsin-Madison. His email address is miller@math.wisc.edu.

years later, they remain impenetrable to all but the most diligent and patient of readers."

In [R55] she used a Suslin tree to construct a Dowker space. The existence of a Suslin tree is consistent with ZFC but not provable from ZFC. In [R71a, R71b] she constructed a Dowker space just in ZFC. This space has cardinality $(\aleph_\omega)^{\aleph_0}$, whereas the Suslin tree yields a Dowker space of size only $\aleph_1$. Also, in 1976 [JKR] she showed that CH yields a Dowker space of size $\aleph_1$. It is still an open question whether one can prove in ZFC that there is a Dowker space of size $\aleph_1$. There is one of size $\aleph_{\omega+1}$ by Kojman and Shelah [KS].

Her work on Dowker spaces led to an invited address at the International Congress of Mathematicians in 1974. It also led to her interest in the box topology, because her Dowker space of size $(\aleph_\omega)^{\aleph_0}$ is a special kind of box product.

Mary Ellen is famous for her work on box products. If X_n (for $n \in \omega$) are topological spaces, then $\square_n X_n$ denotes the product of the spaces $\prod_n X_n$ using the *box topology*; a base for this topology is given by all sets $\prod_n U_n$, where each U_n is open in X_n. The more well-known Tychonov topology, used to prove the Tychonov Theorem (1935), requires that $U_n = X_n$ for all but finitely many n. Mary Ellen was the first person to prove anything nontrivial about box products. In [R72b] she showed that, assuming CH, $\square_n X_n$ is normal, and in fact paracompact, whenever all the X_n are compact metric spaces. Also, her 1974 paper [R74] shows that $\square_n X_n$ is paracompact whenever all the X_n are successor ordinals; this easily generalizes to the case where the X_n are compact scattered spaces (see [Ku]). It was later shown by Eric van Douwen, in ZFC, that there are always compact Hausdorff X_n for which $\square_n X_n$ is not normal. The question of which of Mary Ellen's positive results can be proved in ZFC remains an outstanding unsolved problem in topology. Even the case where
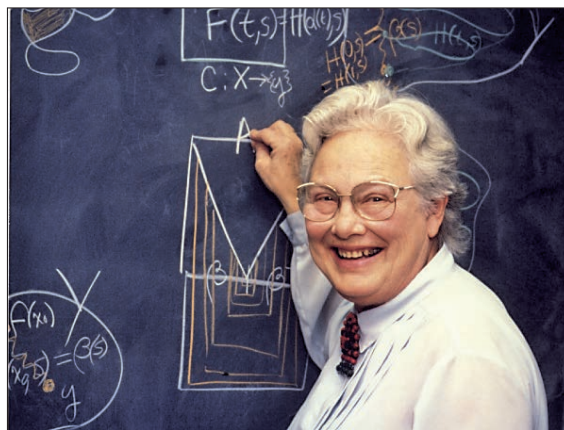

Mary Ellen lecturing.

At the Kunen Fest 2009: (left to right/front row, back row) Ken Kunen, István Juhász, Mary Ellen, Jerry Keisler, Arnold Miller, Franklin Tall, Judy Roitman.

all $X_n = \omega + 1$ remains open, although this case (or when all X_n are compact metric) does follow from Martin's Axiom.

Mary Ellen is also famous for her work on $\beta\mathbb{N}$, the space of ultrafilters on the natural numbers, starting in 1966. She was coinventor of two well-known partial orders on this space: the Rudin-Keisler order and the Rudin-Frolik order. The basic properties of these are given in her 1971 paper [R71c], although their historic roots go back somewhat earlier.

The Rudin-Frolik order led to the first proof in ZFC that the space of nonprincipal ultrafilters, $\mathbb{N}^* = \beta\mathbb{N} \setminus \mathbb{N}$, is not homogeneous. Under CH this was already known by a result of Walter Rudin (1956), who proved from CH that there is a P-point $\mathcal{U} \in \mathbb{N}^*$ (that is, $\mathcal{U}$ is in the interior of every G_δ set containing $\mathcal{U}$). Nonhomogeneity follows because every infinite compactum also has a non-P-point $\mathcal{V}$, and no homeomorphism of $\mathbb{N}^*$ can move this $\mathcal{V}$ to Walter's $\mathcal{U}$. It was shown much later (Shelah, in the 1970s) that one cannot prove in ZFC that these P-points exist.

For the Rudin-Frolik order, for $\mathcal{U}, \mathcal{V} \in \mathbb{N}^*$, say that $\mathcal{U} <_{\mathrm{RF}} \mathcal{V}$ iff $\mathcal{V}$ is a $\mathcal{U}$-limit of some discrete ω-sequence of points in $\mathbb{N}^*$. One can show that this is a partial order; also, if $\mathcal{U} <_{\mathrm{RF}} \mathcal{V}$, then no homeomorphism of $\mathbb{N}^*$ can move $\mathcal{V}$ to $\mathcal{U}$, proving nonhomogeneity.

The Rudin-Keisler order comes naturally out of the notion of induced measure. If $\mathcal{U}, \mathcal{V}$ are ultrafilters on any set I, we say that $\mathcal{U} \leq_{\mathrm{RK}} \mathcal{V}$ iff there is a map $f : I \to I$ that induces the measure $\mathcal{U}$ from $\mathcal{V}$; that is, $\mathcal{U} = \{X \subseteq I : f^{-1}(X) \in \mathcal{V}\}$. When $\mathcal{U}, \mathcal{V} \in \mathbb{N}^*$, $\mathcal{U} <_{\mathrm{RF}} \mathcal{V}$ implies that $\mathcal{U} \leq_{\mathrm{RK}} \mathcal{V}$ and $\mathcal{V} \not\leq_{\mathrm{RK}} \mathcal{U}$. This order is of importance in model theory, in the theory of ultraproducts, since $\mathcal{U} \leq_{\mathrm{RK}} \mathcal{V}$ yields a natural elementary embedding from $\prod_i \mathfrak{A}_i / \mathcal{U}$ into $\prod_i \mathfrak{A}_i / \mathcal{V}$. It is also important in

the combinatorics of ultrafilters, since the Rudin-Keisler minimal elements of $\mathbb{N}^*$ are precisely the Ramsey ultrafilters; such minimal elements exist under CH but not in ZFC. It is true, but not completely trivial, that neither of these two orders is a total order; that is, in ZFC there are $\mathcal{U}, \mathcal{V} \in \mathbb{N}^*$ such that $\mathcal{U} \not\leq_{\mathrm{RK}} \mathcal{V}$ and $\mathcal{V} \not\leq_{\mathrm{RK}} \mathcal{U}$ (and hence also $\mathcal{U} \not<_{\mathrm{RF}} \mathcal{V}$ and $\mathcal{V} \not<_{\mathrm{RF}} \mathcal{U}$). The paper [RS] (1979) of Mary Ellen and Saharon Shelah gives the strongest possible result: for each infinite κ, there is a family of 2^{2^κ} ultrafilters on κ that are pairwise incomparable in the Rudin-Keisler ordering. Mary Ellen worked extensively on the question of S- and L-spaces. She produced the first S-space (a hereditarily separable space that is not hereditarily Lindelöf) assuming the existence of a Suslin tree in 1972 [R72a]. Her Dowker space constructed from CH (see above) is also an S-space. Her 1975 monograph [R75] devotes an entire chapter to S- and L-spaces. To quote Stevo Todorčević, "The terms 'S-space' and 'L-space,' which are predominant in most of the literature on this subject, are also first found in these lectures. This shows a great influence not only of [R75] but also of M. E. Rudin's personality on the generation of mathematicians working in this area, since it is rather unusual in mathematics to talk about certain statements in terms of their counterexamples."

In 1999, almost a decade after her retirement, Mary Ellen settled a long-standing conjecture in set-theoretic topology by showing that every monotonically normal compact space is the continuous image of a linearly ordered compact space. This paper [R01] was the final one in a series of five which gradually settled more and more special cases of the final result. The construction of the linearly ordered compact space is extraordinarily complex, and to this date there is no simpler proof known.

At the time of Walter's memorial gathering in 2010: Mary Ellen with grandson Deniz, granddaughter Sofie, brother Joe Estill, daughter Eleanor, son Charlie, and granddaughter Natalie.

Mary Ellen was by consensus a dominant figure in general topology. Her results are difficult, deep, original, and important. The connections she found between topology and logic attracted many set-theorists and logicians to topology. The best general topologists and set-theorists in the world passed regularly through Madison to visit her and work with her and her students and colleagues.

She had eighteen PhD students, many of whom went on to have sterling careers of their own. To quote one of them, Michael Starbird, "From the perspective of a graduate student and collaborator, her most remarkable feature is the flood of ideas that is constantly bursting from her.... It is easy to use the Mary Ellen Rudin model to become a great advisor. The first step is to have an endless number of great ideas. Then merely give them totally generously to your students to develop and learn from. It is really quite simple. For Mary Ellen Rudin."

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Mathematics and Teaching

Hyman Bass

Induction

I was not born to be a mathematician. Like many, I was drawn to mathematics by great teaching. Not that I was encouraged or mentored by supportive and caring teachers—such was not the case. It was instead that I had as teachers some remarkable mathematicians who made the highest expression of mathematical thinking visible and available to be appreciated. This was like listening to fine music with all of its beauty, charm, and sometimes magical surprise. Though not a musician, I felt that this practice of mathematical thinking was something I could pursue with great pleasure and capably so, even if not as a virtuoso. And I had the good fortune to be in a time and place where such pursuits were comfortably encouraged.

The watershed event for me was my freshman (honors) calculus course at Princeton. The course was directed by Emil Artin, with his graduate students John Tate and Serge Lang among its teaching assistants. It was essentially a Landau-style course in real analysis (i.e., one taught rigorously from first principles). Several notable mathematics research careers were launched by that course. Amid this cohort of brilliant students, I hardly entertained ideas of an illustrious mathematical future, but I reveled in this ambience of *beautiful thinking*, and I could think of nothing more satisfying than to remain a part of that world. It was only some fifteen years later that I came to realize that this had not been a more-or-less standard freshman calculus course.

Certain mathematical dispositions that were sown in that course remain with me to this day, and influence both my research and my teaching. First is the paramount importance of proofs as the defining source of mathematical truth. A theorem is a distilled product of a proof, but the proof is a mine from which much more may often be profitably extracted. Proof analysis may show that the argument in fact proves much more than the theorem statement captures. Certain hypotheses

may not have been, or only weakly, used, and so a stronger conclusion might be drawn from the same argument. Two proofs may be observed to be structurally similar, and so the two theorems can be seen to be special cases of a more unifying claim. The most agreeable proofs explain rather than just establish truth. And the logical narrative clearly distinguishes the illuminating turn from technical routine.

Artin himself once reflected on teaching in a review published in 1953.

> We all believe that mathematics is an art. The author of a book, the lecturer in a classroom tries to convey the structural beauty of mathematics to his readers, to his listeners. In this attempt, he must always fail. Mathematics is logical to be sure, each conclusion is drawn from previously derived statements. Yet the whole of it, the real piece of art, is not linear; worse than that, its perception should be instantaneous. We have all experienced on some rare occasion the feeling of elation in realising that we have enabled our listeners to see at a moment's glance the whole architecture and all its ramifications.

Two things of a more social character about mathematics also impressed me. First, the standards for competent and valid mathematical work appeared to be clear, objective, and (so I thought at the time) culturally neutral. The norms of mathematical rigor were for the most part universal and shared across the international mathematics community. Of course mathematical correctness is not the whole story; there is also the question of the interest and significance of a piece of mathematical work. On this score matters of taste and aesthetics come into play, but there is still, compared with other fields, a remarkable degree of consensus among mathematicians about such judgments. One circumstance that readily confers validation is a rigorous solution to a problem with high pedigree, meaning that it was posed long ago and has so far defied the efforts of several recognized mathematicians.

Hyman Bass is professor of mathematics at the University of Michigan. His email address is hybass@umich.edu.

A social expression of this culture of mathematical norms stood out to me. Success in mathematics was independent of outward trappings, physical or social, of the individual. This was in striking contrast with almost every other domain of human endeavor. People, for reasons of physical appearance, affect, or personality, were often less favored in nonmathematical contexts. But, provided that they met mathematical norms, such individuals would be embraced by the mathematics community. At least so it seemed to me, and this was a feature of the mathematical world that greatly appealed to me. I have since learned that, unfortunately, many mathematicians individually compromised this cultural neutrality, allowing prejudice to discourage the entry of women and other culturally defined groups into the field.

One effect of this intellectual indifference to social norms in mathematics is that a number of accomplished mathematicians do not present the socially favored images of appearance and/or personality, and so the field is sometimes caricatured as being one of brilliant but socially maladroit and quirky individuals. On the contrary, it is a field with the full range of personality types, and it is distinctive instead for its lack of the kind of exclusion based on personality or physical appearance that infects most other domains of human performance. Perhaps the intellectual elitism and sense of aristocracy common to many mathematicians act as a counterpoint to this social egalitarianism.

The second social aspect of mathematics that stood out to me concerned communication about mathematics to nonexperts. Throughout my student years, undergraduate and graduate, I was amazed and excited by the new horizons being opened up. I enthusiastically tried to communicate some of this excitement to my nonmathematical friends, from whom I had eagerly learned so much about their own studies. These efforts were increasingly frustrated despite my efforts to put matters in analytically elementary terms. I think perhaps that I had already become too much of a mathematical formalist and considered the formal rendering of the ideas an important part of the message. This rendering was often inaccessible to my friends despite my enthusiasm. As my research career entered more abstract theoretical domains, I gradually, and with disappointment, retreated somewhat from efforts to talk to others about what I did as a mathematician. Samuel Eilenberg, my mentor when I first joined the Columbia University faculty, once said something to the effect that

> Mathematics is a performance art, but one whose only audience is fellow performers.

I remain to this day deeply interested in this communication problem, and I have admired and profited from the growing number of authors who have found the language, representations, styles, and narratives with which to communicate the nature of mathematics, its ideas, and its practices. Also, my current studies of mathematics teaching have reopened this question, but now in a somewhat different context. For twelve years of schooling, mathematics has a captive audience of young minds with a natural mathematical curiosity too often squandered. And these children's future teachers are students in the mathematics courses we teach.

Mathematical Truth and Proof

Each discipline has its notions of truth, norms for the nature and forms of allowable evidence, and warrants for claims. Mathematics has one of the oldest, most highly evolved, and well-articulated systems for certifying knowledge—deductive proof—dating from ancient Greece and eventually fully formalized in the twentieth century. There may be philosophical arguments about allowable rules of inference and about how generous an axiom base to admit, and there may be practical as well as philosophical issues about the production and verification of highly complex and lengthy, perhaps partly machine-executed, "proofs." But the underlying conceptual construct of (formal) proof is not seriously thrown into question by such productions, only whether some social or artifactual construction can be considered to legitimately support or constitute a proof.

Mathematical work generally progresses through a trajectory that I would describe as

$$\text{Exploration} \rightarrow \text{discovery} \rightarrow \text{conjecture} \rightarrow \text{proof} \rightarrow \text{certification}$$

In my work with Deborah Ball (2000, 2003) we have described the first three phases as involving *reasoning of inquiry* and the last two as *reasoning of justification*. The former is common to all fields of science. The latter has only a faint presence in mathematics education, even though it is the distinguishing characteristic of mathematics as a discipline.

Deductive proof accounts for a fundamental contrast between mathematics and the scientific disciplines: they honor very different epistemological gods. Mathematical knowledge tends much more to be cumulative. New mathematics builds on, but does not discard, what came before. The mathematical literature is extraordinarily stable and reliable. In science, by contrast, new observations or discoveries can invalidate previous models, which then lose their scientific currency. The contrast is sharpest in theoretical physics, which historically has been the science most closely allied with the development of mathematics. I. M. Singer is said to have once compared the theoretical physics literature to a blackboard that

must be periodically erased. Some theoretical physicists—Richard Feynman, for instance—enjoyed chiding the mathematicians' fastidiousness about rigorous proofs. For the physicist, if a mathematical argument is not rigorously sound but nonetheless leads to predictions that are in excellent conformity with experimental observation, then the physicist considers the claim validated by nature, if not by mathematical logic—nature is the appropriate authority. The physicist P. W. Anderson once remarked, "We are talking here about theoretical physics, and therefore of course mathematical rigor is irrelevant."

On the other hand, some mathematicians have shown a corresponding disdain for this freewheeling approach of the theoretical physicists. The mathematician E. J. McShane once likened the reasoning in a "physical argument" to that of "the man who could trace his ancestry to William the Conqueror, with only two gaps."

Even some mathematicians eschew heavy emphasis on rigorous proof in favor of more intuitive and heuristic thinking and of the role of mathematics to help explain the world in useful or illuminating ways. In general they do not necessarily scorn rigorous proof, only consign it to a faintly heeded intellectual super-ego. But I would venture nonetheless, that, for most research mathematicians, the notion of proof and its quest are at least tacitly central to their thinking and their practice as mathematicians. And this would apply even to mathematicians who, like Bill Thurston, view what mathematicians do as not so much the production of proofs, but as "advancing mathematical understanding" (Thurston, 1994). It would be hard to find anyone with the kind of mathematical understanding and function of which Thurston speaks who has not already assimilated the nature and significance of mathematical proof.

At the same time, the writing of rigorous mathematical proofs is not the work that mathematicians actually do, for the most part, or what they most cherish and celebrate. Such tributes are conferred instead on acts of creativity, of deep intuitive discovery, of insightful analysis and synthesis. André Weil (1971) said,

> If logic is the hygiene of the mathematician, it is not his source of food; the great problems furnish the daily bread on which he thrives.

Vladimir Arnold offered an even more derisory characterization:

> Proofs are to mathematics what spelling (or even calligraphy) is to poetry. Mathematical works do consist of proofs, just as poems do consist of characters.

But it is proof that finally gives mathematical achievements their pedigree.

The Proof vs. Proving Paradox

Saying that a mathematical claim is true means, for a mathematician, that there exists a proof of it. Strictly speaking, this is a theoretical concept, independent of any physical artifact and therefore also of any human agency. But *proving* is an undeniably human activity and so susceptible to human fallibility. It is an act of producing conviction about the truth of something. A mathematician, in proving a mathematical claim, will typically produce a manuscript purporting to represent a mathematical proof and exhibit it for critical examination by expert peers (certification). But as Lakatos (1976) has vividly described, this process of proof certification can be errant and uneven, though ultimately robust.

The rules for proof construction are sufficiently exact that the checking of a proof should, in principle, be a straightforward and unambiguous procedure. However, formal mathematical proofs are ponderous and unwieldy constructs. For mathematical claims of substantial complexity, mathematicians virtually never produce complete formal proofs. Indeed, requiring that they do so would cause the whole enterprise to grind to a halt. The resulting license in the practices of certifying mathematical knowledge has caused some (nonmathematical) observers to conclude that mathematical truth is just another kind of social negotiation and, so, unworthy of its prideful claims of objective certainty.

I think that this notion is based on a misunderstanding of what mathematicians are doing when they claim to be proving something. Specifically, I suggest that

> Proving a claim is, for a mathematician, an act of producing, for an audience of peer experts, an argument to convince them that a proof of the claim exists.

Two things are important to note here. First, that implicit in this description is the understanding that the peer experts possess the conceptual knowledge of the nature and significance of mathematical proof. Second, the notion of "conviction" here is operationalized to mean that

> The convinced listener feels empowered by the argument, given sufficient time, resources, and incentive, to actually construct a formal proof.

Of course, in this time of computer-aided proofs, some of this certification must be transferred to establishing the reliability of proof-checking software.

In my work with Deborah Ball, we have found this perspective helpful in studying the develop-

ment of what might reasonably be called mathematical proving in the early grades. I say more about this development below.

Compression and Abstraction

Mathematical knowledge is, as I mentioned above, cumulative (nothing is discarded) and also hierarchical. What saves it then from sinking under the weight of its own relentless growth into some dense impenetrable massive network of ideas? It is rescued from this by a distinctive feature of mathematics that some have called *compression.* This is a process by which certain fundamental mathematical concepts or structures are characterized and named and so cognitively rescaled so that they become, for the expertly initiated, as mentally manipulable as counting numbers is for a child. Think for example what a complex of ideas (and mathematical history) is packed into an expression like "complex Lie group," uttered fluently among mathematicians. Think of the years of schooling needed to invest that expression with precise meaning.

A typical form of compression arises from the unification of diverse phenomena as special cases of a single construct (for example, groups, topological spaces, Hilbert spaces, measure spaces, categories and functors, etc.) about which enough of substance can be said in general to constitute a useful unifying theory. This leads to another salient feature of mathematics: *abstraction*. Most mathematics has its roots in science and so ultimately in the "real world." But mathematics, even that contrived to solve real-world problems, *naturally* generates its own problems, and so the process continues with these, leading to successive stages of unification through abstraction until the mathematics may be several degrees removed from its empirical origins. It is a happy miracle that this process of pursuing *natural mathematical questions* repeatedly reconnects with empirical reality in unexpected and unplanned ways. This is the "unreasonable effectiveness" of which Wigner wrote (1960) and of which Varadarajan (2015) writes eloquently in [*]this collection of essays.

Abstraction is often thought to separate mathematics from science. But even among mathematicians there are different professed dispositions toward abstraction. Some mathematicians protest that they like to keep things "concrete," but a bit of reflection on what they consider to be concrete will show it to be far from such for an earlier generation. Indeed, I noticed while a graduate student that the extent to which a mathematical idea was considered abstract seemed more a measure of the mathematician's age than of the cognitive nature of the idea. As new ideas become assimilated into courses of instruction, they become the daily bread and butter of initiates, all the while remaining novel and exotic to many of their elders.

While compression is an essential instrument for the ecological survival of mathematics, its very virtue presents a serious obstacle for the teaching of mathematics. The knowledgeable and skillful mathematician has assimilated and internalized years of successive compression, streamlining of ideas, and habits of mind. But a young learner of mathematics still lives and thinks in a "mathematically decompressed" world, one that has become hard for the mathematically trained person to imagine, much less remember. This presents a special challenge to teachers of mathematics to children. And, interestingly, it requires a special kind of knowledge of mathematics itself which is neither easy for nor common among otherwise mathematically knowledgeable adults. (See Ball et al., 2005, 2008.)

Teaching Mathematics

Among the questions to which our editors invited us to direct attention was, "How are we research mathematicians viewed by others?" For one community, (school) mathematics teachers and education researchers, I have some firsthand knowledge of this after more than a decade of interdisciplinary work in mathematics education, and what I have learned I find both interesting and important for mathematicians to understand. I began this essay with an account of how great university teaching drew me into mathematics. Now, in my close study of elementary mathematics teaching, I have a changed vision of what teaching entails.

Of course many mathematicians, like mathematics educators, are seriously interested in the mathematics education of students. But there are significant differences in how the two communities, broadly speaking, see this enterprise. The mathematicians' interests, naturally enough, are directed primarily at the graduate and undergraduate levels and perhaps somewhat at the secondary level. In contrast, the interests of the educators are predominantly aimed at the primary through secondary levels. But there is a broadening overlap in the ranges of interest of the two communities, and some fundamental aspects of what constitutes quality teaching are arguably independent of educational levels. Nonetheless, in areas of common focus there are often profound differences of perspective and understanding across the two communities about what constitutes quality mathematics instruction. I expand on this below.

There is also a difference in educational priorities between the mathematics and mathematics education communities, a difference whose importance cannot be overstated. Mathematicians are naturally interested in "pipeline" issues, the rejuvenation of the professional community, and so the induction and nurturing of talented and highly motivated students into high-level mathematical study. Mathematics educators, on the

other hand, are professionally committed to the improvement of public education at scale, with the aim of *high levels of learning for all students* and with a heavy emphasis on the word "all." While these two agendas are not intrinsically in conflict or competition, they are often seen to be so, and this can have resource and policy implications. Public education in the US, despite long and costly interventions, continues to perform poorly in international comparisons in terms of meeting workplace demands and even in providing basic literacies. Moreover, there is a persistent achievement gap reflected in underperformance of certain subpopulations that the educational system historically has not served well. These are the "big frontline problems" of mathematics education, and they are just as compelling and urgent to mathematics educators as the big research problems are to mathematicians.

Mathematicians have an excellent tradition of nurturing students of talent. What they are less good at is identifying potential talent. The usual indices, high test scores and precocious accomplishment, are easy enough to apply, but these will typically overlook students of mathematical promise whom the system has not encouraged or given either the expectation of or opportunity for high performance. As a result, mathematical enrichment programs, if not sensitively designed, can sometimes perpetuate the very inequities that mathematics educators are trying to mitigate.

My main focus here, however, is on teaching. Much of what I have learned I owe to work with my colleague and collaborator, Deborah Ball. To facilitate what I want to say, it will be helpful to use a schematic developed by Deborah and her colleagues David K. Cohen and Stephen W. Raudenbush (2003) to describe the nature of instruction.

The "Instructional Triangle"
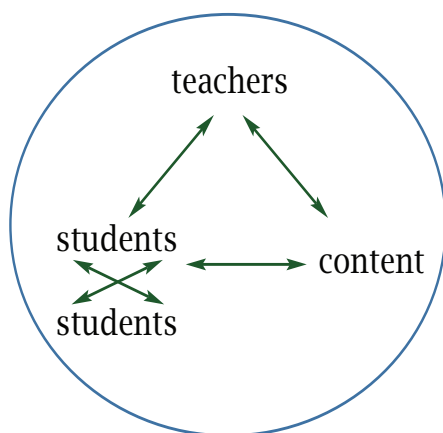
The concept proposed by this image is that instruction is about the interactions of the teacher with students (and of students with each other) around content. The double arrows emphasize that these interactions are dynamic; in particular, changing any one element of the picture significantly alters the whole picture.

Now what I suggest is that most mathematicians' conception of instruction lives primarily at the content corner of the triangle, with its school incarnation expressed in terms of curriculum (including both standards documents and curriculum materials). In this view, with high-quality curriculum in place, the mathematically competent teacher has only to implement that curriculum with intellectual fidelity, and then attentive and motivated students will learn. Of course mathematicians have little direct influence on schoolchildren, but they often have explicit, discipline-inspired ideas about what mathematics children should learn and how. In the case of teachers, mathematicians do bear some direct responsibility for their mathematical proficiency, since many teachers learn much of the mathematics they know in university mathematics courses. Many studies have pointed to weak teacher content knowledge as a major source of underperformance in public education. Of the many remedies proposed, mathematicians have generally favored more and higher-level mathematics courses as a requirement for certification. Unfortunately, none of the interventions based on these ideas so far undertaken have yet produced the desired gains in student achievement for a broad range of students. Note that all of this discussion and debate resides on the content-teacher side of the triangle, with little explicit attention yet given to the role of the students in instruction. Effective teachers teach both math and children.

An educational counterpart to the above "one-sided" (teacher-content) stance is an intellectually adventurous, but somewhat romantic, view of school teaching, this time on the teacher-student side of the triangle. This approach proposes offering tangible and somehow "real-world" related mathematical activities with which to engage learners but leaving the development of mathematical ideas to largely unrestrained student imagination and invention. In such cases the discipline of the mathematical ideas may be softened to the point of dissipation.

The most refined understanding of mathematics teaching, of which Deborah Ball's work is exemplary, insists that teaching must coordinate attention to the integrity of the mathematics and appropriate learning goals with attention to student thinking, which needs to be honored and made an integral part of the instruction. In this view, the effective teacher has not only a deep understanding of and fascination with the mathematics being taught but also a dual knowledge of and fascination with student thinking. The underlying premise is that children have significant mathematical ideas, albeit imperfectly

expressed, and that a part of the teacher's work is to recognize the presence of those ideas (for which a sophisticated knowledge of mathematics is needed!), to give them appropriate validation, and to help students shape them into a more developed articulation and understanding. It is the coordination of these dual spheres of attention, both to the mathematics and to students' thinking, that makes effective teaching the intricate and skilled work that it is.

This is a kind of professional practice that discursive rhetoric cannot adequately capture. It is best conveyed through an examination of teaching practice itself. So let me offer a vignette. Consider the teaching of mathematical proving. This is typically first done in high school geometry, but there are good reasons to argue that it should be done developmentally, starting in the early grades. What might this mean or look like? After all, young children have no concept of anything approaching mathematical proof, and no one seriously argues that this should be formally taught to them. First of all, what is the intellectual imperative for proving that can be made meaningful to young children? Our view is that it is the persistent question, "Why are things true?" Deductive proof is the refined method devised by mathematicians to answer that very question. Learning the methods of deductive proving takes time, but the question Why are things true? is itself immediately compelling. The underlying pedagogy is that students progressively learn the methods of constructing compelling mathematical arguments in the course of repeatedly trying to convince others of things they have good reasons to believe to be true. In other words, students can be helped to construct the infrastructure of proving in the very course of proving things (to the best of their growing abilities).

To illustrate this idea, I turn to an episode from a third-grade class (8-year-olds). The children have been exploring even and odd numbers. Although they do not yet have formal definitions, they rely on intuitive ideas of even and odd based on notions of fair-sharing, and they can identify whether particular (small) numbers are even or odd. They begin to notice addition patterns, like: even + even = even, even + odd = odd, and odd + odd = even. The teacher asks them whether they can "prove" that "Betsy's Conjecture" (odd + odd = even) is *always* true. Some of the children have tested the conjecture with lots of numbers, and they are thereby convinced that it must be true. The teacher challenges them, "How do you know that someone might not come up with a new example that doesn't work?" The children are left to ponder that, some of them working collaboratively in small groups.

The next day, the teacher asks the class what they found out. Several hands go up, and she calls on Jeannie, who, speaking also for her partner, Sheena, says, "We were trying to prove that…you can't prove that Betsy's Conjecture always works… because numbers go on and on forever, and that means odd numbers and even numbers go on forever and, um, so you couldn't prove that all of them work." This stunning assertion is at once insightful and revolutionary. Jeannie's comment reflects the fact that Betsy's Conjecture is not just one, but rather infinitely many claims, and so not susceptible to empirical verification. Though articulated somewhat informally, she has realized that the cases of the conjecture go on and on.

A second student, Mei, objects to this argument. She objects not to the reasoning but rather to an important inconsistency. She points out that prior claims for which the class had achieved consensus were also not checked in all cases, and Jeannie and her partner had not raised any similar objection to those earlier claims. She challenges the need to make sure that the claim works for all cases, since they had not tried to do this for other conjectures.

In both of these contributions, one can see the process by which the class is beginning to construct the very norms of mathematical reasoning: rejecting empirical methods for an infinitely quantified claim in the first instance and the need for consistency of logical methods in the second. And all of this is still short of proving Betsy's Conjecture.

But the next day, Betsy produces a "proof" of her conjecture. At the board she draws a row of seven small circles and then to the right another row of seven small circles. Then she partitions the two rows into three groups of two, with one left over, and the ones left over next to each other in the middle:

$$\underline{o}\,\underline{o}\,\underline{o}\,\underline{o}\,\underline{o}\,\underline{o}\,o \quad o\,\underline{o}\,\underline{o}\,\underline{o}\,\underline{o}\,\underline{o}\,\underline{o}$$

Then she turns to the class and explains haltingly, "If you have an odd number and group it by twos you have one left over, so if you have two odd numbers and group them by twos, then the ones left over can be grouped together so you have an even number." What is most significant about this oral argument is she makes no reference to the specific numbers 7 and 7 that she has drawn, but rather speaks generically of "an odd number."

How does this demonstration surmount the dilemma raised by Jeannie and Sheena? Betsy has implicitly invoked a general definition of odd number—a number that when grouped by twos has one left over—and this definition, being itself infinitely quantified (it characterizes all odd numbers), can support a conclusion of similarly infinite purview. Betsy's oral argument might be algebraically expressed in the form

$$(x_2 + 1) + (1 + y_2) = x_2 + (1+1) + y_2 = (x+1+y)_2.$$

(Note that, for children at this stage, $2x = x + x$ is not the same as $x_2 = 2+2+\cdots+2$.) But, although she

is thinking in general terms, Betsy does not yet know how to represent her ideas generally using algebraic notation.

Notice for each of these students—Jeannie, Mei, and Betsy—the significance of the mathematical ideas, albeit sometimes expressed with difficulty. Episodes like this demonstrate what it might look like to develop the norms of proving in the course of constructing more and more well-developed arguments to convince others of the truth of claims. But this is not the whole story. This narrative resides, as does much of the education research literature, on the student-content side of the instructional triangle, focusing on accomplished student performance. The teacher seems invisible.

The above kind of collective interaction and learning does not occur spontaneously, unmediated by well-informed and purposeful instruction. The question of what makes for effective teaching has to do with understanding the knowledge, skills, and sensibilities (both mathematical and pedagogical) and, above all, the practices that enable instruction that can elicit the kind of motivation and reflective engagement of students described in the episode above. The kind of mathematical knowledge required includes not only a robust understanding of the mathematical terrain of the work and corresponding learning goals but also an ability to hear, in incipient and undeveloped form, significant, though often not entirely correct, mathematical ideas in student thinking. I emphasize that the latter entails a special kind of knowledge of mathematics, not just psychology. Teaching requires the skills to not only hear and validate and give space to these ideas, but also to help students reshape them in mathematically productive ways. The teacher needs to know how to instruct with questions more than with answers and to give students appropriate time, space, and resources to engage these questions. The actions to accomplish this, though purposeful, structured, and carefully calibrated to the students, are also subtle, deliberately focusing on student performance. And so, to the naive observer, it often can appear that "the teacher is not doing much." The central problem of teacher education is to provide teachers with the knowledge and skills of such effective practice.

The idea of developmental learning, such as we saw with the third-graders above, was also a feature of my calculus course back at Princeton in 1951. I first learned in that course what (a strange thing) a real number was (mathematically),[1] even though I had been working comfortably with real numbers throughout the upper high school grades. With regard to proving, while we learned, through witnessing stunning examples and through practice problems how to construct reasonably

rigorous proofs, it was still always the case that the claims in question seemed at least reasonable and sufficiently meaningful that general mathematical intuition could guide us. But I was at first stymied by a problem on one of our take-home exams. A function $f(x)$ was defined by: $f(x) = 0$ for x irrational, and $f(x) = 1/q$ if x is rational, equal to p/q in reduced form. The question was, "Where is f continuous?" At first sight this question seemed outrageous. How could one possibly answer it? It was impossible to sketch the graph. Intuition was useless. After some reflection I resigned myself to the fact that all we had to work with were definitions of f and of continuity. It was a great revelation to me that these definitions and a modest amount of numerical intuition sufficed to answer the question. This was a great lesson about the nature and the power of deductive reasoning, to which my enculturation, though at a different level, was not so different from that of the third-graders above.

The construction and timing of such a problem was itself a piece of instruction. I wish now that we had video records of Emil Artin's calculus teaching that I could show to an accomplished teacher, like Deborah, to analyze the pedagogical moves, including interaction with students, of which his practice was composed. Much as I profited from that instruction, I was not prepared to see the craft of its construction.

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[1]*An equivalence class of Cauchy sequences of rational numbers.*

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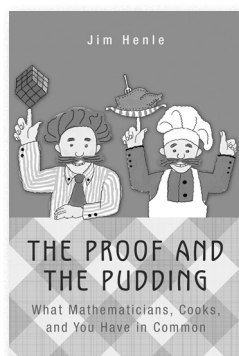
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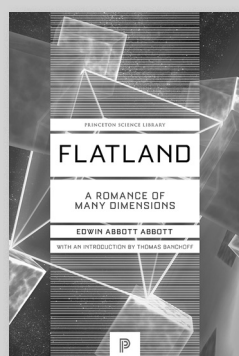
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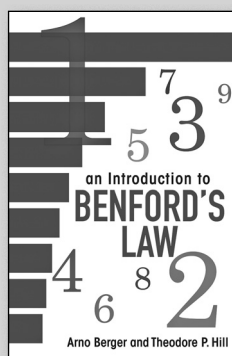
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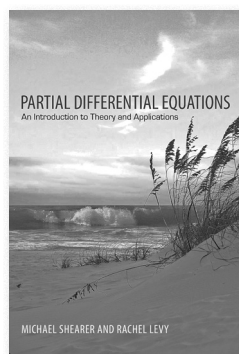
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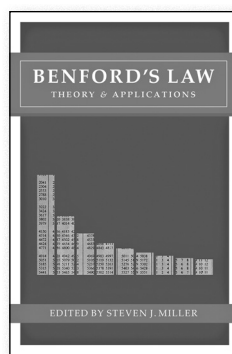
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Theory and Applications

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Professional Development in Teaching for Mathematics Graduate Students

Jessica M. Deshler, Shandy Hauk, and Natasha Speer

"My 'professional development' before going into a classroom as a TA was 'Here's the book, here's a syllabus, show up Monday. Turn in grades in December and don't sleep with any students in between.' Since then, I've gotten pretty good at handling teaching, but it has taken awhile."

"I was very lucky to get the mentoring in teaching I received when I started as a TA. I learned to teach well quickly, and didn't need much help after my first year."

"I am so thankful to have received the on-going professional development I had as a TA throughout my doctoral program. As I enter my first faculty position I'm confident in my abilities to adapt my teaching to a new environment and a new student population because of it."

Figure 1. Statements from mathematics graduate students describing TA experiences.

The purpose of this article is twofold: to give a sense of the current lay of the land in the preparation of mathematics graduate student teaching assistants (TAs) and to describe the collegiate mathematics education research base informing the next generation of college mathematics instructor preparation. We anchor discussion in three common types of TA preparation programs, each represented in one of the quotes above. Notably, the first quote represents a sink or swim experience that is becoming rare in US PhD-granting mathematics departments. Preparation of TAs for their instructional roles has blossomed in the last twenty years. The second quote is representative of current practices in many departments. The third quote illustrates the activities in innova-

tive departments that are already implementing best practices suggested by research in collegiate mathematics education: sustained professional growth about teaching and learning.

To highlight the challenges and benefits of spending time paying attention to teaching, we provide information from postsecondary and related secondary-level educational research of several types. This includes basic and applied educational research that identifies good instructional practices, examines experiences TAs bring with them to teaching, provides frameworks for the structuring of TA preparation, and gives insight into the kinds of mathematics-specific and teaching-specific knowledge that needs to be developed among TAs. And, once a program for supporting TAs to learn and grow as instructors is put in place, evaluation research explores the implementation of efforts to improve TAs' teaching and the related impacts on undergraduate student learning. We close with promising practices and sketch anticipations for the future of the field of related research.

Though not common thirty years ago, today most doctorate- and master's-granting institutions provide some kind of TA preparation for teaching [4a]. The content for this professional development often comes from mathematicians offering their collective wisdom from practical

Jessica M. Deshler is assistant professor of mathematics at West Virginia University. Her email address is `deshler@math.wvu.edu`.

Shandy Hauk is senior research associate at WestEd and graduate faculty member in mathematical sciences at the University of Northern Colorado. Her email address is `shauk@wested.org`.

Natasha Speer is associate professor of mathematics at the University of Maine. Her email address is `speer@math.umaine.edu`.

experience. At its most basic, TA "training" these days consists of one to six hours of orientation to teaching during the week before classes begin and a one-semester weekly seminar on particular course topics (e.g., a course coordination meeting for those involved in teaching Calculus I). For a growing number of departments, a second kind of TA preparation is available as a semester or more of activities guided by materials such as Sarkisian's [15] book for international TAs or a college mathematics instruction-specific resource like DeLong and Winter's book [7] or Friedberg et al.'s [9] cases. A third level of TA instructional learning includes presemester and first-year support along with professional development during subsequent years of teaching. While TA development across time can occur in course-specific coordination meetings, some institutions have ongoing seminars attended by new and experienced TAs as well as faculty and others interested in college mathematics instruction. Currently, regardless of department-organized supports, about two-thirds of TAs (domestic and international) rely at least in part on "unofficial" types of professional learning that cannot be listed on a curriculum vitae and that depend on local department culture; these include regular unstructured conversations with faculty members who make themselves available to TAs to talk about teaching [4e].

Research to Inform Practice

Today's cutting-edge research on novice college mathematics instructor and TA development depends on frameworks that connect theories of learning and teaching to undergraduate student achievement. Like the much longer history of research on precollegiate school teaching, this new postsecondary work provides research-based guidance for instructor development. Rapid progress in the field has been possible largely because it has focused on extending results about good instructional practices and teacher knowledge development from the established precollegiate mathematics (and science) education literature.

While some issues of college teaching cut across disciplines, many are discipline specific. Researchers have documented features of the culture and community of mathematics and the influences in that community, particularly among TAs. For example, the research reported in a special issue of *Studies in Graduate and Professional Student Development* [4] represents some of the recent steps toward understanding how graduate students grow as instructors within the mathematics community. The articles in that volume include summative, statistical, and case study reports about TAs' teaching [4a], [4b], [4c], TA views about the teaching and learning of mathematics [4d], [4h], TA perceptions of mathematics departmental support [4e], what TAs do when they plan for class [4f], and enculturation experiences for international TAs in mathematics departments [4g]. The result

of this and associated work is an understanding that mathematics TA development takes more than relying on a university center offering general professional support.

What Are Good Instructional Practices?

What instructors do in the classroom makes a difference in the learning opportunities students have. We know from collegiate and precollege education research that students learn more deeply with higher frequencies of particular instructional practices. These include working together on tasks, giving presentations, and engaging in whole-class and group discussions where explanation and justification are required [14]. For example, if we define a successful calculus program as Bressoud and others have in a recent study [5], then it turns out that instruction characteristic of highly successful programs has students work together to understand and explain their problem solving. In addition, as part of the same Mathematical Association of America (MAA) calculus study, researchers have identified structural components of successful programs. These include various course coordination policies and aspects of department culture (e.g., encouraging experimentation with student-active classroom strategies) and, notably, professional development for TAs. In particular, the study reports that TA professional preparation in successful programs includes both an intensive initial preparation experience plus ongoing learning opportunities through seminars, courses, and/or mentoring.

What Experience of Teaching and Learning Do TAs Bring to Instruction?

Like most mathematicians, novice college mathematics instructors' experiences as learners typically include a history of success in undergraduate mathematics, a notable absence of precalculus courses taken as an undergraduate, and great familiarity with lecture-based mathematics classes. So, not surprisingly, mathematics TAs report the greatest comfort with lecture and find some of the greatest challenge in working with students whose backgrounds or experiences are unlike their own (Figure 1). Yet, throughout graduate school and over a career, instructors most often teach students whose expertise and experience with mathematics is quite distinct from their own. Nearly two-thirds of instructional assignments in PhD-granting departments are in first-year courses like calculus and below [13].

While lecture is the most familiar teaching strategy, graduate students have a wealth of experience in learning mathematics in addition to attending lectures. They are familiar with sense-making strategies associated with the norms of seminars, particularly for proof writing, validation, and justification. Part of becoming an expert in advanced mathematics is developing skills to coordinate and

choose flexibly among multiple representations and to critique one's reasoning (and that of others) using why, how, and why-not questions. When used to scaffold conversations in college classrooms, these questioning strategies also turn out to be the earmarks of successful instruction [5, 12]. Yet, as undergraduates, TAs may not have taken courses where instructors modeled these effective active-learning approaches. Current thinking in TA development includes how to leverage the fact that the approaches to learning we want graduate students to develop in their study of advanced mathematics have a great deal in common with the learning opportunities we would like them to create for their own undergraduate students.

> In all cases, good TAs are a benefit to a mathematics department, both in the actual teaching of mathematics to undergraduates and in relations with other departments and the administration. Bad TAs, as measured by student complaints, are a liability.
>
> —*Friedberg* [8, p. 842]

What Are Good Models for Novice Instructor Development?

Suppose a department is moving into an expansion of TA development. What is reasonable to expect? Based on lessons learned in precollegiate education research, the greatest improvements in student learning come when teacher professional development has a format with [3]:

(1) An intensive initial experience, plus

(2) A spaced-across-time follow-up that includes sustained engagement with at least two components such as:

(a) Examining student thinking and student work

(b) Collaborating in teams to learn about teaching

(c) Engaging in plan-implement-assess-reflect cycles

(d) Analyzing and designing assessments

(e) Working with a mentor through multiple classroom visits and conversations

Figure 2 illustrates this research-based constellation of effective professional learning components. Note that while public presentation to others about instructional practices (e.g., in a teaching seminar) is a support for better teaching, at least two other aspects appear to be necessary. We know from precollegiate education research that successful professional development programs focus on helping teachers understand how
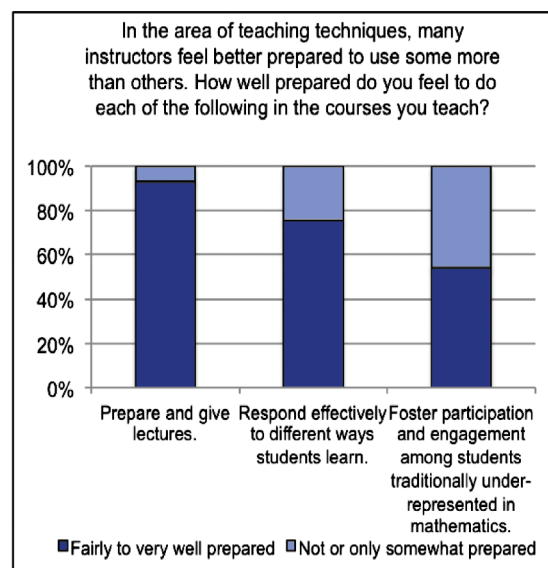
Figure 1. TAs views of their readiness to implement certain instructional techniques. Source: 203 responses by TAs at Group I universities; current work by Hauk.

students learn and on building skill with pedagogical strategies that are effective for deepening students' subject-matter knowledge. Moreover, in the Blank and de las Alas [3] meta-analysis, effectiveness increased with collective participation of instructors in a department. Other development activities (e.g., by a university-wide office) may offer limited opportunities for such collaboration.

We know that when secondary teachers use active learning, reflective planning, student-responsive teaching, and make connections within and among these areas, teacher knowledge grows and desired changes in instructional practice occur. That similar results hold for college instruction has
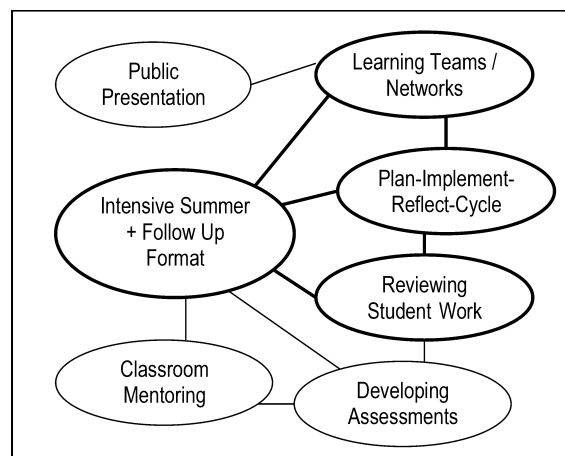
Figure 2. Constellations of effective professional development (based on [3]). Darkened set of connected ovals is one example of an effective constellation.

been confirmed in several studies, particularly as TAs attend to their students' thinking [4h]. Perhaps not surprisingly, when instructors observe, listen to, and talk with students they gain knowledge of how students think. What may be less obvious is that it is a cyclic process. That is, if instructors are armed with knowledge of student thinking, they are both more likely to provide students with learning opportunities in the present and to enrich their own opportunities to build knowledge of student thinking in the future. College-level research has illustrated that effective planning and instructional decisions take into consideration the ways students think [4f]. Such learning in and from teaching is quite context specific. As discussed below, it weaves together content knowledge about mathematics with knowledge about teaching.

What Is Pedagogical Content Knowledge (PCK)?

Those who have taught calculus recently have probably witnessed the following phenomenon. Students learn the chain rule to calculate derivatives. Some students then get carried away and either apply it to every function (whether or not it is appropriate) or iterate its application more times than necessary on "inner" functions. Similarly, experienced instructors are also likely to be familiar with a number of strategies that students might use successfully to factor second-degree polynomial expressions, even if they themselves were taught (and prefer) just one method. Evidence has accumulated that this kind of discipline-specific knowledge for teaching plays a substantial role in shaping instructional practices. This pedagogical content knowledge (PCK) is a kind of mathematical knowledge that supports effective mathematics instruction [1, 16]. The research on PCK in collegiate and precollegiate settings has provided evidence that the work of teaching demands more than just knowledge of the content being taught. In particular, knowledge of typical difficulties and various ways of thinking experienced by students along with knowledge of especially illuminating examples are major factors that shape instructors' practices and their students' learning. In addition, even with ongoing, sustained professional learning, it is possible to return to "novice instructor" status and be in need of additional professional development if faced with a new type of course or a variation of student population in a teaching assignment. Even experienced faculty struggle with the demands placed on their own PCK in new and highly interactive classroom contexts. The growing body of research in collegiate mathematics education points to several aspects of PCK development as key to effective instruction, like using student thinking, attending to computational and conceptual understanding, and orchestrating productive classroom discussions.

In part, mathematics TAs build pedagogical content knowledge through attention to student thinking when they grade or respond to student work. They also might have one-on-one conversations with students in office hours, a tutoring lab, or during class. TAs can learn to use all that student-based information productively as they plan for and implement interaction with students [11]. In addition to anticipation about student thinking, PCK includes awareness of what concepts are essential in a particular course and knowledge related to communicating about mathematics given the variety of thinking and preparation among students in the room [10]. TAs may gain some knowledge about prerequisite and subsequent concepts from their own experiences as students but need guidance to understand the experiences and needs of undergraduates who are not mathematics majors.

> Until recently, it was hardly acknowledged that teaching entails knowledge and skills that are more than academic subject-matter knowledge combined with formally lucid exposition and a sympathetic disposition toward students. In fact, it involves a kind of knowledge of mathematics itself distinct from what research mathematicians require for their research or typically know. Moreover, it is only recently being recognized that this knowledge and skill can be taught and learned.
> —*Bass* [2, p. 109]

What about Professional Development for Teaching after Graduate School?

In addition to classroom-specific skills, to flourish in their careers, graduate students need to develop awareness and knowledge of resources for professional learning beyond graduate school. There are many potential sources of professional development available for new college faculty that might be shared in a TA development program. For example, more than 10 percent of the people who complete PhDs in mathematics each year and are hired into tenure-track positions in US departments become MAA Project NExT Fellows (about eighty Fellows per year). Project NExT participants engage in professional learning and networking about teaching [17]. In addition, the AMS, MAA, and the American Mathematical Association of Two-Year Colleges (AMATYC) have programs, groups, and conference sessions that are valuable resources for new college faculty.

Determining the Effectiveness of TA Professional Development Programs

Given what is known about the structure, time, community supports, and pedagogical content knowledge development needed for effective TA preparation, we come to an obvious question. When we implement TA professional development, how do we know if it is working?

Let us start with the purpose of the endeavor: to help TAs develop as instructional professionals in both the short and long term. Research suggests that it is worthwhile to pay attention to knowledge and changes in knowledge (e.g., of mathematics, of pedagogy, of pedagogical content knowledge). It is also valuable to attend to shifts in TA beliefs about teaching, learning, and the doing of mathematics and to types and evolution in use of instructional practices while also considering increases in students' success.

Evaluation research focuses on examining how a program is working. First, there is a need to identify information to collect systematically. This will include triangulating among basic methods of capturing information about teaching: surveys, interviews, observations, and portfolios/artifacts (see [18] for an accessible primer on these methods). In some cases we can collect data before TAs participate in professional development so that it might be compared to another data set collected later. In other cases, it is more useful to identify departmental or development goals and gather data midstream and/or at strategic points in a program. For example, if the goal is that TAs are effective teachers, possible indicators could be that outcomes of interest (e.g., grade distribution, student evaluations, etc.) among TAs' students is within the 95 percent confidence interval of that among experienced faculty members' students. More than statistics, effective evaluation of a TA preparation program will include details that provide context for any quantitative results. This can include structured reporting in a teaching portfolio, TA comments on the departmental TA experience, analysis of undergraduate student written comments on midterm and end-of-term feedback forms, and TA response to and sense-making about these things.

Whatever the approach, it is essential to identify information to gather, get and analyze it, and to then determine what the lessons are to be learned from it. Equally critical is that the next iteration of TA development in the department be informed by those lessons learned.

Conclusion

Every future mathematician, scientist, and engineer takes many mathematics courses in college. Moreover, every future elementary, middle, and high school teacher takes mathematics courses as an undergraduate. For many, TAs provide some of this instruction. Thus, the quality of learning opportunities for a broad cross-section of the nation's college students is shaped by TAs' preparation to teach. The importance of teaching-related preparation and development increases even further as we recognize that subsequent generations of postsecondary faculty will come from current pools of graduate students. Many of these graduate students will go on to faculty positions at undergraduate institutions, dispersing among more than four thousand research and comprehensive universities, liberal arts colleges, and community colleges in the country. More than 70 percent of those who complete the PhD in mathematics and go into academic positions will spend their careers outside the kind of universities they attend [6]. Before TAs leave for jobs where the quality of their teaching is at least as important as their research production, graduate mathematics programs can serve TAs, the academy, and the nation with carefully designed and well-maintained programs of professional development in teaching. A graduate teaching assistantship may or may not prepare a newly minted doctoral graduate for the teaching challenges in a four-year or two-year college. However, a good TA development program produces instructors who can learn from their own practice and who know to seek collegial support. In a new faculty role, those skills are essential for continued professional growth.

We are only at the beginning of a complex process of understanding how the teaching and learning of college mathematics take place and how the experience of novice instructors, like TAs, plays out. Topics for research conducted in the college context that are likely to be important for work with TAs include: how novice college instructors learn to teach, how characteristics of instructors and their practices shape undergraduates' learning, how culture and context shape everything, and how college mathematics curriculum and teaching methods are understood, adopted, and enacted. Researchers in collegiate mathematics education are beginning to make progress with some of these topics. In particular, there is a special interest group of the MAA on research in undergraduate mathematics education and a working group within it that focuses on research around becoming an effective college mathematics instructor, including TA and faculty development (see `sigmaa.maa.org/rume`). In addition, a new, NSF-funded effort through the MAA (DUE-1432381) aims to create a Web portal for TA professional development materials and related research and evaluation (`www.maa.org/programs/faculty-and-departments/cominds`).

Finally, insights from experienced college mathematics instructors are crucial in the development of the next generation of college mathematics faculty. Say "Yes!" when collegiate mathematics education researchers ask if they can come visit

your classroom or do an interview. Knowing what and how people have learned from their own teaching experiences will shape future research and development intended to help others learn to learn from practice.

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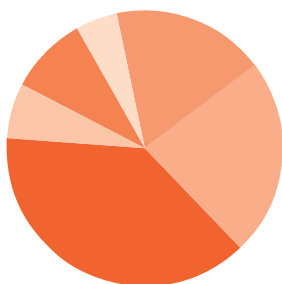
2014-2015
Faculty Salaries Report

William Yslas Vélez, James W. Maxwell, and Colleen A. Rose

This report provides information on the distribution of 2014–15 academic-year salaries for tenured and tenure-track faculty at four-year mathematical sciences departments in the US by the departmental groupings used in the Annual Survey. (See page 649 for the definitions of the various departmental groupings.) Salaries are described separately by rank. Salaries are reported in current dollars (at time of data collection). Results reported here are based on the departments that responded to the survey, with no adjustment for non-response.

Departments were asked to report for each rank the number of tenured and tenure-track faculty whose 2014–15 academic-year salaries fell within given salary intervals. Reporting salary data in this fashion ensures confidentiality of individual reponses, though it does mean that the reported quartiles are only approximations. The quartiles reported have been estimated assuming that the density over each interval is uniform.

When comparing current and prior year figures, one should keep in mind that differences in the set of responding departments may be one of the most important factors in the change in the reported mean salaries. This report uses the new groupings of doctoral-granting mathematics departments adopted in 2012 by the Joint Data Committee. Additional detail is provided on page 649.

Math. Public Large Group Faculty Salaries
Doctoral degree-granting departments of mathematics
23 responses out of 26 departments (88%)

| Rank | No. Reported | 2014–15 | | | | 2013–14 |
		Q_1	Median	Q_3	Mean	Mean
New-Hire Asst Prof	38	85,600	88,200	92,500	87,657	85,322
Assistant Professor*	152	83,000	87,100	90,900	86,745	82,907
Associate Professor	211	84,400	91,400	97,500	91,842	88,646
Full Professor	792	111,200	129,800	158,200	139,352	133,858

*Includes new hires.

William Yslas Vélez is a professor in the Department of Mathematics at University of Arizona. James W. Maxwell is AMS Coordinator of special projects. Colleen A. Rose is AMS survey analyst.

Math. Public Medium Group Faculty Salaries
Doctoral degree-granting departments of mathematics
37 responses out of 40 departments (93%)

Rank	No. Reported	2014–15				2013–14
		Q₁	Median	Q₃	Mean	Mean
New-Hire Asst Prof	46	72,700	78,600	86,200	78,096	75,415
Assistant Professor*	233	72,100	77,300	82,400	76,611	74,640
Associate Professor	316	75,100	82,000	89,500	82,613	80,744
Full Professor	691	95,100	108,700	131,100	115,965	113,309

2014–15 Academic-Year Salaries (in thousands of dollars)
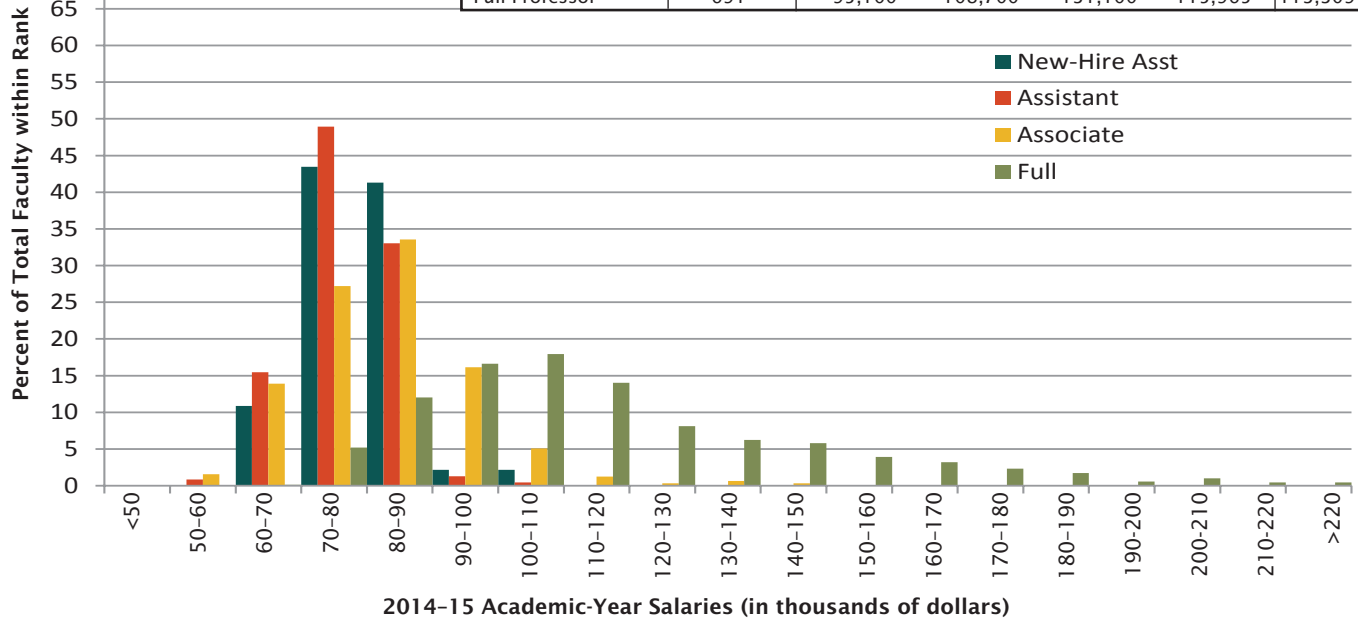
Math. Public Small Group Faculty Salaries
Doctoral degree-granting departments of mathematics
49 responses out of 64 departments (77%)

Rank	No. Reported	2014–15				2013–14
		Q₁	Median	Q₃	Mean	Mean
New-Hire Asst Prof	53	67,000	71,800	78,100	72,069	68,686
Assistant Professor*	234	64,400	69,100	74,100	69,364	67,466
Associate Professor	351	69,600	75,700	81,800	76,247	73,616
Full Professor	579	86,900	96,400	109,900	102,209	99,278

2014–15 Academic-Year Salaries (in thousands of dollars)

*Includes new hires.

Math. Private Large Group Faculty Salaries
Doctoral degree-granting departments of mathematics
15 responses out of 24 departments (63%)

| Rank | No. Reported | 2014–15 | | | | 2014–14 |
		Q₁	Median	Q₃	Mean	Mean
New-Hire Asst Prof	9	91,900	96,700	102,500	97,278	98,222
Assistant Professor*	49	87,700	92,500	97,800	92,613	90,714
Associate Professor	53	93,800	102,000	113,600	103,491	99,797
Full Professor	258	123,800	145,000	167,700	148,894	145,677

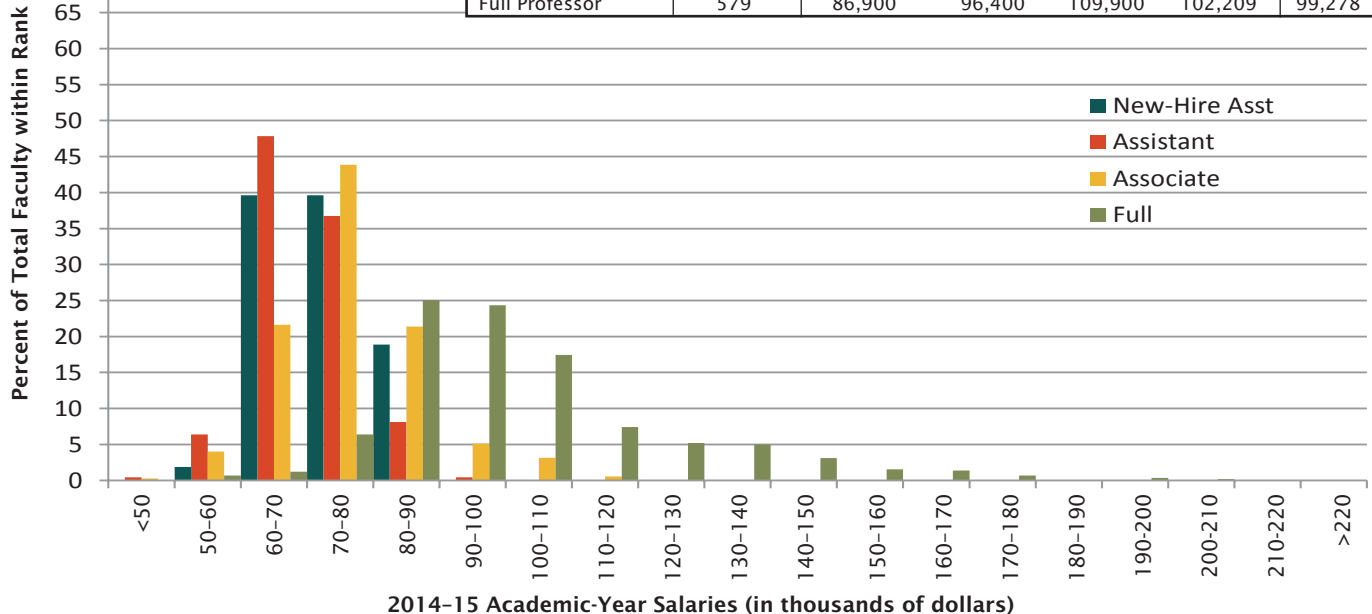**2014–2015 Academic-Year Salaries (in thousands of dollars)**

Math. Private Small Group Faculty Salaries
Doctoral degree-granting departments of mathematics
22 responses out of 28 departments (79%)

| Rank | No. Reported | 2014–15 | | | | 2013–14 |
		Q₁	Median	Q₃	Mean	Mean
New-Hire Asst Prof	19	71,700	77,900	82,500	77,498	76,265
Assistant Professor*	84	72,900	80,100	85,300	79,782	78,450
Associate Professor	126	79,600	85,900	92,960	85,500	84,599
Full Professor	218	101,200	118,300	140,800	125,740	124,501

2014–15 Academic-Year Salaries (in thousands of dollars)

*Includes new hires.

Applied Mathematics Group Faculty Salaries
Doctoral degree-granting departments of applied mathematics
15 responses out of 24 departments (63%)

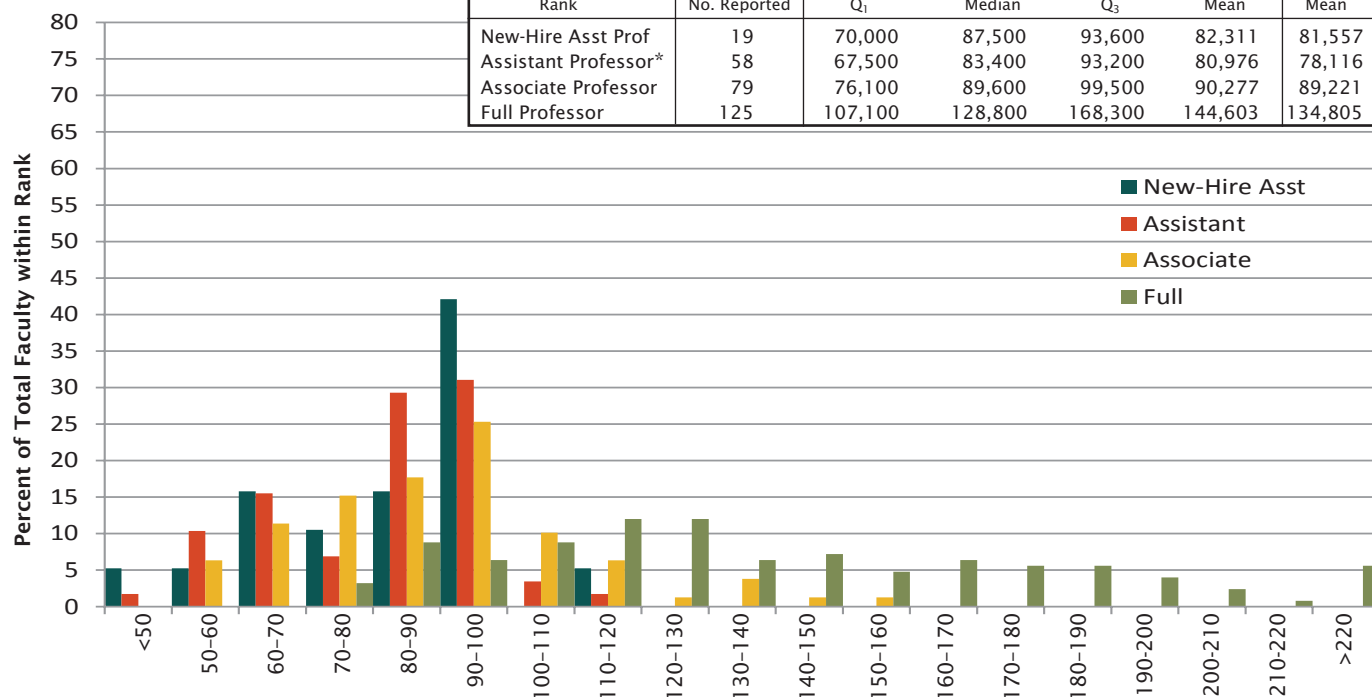| Rank | No. Reported | 2014–15 | | | | 2013–14 |
		Q1	Median	Q3	Mean	Mean
New-Hire Asst Prof	19	70,000	87,500	93,600	82,311	81,557
Assistant Professor*	58	67,500	83,400	93,200	80,976	78,116
Associate Professor	79	76,100	89,600	99,500	90,277	89,221
Full Professor	125	107,100	128,800	168,300	144,603	134,805

2014–15 Academic-Year Salaries (in thousands of dollars)

Statistics Group Faculty Salaries**
Doctoral degree-granting departments of statistics
22 responses out of 58 departments (38%)

| Rank | No. Reported | 2014–15 | | | | 2013–14 |
		Q1	Median	Q3	Mean	Mean
New-Hire Asst Prof	7	75,200	87,500	97,500	85,029	76,756
Assistant Professor*	73	84,100	88,900	94,500	93,559	83,079
Associate Professor	82	87,100	93,400	99,400	93,042	94,259
Full Professor	181	116,200	140,600	171,500	152,075	140,073

2014–15 Academic-Year Salaries (in thousands of dollars)

*Includes new hires.
**Faculty salary data provided by the American Statistical Association.

Biostatistics Group Faculty Salaries**
Doctoral degree-granting departments of biostatistics
11 responses out of 43 departments (26%)

| Rank | No. Reported | 2014–15 | | | | 2013–14 |
		Q_1	Median	Q_3	Mean	Mean
New-Hire Asst Prof	5	73,800	86,700	91,300	83,785	-
Assistant Professor*	52	80,700	86,900	93,000	87,233	92,643
Associate Professor	44	92,900	102,900	113,500	103,552	108,645
Full Professor	85	136,300	157,000	186,300	165,563	171,744

Percent of Total Faculty within Rank
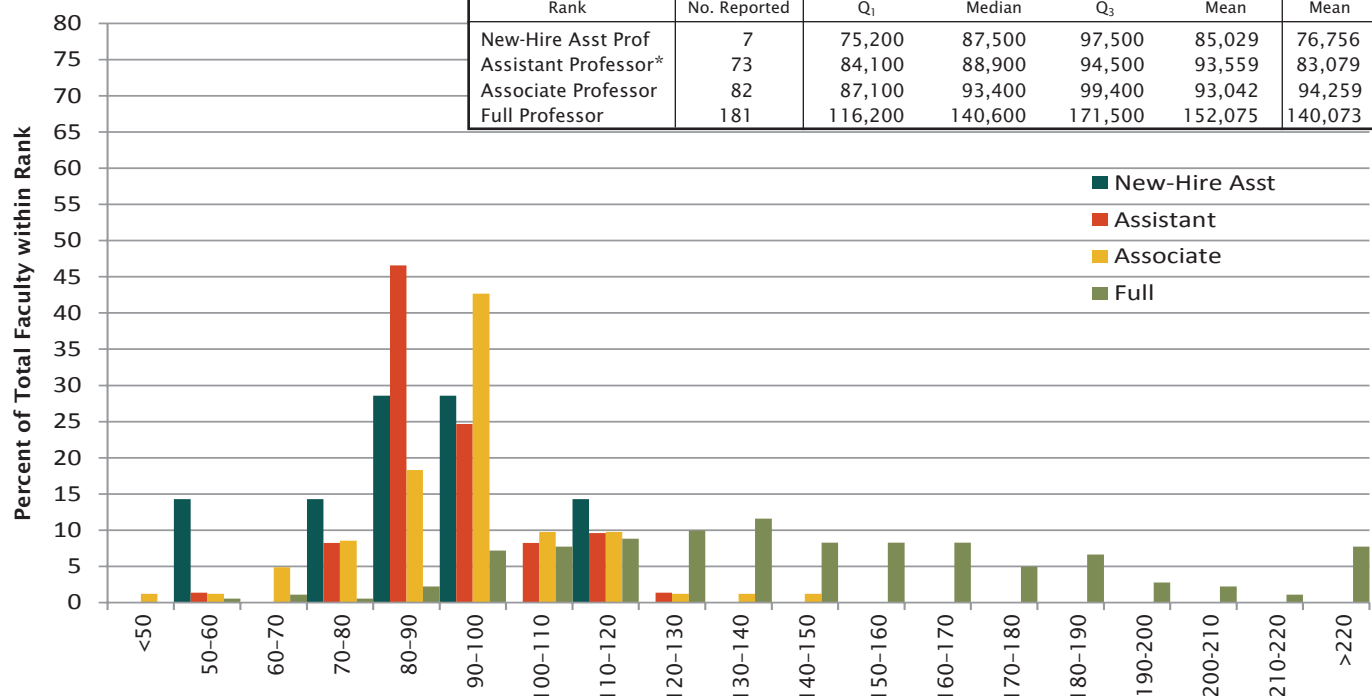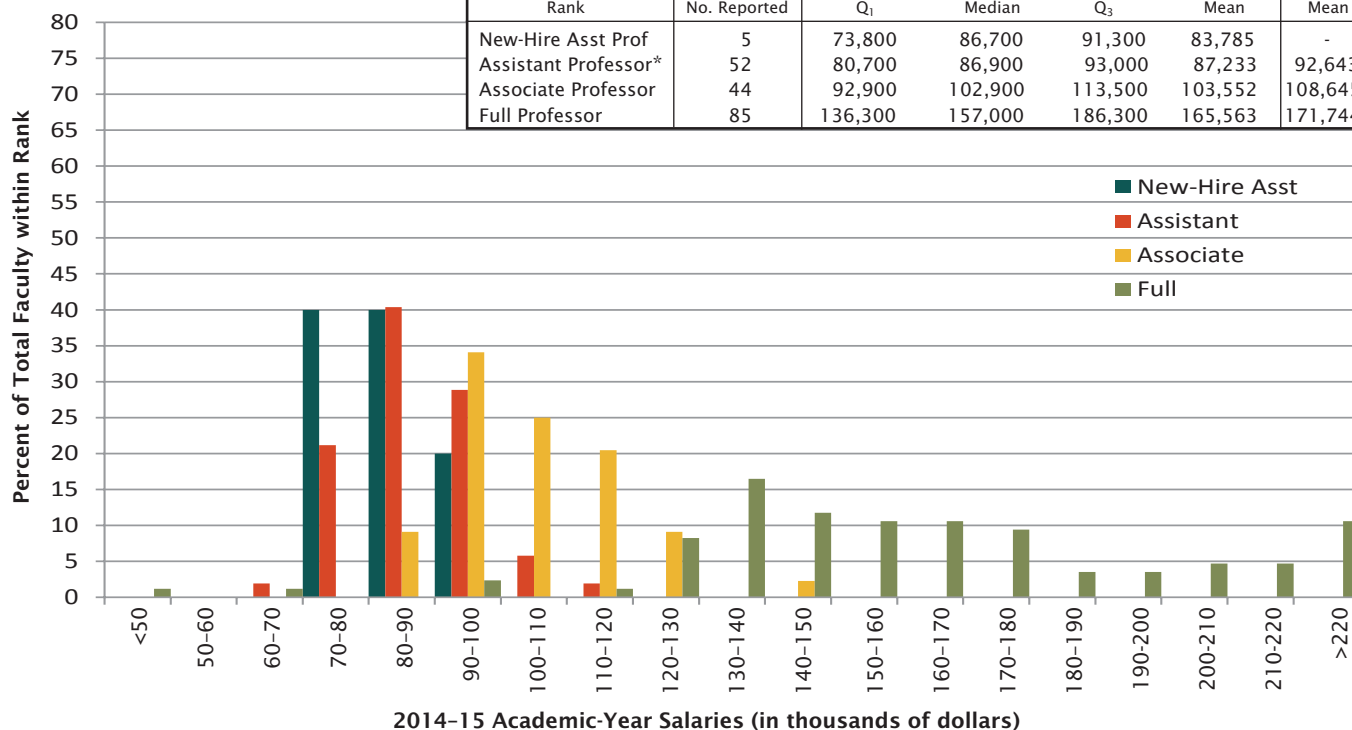
■ New-Hire Asst
■ Assistant
■ Associate
■ Full

2014–15 Academic-Year Salaries (in thousands of dollars)

Master's Group Faculty Salaries
Master's degree-granting departments of mathematics
95 responses out of 177 departments (54%)

| Rank | No. Reported | 2014–14 | | | | 2013–14 |
		Q_1	Median	Q_3	Mean	Mean
New-Hire Asst Prof	88	55,400	61,700	68,800	62,230	59,810
Assistant Professor*	377	56,200	62,500	69,100	62,527	60,331
Associate Professor	631	63,400	71,200	80,200	72,622	70,515
Full Professor	707	80,200	91,000	105,300	94,018	90,532

Percent of Total Faculty within Rank

■ New-Hire Asst
■ Assistant
■ Associate
■ Full

2014–15 Academic-Year Salaries (in thousands of dollars)

*Includes new hires.
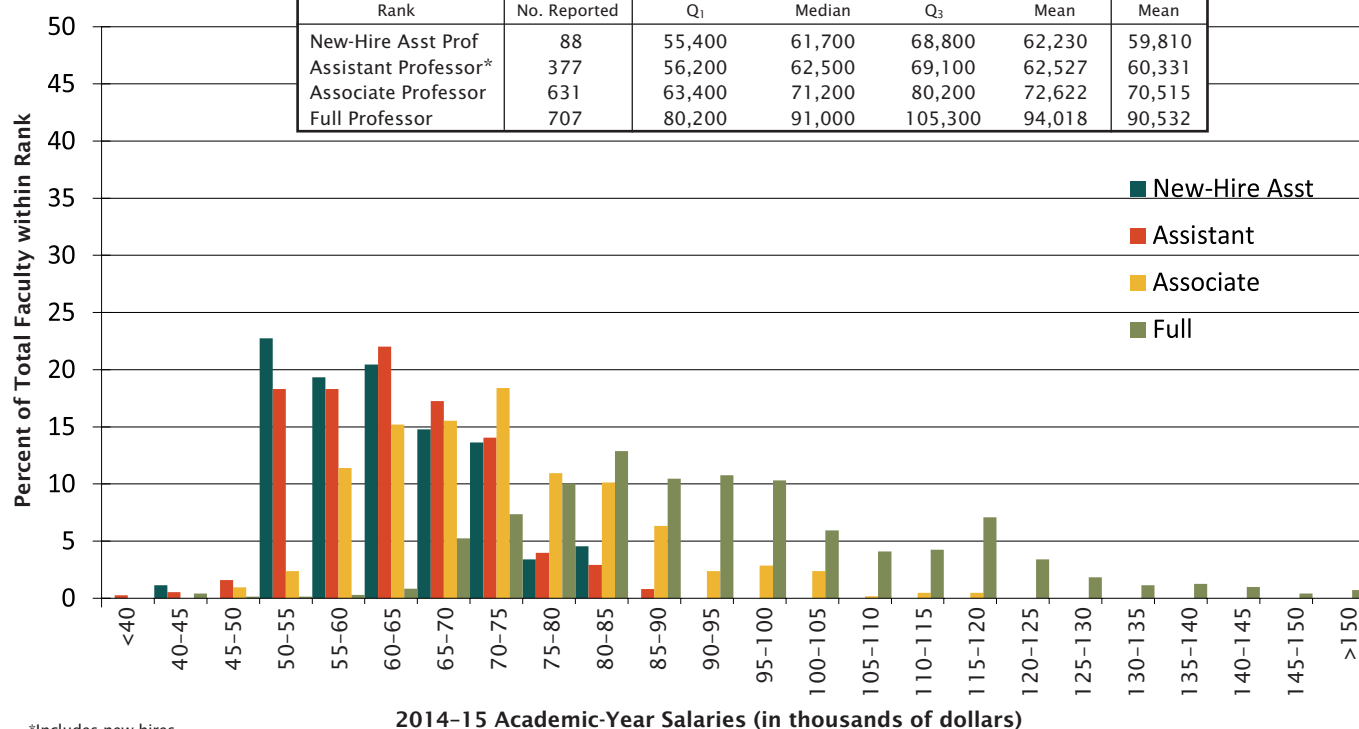**Faculty salary data provided by the American Statistical Association.

Bachelor's Group Faculty Salaries
Bachelor's degree-granting departments of mathematics
312 responses out of 1,007 departments (31%)

Rank		2014–15				2013–14
	No. Reported	Q₁	Median	Q₃	Mean	Mean
New-Hire Asst Prof	136	50,400	56,300	64,300	56,941	56,530
Assistant Professor*	797	50,900	57,100	64,900	58,478	58,131
Associate Professor	883	59,400	67,600	80,200	71,222	69,713
Full Professor	953	72,800	85,400	104,200	90,640	90,143

*Includes new hires.

2014–15 Academic-Year Salaries (in thousands of dollars)

Legend: New-Hire Asst, Assistant, Associate, Full

Departmental Groupings

Starting with reports on the 2012 AMS-ASA-IMS-MAA-SIAM Annual Survey of the Mathematical Sciences, the Joint Data Committee has implemented a new method for grouping the doctorate-granting mathematics departments. These departments are first grouped into those at public institutions and those at private institutions. These groups are further subdivided based on the size of their doctoral program as reflected in the average annual number of PhDs awarded between 2000 and 2010, based on their reports to the Annual Survey during this period. Furthermore, doctorate-granting departments which self-classify their PhD program as being in applied mathematics will join with the other applied mathematics departments previously in Group Va to form their own group. The former Group IV will be divided into two groups, one for departments in statistics and one for departments in biostatistics.

For further details on the change in the doctoral department groupings see the article in the October 2012 issue of *Notices of the AMS* at www.ams.org/notices/201209/rtx120901262p.pdf.

Math. Public Large consists of departments with the highest annual rate of production of PhDs, ranging between 7.0 and 24.2 per year.
Math. Public Medium consists of departments with an annual rate of production of PhDs, ranging between 3.9 and 6.9 per year.
Math. Public Small consists of departments with an annual rate of production of PhDs of 3.8 or less per year.
Math. Private Large consists of departments with an annual rate of production of PhDs, ranging between 3.9 and 19.8 per year.
Math. Private Small consists of departments with an annual rate of production of PhDs of 3.8 or less per year.
Applied Mathematics consists of doctoral-degree-granting applied mathematics departments.
Statistics consists of doctoral-degree-granting statistics departments.
Biostatistics consists of doctoral-degree-granting biostatistics departments.
Group Masters contains US departments granting a master's degree as the highest graduate degree.
Group Bachelors contains US departments granting a baccalaureate degree only.

Listings of the actual departments that compose these groups are available on the AMS website at www.ams.org/annual-survey/groups.

Obtain a Special Faculty Salaries Analysis

See how the salaries of your department's tenured/tenure-track faculty compare to those in similar departments. The only requirement is that your department must have responded to our latest Faculty Salary survey.

Send a list of your peer institutions (a minimum of 12 institutions is required) to `ams-survey@ams.org` along with the date by which the analysis is needed. (If not enough of your peer group have responded to the salary survey, you'll be asked to provide additional institutions.) A minimum of two weeks is needed to complete a special analysis.

The analysis produced includes a listing of your peer group institutions along with their salary survey response status; a summary table including the rank (assistant, associate, and full professor);the number reported in each rank; the 1st quartile, median, 3rd quartile, and mean salaries for each along with bar graphs.

Acknowledgements

The Annual Survey attempts to provide an accurate appraisal and analysis of various aspects of the academic mathematical sciences scene for the use and benefit of the community and for filling the information needs of the professional organizations. Every year, college and university departments in the United States are invited to respond. The Annual Survey relies heavily on the conscientious efforts of the dedicated staff members of these departments for the quality of its information. On behalf of the Data Committee and the Annual Survey Staff, we thank the many secretarial and administrative staff members in the mathematical sciences departments for their cooperation and assistance in responding to the survey questionnaires.

About the Annual Survey

The Annual Survey series, begun in 1957 by the American Mathematical Society, is currently under the direction of the Data Committee, a joint committee of the American Mathematical Society, the American Statistical Association, the Mathematical Association of America, and the Society of Industrial and Applied Mathematics. The current members of this committee are, David Cox, Charles Epstein, Amanda Golbeck, Loek Helminck, Abbe H. Herzig, Ellen Kirkman, Patti Lock, Nate Ritchey, James W. Maxwell (ex officio), William Yslas Vélez (chair) and Edward Waymire. The committee is assisted by AMS survey analyst Colleen A. Rose. In addition, the Annual Survey is sponsored by the Institute of Mathematical Statistics. Comments or suggestions regarding this Survey Report may be emailed to the committee at `ams-survey@ams.org`.

Math in the Media

A survey of math in the news

"Math Games of Martin Gardner Still Spur Innovation"

Scientific American

"A safer world through disease mathematics"

Santa Fe New Mexican

"Together and Alone, Closing the Prime Gap"

Quanta Magazine

"Math Might Help Nail Oceans' Plastic 'Garbage Patch' Polluters"

NBC News

"Wheels when you need them"

Science

"Top Math Prize Has Its First Female Winner"

The New York Times

"How math is growing more strawberries in California"

PBS News Hour

"Can math save Illinois from gerrymandering?"

Chicago Sun-Times

"The Quest for Randomness"

American Scientist

"The Colbert Report, an interview with Ed Frenkel"

Comedy Central

"Calculating women: How to get more girls into math"

Christian Science Monitor

"The Minds Behind the MOOCs"

The Chronicle of Higher Education

See the current **Math in the Media** and explore the archive at **www.ams.org/mathmedia**

AMS
AMERICAN MATHEMATICAL SOCIETY

The Nesin Mathematics Village in Turkey

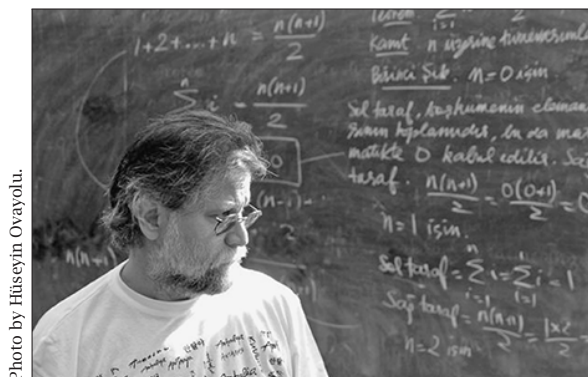*Krishnaswami Alladi and Gabriela Asli Rino Nesin*

Photo by Hüseyin Ovayolu.

Ali Nesin with surprisingly tame hair.

PREFACE:

Krishnaswami Alladi

In August 2014, my wife, Mathura, and I were on a three-week visit to Turkey. I participated in a conference on algebra and number theory in Samsun on the Black Sea coast in northern Turkey, and after that we went on a one-week sightseeing tour of Turkey. Professor Ali Bülent Ekin of the University of Ankara, who was one of the organizers of the conference and my host in Turkey, graciously offered to take us on a 1,500-mile journey to see several ancient historical sites of the Greek, Roman, and Ottoman periods. One of the places we visited was Selçuk, a town which is close to the city of İzmir and known for the well-preserved ruins of Ephesus, as well as the not-so-well-preserved ruins of the Temple of Artemis, one of the Seven Wonders of the Ancient World. After a long, enjoyable, but tiring day of

sightseeing, Ali Bülent suggested at dinner that we should see the Mathematics Village on the outskirts of Selçuk that very night. It was late, and so I felt that the Mathematics Village might be closed. But Ali Bülent said that it was only 9 p.m., and the night was young. So we departed for the Mathematics Village right away without any appointment to see anyone.

The Mathematics Village is nestled in a mountainous region in the village of Şirince, and it was quite scary as Ali Bülent navigated the narrow unpaved roads to reach the Village. It was pitch dark as we parked, but in the glare of our headlights we suddenly saw a female student emerge from a path, proceed to her tent, pick up a notebook, and head back along the path from which she came. So we knew we were at the right place and followed that path. A lovely set of buildings loomed very soon, and we were greeted by a cheerful band of students. We were taken immediately to the terrace where Prof. Ali Nesin, the founder of this wonderful institution, and his daughter, Gabriela, were in discussion with students at dinner. They spontaneously invited us to join them at dinner, but we had to decline the kind invitation since we had already dined in Selçuk. Gabriela then showed us around this remarkable place. We were simply overwhelmed by what we saw.

The Mathematics Village is a unique institution. It offers short but intense courses to mathematics students from high school and college. The students are immersed in mathematics for the few weeks they are there, learning from the professors who teach, as well as from discussions among themselves. The students could relax in the evenings by playing Ping-Pong or cards or by simply reading in the excellent library or in the wooded environs. Most students are housed in stone and clay houses, but as demand almost always surpasses capacity, some have to be put up in tents. At the time we visited, there were about four hundred students in attendance. Teaching is voluntary; while the Mathematics Village does not

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Krishnaswami Alladi is professor of mathematics at the University of Florida. His email address is `alladik@ufl.edu`.

Gabriela Asli Rino Nesin is a graduate student in computer science at the University of Leicester. Her email address is `garn1@le.ac.uk`.

provide honoria for the teachers, it provides free accommodations and meals. It is a sylvan setting in which to either learn or teach mathematics. As we toured the Village, I was impressed to see some students in discussion in front of a blackboard in a courtyard and some others in the library, even in the late hours. So in the midst of the sightseeing tour, we had a wonderful opportunity to visit this remarkable institution.

Gabriela, who occasionally volunteers at the Village as well, has described the conception and evolution of this rather unique educational enterprise.

The Village from afar. The two blue domes (one of which is almost hidden) are the female and male Turkish baths. The large white building on the right is the library.

THE MATHEMATICS VILLAGE: PAST, PRESENT, AND FUTURE

Gabriela Asli Rino Nesin

The most popular T-shirt for sale at the Nesin Mathematics Village these days depicts a distracted mathematician who, after having completely filled his blackboard with a gigantic equation, simply keeps going on the wall next to it. The caption under it reads "Mathematicians without borders...." It is quite fitting (pardon the pun), both to the steady expansion of the Mathematics Village over the past seven years and to the voluntary nature of the Village; hence the parallel to the famous Médecins Sans Frontières.

The Nesin Mathematics Village is a small non-governmental organization that has "colonized" a hillside near İzmir, Turkey, and has dedicated itself exclusively to the nonprofit teaching and practice of mathematics. Based on the academia of ancient Greece, it is a place where mathematics is done at every hour, in any place, and in any position, horizontal or vertical. In the next few pages I will attempt to give a taste of what the Mathematics Village does. But first, I will start by describing how the idea originated and how it graduated from idea to reality. I will then describe the various programs taking place there each summer and the various facilities available both to aspiring and card-holding mathematicians. Finally, I will show how one can take part in this enterprising project.

Origins
Aziz Nesin and the Nesin Foundation
The wild-haired, bearded, and bespectacled mathematician on the T-shirt bears a strong resemblance to the man who founded the Village, Ali Nesin. Although he has become a somewhat well-known figure in Turkey, he owes part of that fame to his father, Aziz Nesin. Aziz was one of the most famous and prolific writers in Turkey and at the same time an important leftist figure, penning many works of political satire. This and the fact that he was most likely the first publicly self-declared atheist

in Turkey, made him beloved to some and a sworn enemy to others.

In the seventies the income from his books allowed him to open the Nesin Foundation, a nonprofit organization taking in children from disadvantaged families and giving them a home as well as sending them to school until they completed their education (including university studies). What, one might ask, does this have to do with mathematics? Essentially, the Mathematics Village's land and assets are owned by the Nesin Foundation, and their destinies are as such very closely tied. Furthermore, the basic principles governing both are essentially the same: access to knowledge, education, and freedom.

But now let us describe how the need for a Mathematics Village became apparent, starting twelve years before it opened.

Bilgi University and Its Mathematics Summer Schools
At Aziz Nesin's death in 1995, Ali left his post as associate professor at the University of California at Irvine in order to take over direction of the Nesin Foundation in Istanbul. As luck would have it, in 1996 a private university named Istanbul Bilgi University was preparing to open its doors and hired Ali as head of the Department of Mathematics. He quickly gathered a small but tightly knit group of Turkish and foreign academics which gradually gained the reputation of providing one of the best mathematics educational programs in Turkey. The department was extremely ambitious: the students were taught axiomatic set theory the first year, including ordinals, cardinals, the Axiom of Choice, Zorn's Lemma, and even nonstandard numbers.

The advantage of a small department was that staff were able to follow students almost individually. In a class of four, one absentee meant

Photo by Burak Barutcu.

Özlem Beyarslan teaching a high school lecture on vector spaces in the Aziz Nesin Amphitheatre.

25 percent of the class was missing; it wasn't uncommon to get a phone call when one had overslept. However, it soon became apparent that more time was needed to rectify the holes left by Turkey's test-oriented high school education than was accounted for in the curriculum.

From 1998 onward summer schools of a month and a half were therefore organized in various vacation spots in Turkey, where students would study during the day and swim and bond in the remaining time. However, these summer schools (although partially funded by Bilgi University) became more and more expensive. There were other logistical problems: they once had to improvise whiteboards by sticking paper behind window panes, and it is virtually impossible to prove theorems with Enrique Iglesias blaring in the background. Ali began to think that the only way to get something done right was to do it himself.

Meanwhile, an old friend of Ali's, Sevan Nişanyan, was building a picturesque hotel in a small village near Selçuk, İzmir, called Şirince.

How the Village Was Built

In 2007 Ali Nesin bought a 2.5-acre plot of land one kilometer from Şirince and started construction on it according to the plans drawn up by Sevan and him (quite modest to begin with, although they have mushroomed over time). Sevan Nişanyan was instrumental in making the Village the place it is today; his architectural knowledge, good taste, and boundless energy have been invaluable.

That first summer of 2007 around one hundred students, mostly from Bilgi University, attended the summer school at various times. Most slept in tents. Besides attending the usual six to eight hours of lectures, students and lecturers cooked and cleaned for the whole group, planted trees, and helped the construction workers carry materials and build walls.

The structures were, and still are, built out of stone slabs, straw and clay. The first lecture hall, the Robert Langlands Lecture Hall, was built around an old tree which still juts out of its roof like a sentinel. Huge wooden beams from old train tracks were used to build the steps of the Aziz Nesin Amphitheatre, and the climbing vines which today provide its much-needed fresh green shade were planted.

Legal Issues

The area in and around Şirince is designated a protected area, making authorization for construction very difficult to obtain, since it is firmly under the control of local authorities. Although the Mathematics Village is outside the protected area, authorization for construction was never granted owing to antipathy toward the Nesin name. One of the objections raised was that it was illegal to establish an educational facility without permission from the government, even though the Mathematics Village is a nonprofit organization, does not conduct exams, or offer degrees or diplomas.

The struggles are far from over. Despite all this, the Village believes that as community support and international recognition grow, these persecutions will disappear. Furthermore, a strong communal feeling is born in trying to overcome such obstacles together.

The Mathematics Village Today
Summer School Social Structure

By 2009 facilities had expanded so much that many more students from other universities could be accepted, and Bilgi students ceased being a majority. As the summer schools gained momentum, postgraduate students also started attending them. They volunteered to teach, attended classes they were interested in, and had opportunities to chat to and collaborate with colleagues and professors from around the world—an ideal and relaxed academic environment.

A standard fee to attend the Mathematics Village was decided upon, but it quickly became apparent that many university students could not afford this, as they were often no longer supported by their parents. The Village accepted the students anyway, paying for their accommodations and food costs out of its own pocket and naturally finishing each summer with a significant deficit. Even the support of the Turkish Mathematical Society and the generous donations from the Turkish population (many of them from families that could barely afford such donations) could not compensate for the losses. Due to high demand and as a way to partially counteract the deficit, the Mathematics Village decided to expand its

audience to high school students, starting from the age of fourteen.

The high school summer schools have since become a huge hit, with the number of applications more than triple actual capacity. Although some grants are provided for disadvantaged students, the families of most high school students are more than able and happy to pay the modest fee of US$500 for two weeks. It has become a badge of honor for a family to have sent a child to the Mathematics Village. As a result, the Village now carefully makes sure that the student really wants to attend and is not caving in to the pressure of his or her family. On the other hand, there have been a couple of cases of kids running away from home *to* the Mathematics Village when their parents refused to let them come to "the atheist camp"! Whatever surplus the Village obtains from high school fees is channelled toward grants for undergraduate and postgraduate students lacking the means to attend.

During their two-week stay, all high school students will be under the responsibility of a "big brother or sister," akin to scout leaders and almost always university students who have volunteered for the role. They make sure their group attends classes, goes to bed on time, and generally avoids hurting itself (no mean task considering it is composed of hormonal beings in close proximity to Şirince, renowned for its fruit wine!).

Since the number of official staff at the Village is very low, it mostly operates on the commune model. Upon their arrival, students are split up into small groups containing a mixture of high school and university students, with a roughly equal ratio of each. For the next two weeks, these groups will complete the necessary chores to be done in the Village. One day a group will help the cook peel potatoes, the next day it will be on rubbish duty, on the third day responsible for replenishing the various water coolers scattered around the Village, and so forth. Surprisingly enough, far from complaining about this work, many students feel that they have significantly contributed to life at the Village, thus getting a feeling of ownership and community which does not leave them even years later.

Course Structure

The courses are organized in two-week blocks in order to fit the length of students' stays.

Ordinary high school education in Turkey is geared toward the university entrance examinations. As a result, the emphasis is on memorization, mindless competition, and end result rather than thought processes. The Mathematics Village aims to counteract this by giving high school students a glimpse of what university-level mathematics is.

Photo by Burak Barutcu.

View of the library conference hall from the second floor.

They learn to think for themselves, argue coherently, and spot logical fallacies. Most importantly, they see the process of solving a problem whose solution is not known beforehand. As an example, an exercise that Ali Nesin often does with a group of new students is to determine whether the mathematical group generated by the Turkish alphabet and with all of the students' names as relators gives the trivial group. Students are encouraged to participate, and it often gets difficult to quiet down the shouting out of ideas from every corner of the classroom.

High school students learn about such diverse topics as graph theory, probability, combinatorics, game theory, and basic analysis and algebra. These are supplemented by eclectic exercise sessions where students are introduced to such problems as Hilbert's Hotel and encouraged to construct their own proofs.

An excerpt from a conversation between a student (who attended for the first time at the age of fourteen) and Ali Nesin when they met at a book signing shows the results:

"You came to the Village, didn't you?" Ali asked.

"Yes, four times actually," he said.

"Did it make a difference?"

"A big one."

"How's that?"

"Sir, when I first came I didn't understand anything. Only the last two days I vaguely had the feeling I was getting it. More than the things I understood, I was so happy to have finally understood something that I came back the next year. The first week I understood nothing again, but I understood everything that was being done the second week! On my third visit I missed nothing. On the fourth I was guessing the teacher's next sentence… High school feels boring now."

The university-level teaching is organized around themes if the lecturers' time permits, allowing not only for concentration of research

Students and teachers listening to a lecture in an open-air theater.

interests but also preparing the ground for cooperation between colleagues in the same or related fields. This year, for example, the second and third weeks saw courses called Reflection Groups, Introduction to Classical Groups, Fundamental Groups, and Three Groups Every Mathematician Has to Know. The range of subjects is too wide to cover here, but university students can learn about anything from Lie algebras to Fourier analysis, from measure theory to representation theory of groups. Some classes can be said to be interdisciplinary between mathematics and philosophy, physics, or computer science, such as Recursion Theory, Gödel's Incompleteness Theorem, or linear programming.

All teaching at the Village is voluntary. In return, lecturers' accommodations and meals are free. Given this, the number of academics who have decided to teach at the Maths Village over the years is truly impressive. Lecturers have come from all over the world, including Alexandre Borovik from Manchester, Edriss Titi from UCI, Max Dickmann from Paris 7, and Ryan O'Donnell from Carnegie Mellon. This list is by no means exhaustive, as listing all contributors here would be impossible.

Apart from the regular teaching, people who do not have enough material for an entire course or simply wish to talk about their own research give seminars in the cool evening breeze at the Aziz Nesin Amphitheatre, organized from 9 to 11 p.m. and attended by whoever wishes to or has enough energy left. These evening talks are very informal—many bring their wine left over from dinner—and are the perfect opportunity to get colleagues' ideas and input to one's research.

Facilities

The physical structure of the Village today has expanded to contain sixteen dorms (capacity 169), two amphitheatres, two closed and four open-air lecture rooms, one male and one female hammam (Turkish baths), twenty-nine single or double rooms/houses, a fully functional kitchen and cafeteria, a small shop and a magnificent two-story library with a cool breezy terrace in front of it. Even though housing capacity is constantly expanding, many students still stay in tents and therefore pay discounted fees.

The library has an open-plan central area decorated with geometric mosaics. Two gigantic wheel-like chandeliers light a conference hall on the ground floor, seating one hundred fifty. On the second floor balconies overlook the hall; this is where the bookshelves are. Their half-emptiness shows optimism for the future: the library is eager to accept donations of old books and journals. The second floor also holds tables for silent working. It is one of the most peaceful places in the Village, not least because it offers an absolutely unfettered view of the opposing valley. However, the library is far from the only place for working; several isolated areas are available throughout the Village for those who want to escape the excessive friendliness of their colleagues.

Around fifteen paid staff and nearly one hundred volunteers work there every year. The two-week cycles start and end on Sundays, and on that day near-perfect organization is needed to take care of the departure and arrival of hundreds of students without devolving into utter chaos. Ali Nesin sits down with each individual undergraduate student to advise them on which classes they can attend given their background.

No one knows how he manages it, but the cook, Chef Asım, puts out three delicious meals a day and cake at tea time on top of it all.

There are no TVs or broadcast music, although there are occasionally film screenings on the projector in the library. Some evenings students take out their musical instruments—a guitar, occasionally a saz or a kemençe—and give an impromptu concert. Traditional and modern Turkish songs are played, and the listeners join in. To avoid disturbing people who have work to do or need to get up early to attend class, these mini music sessions are often held on Wednesday evenings, as Thursdays are the official day off in the Village.

Each Thursday, a vacation activity is organized. It can be a trip to the nearby Kuşadası, to the further but much more beautiful Kuşadası National Park beach, or a boat tour. Those who wish can organize their own trips, for example, to the historical ruins in Selçuk or the neighboring famous ancient Greek city of Ephesus. Alternatively, one can stay in the Village to catch up on sleep or work in the various secret corners of the Village on the hammocks or swings and couches.

More Mathematics

Past Conferences, Workshops, and Research Groups

The main focus of this article has been summer schools, as they are the most active periods of the year for the Nesin Mathematics Village. However, for many years now the Village has also hosted various workshops and conferences throughout the year.

There are various winter schools held during January and February. Some of the workshops which have taken place at the Village are the Algebra and Analysis Workshops in January–February 2014 and October 2013 respectively, the Mathematical Evolution Workshop in September 2013, the Computer Science Workshop in October 2012, and the Workshop on Function Field Arithmetic in June 2014. In May 2014 a summer school Around Valuation Theory was held. The XV Antalya Algebra Days conference, traditionally held in Antalya, as the name indicates, was held in the Mathematics Village in May 2013. Some of the invited speakers were Gregory Cherlin, Martin Ziegler, Ian Leary, and Serge Bouc. The seventeenth edition of this conference will be held in the Village as well, in May 2015.

Recently, the Mathematics Village has started a new initiative whereby research groups of any size can gather in the Mathematics Village for intensive periods of work and collaboration. I personally saw the benefit of this initiative; the day after we arrived, my supervisor and I sat down to work on a problem that had been eluding us for a long time at 9 a.m. after a nice breakfast. Three hours later, we had the basis of a paper—the air of the Mathematics Village is inspiring!

How You Can Use or Contribute to the Mathematics Village

As described above, the Nesin Mathematics Village is a perfect place to organize a conference or a workshop. The communal feeling of the Village is very likely to leak into any activity taking place there, and the relaxed and intimate surroundings foster communication and collaboration among participants. The same holds for research groups; there are uncountably many corners of the Mathematics Village where a small group can hole up and discuss to their hearts' content without distractions.

Volunteers for teaching are always welcome. Unfortunately, all high school courses must be taught in Turkish, as the students do not necessarily know foreign languages, but any undergraduate or postgraduate course may be taught in English. One of the most common pieces of feedback I have gotten from lecturers at the Mathematics Village is

The boy in the purple shirt follows the solution and explains it to a classmate.

Photo by Alexandre Borovik.

how astounded they are at the level of enthusiasm of the students; the sheer hunger for knowledge they have is truly admirable, especially considering that attending these courses is entirely due to personal interest and does not provide any course credits or diploma of any kind.

Teaching and research need not be exclusive. Here is Alexandre Borovik's account of one of his many experiences at the Village:

"For me, the Village is a place of research; I come there to work with my friends and co-authors, Adrien Deloro from Paris and Sükrü Yalçınkaya from Istanbul. We are working on several loosely related projects focused, roughly speaking, on achieving a better understanding of the group SL_2 at a very detailed, "subatomic" level. To get some taste, see our preprints. The Village is a paradise for work in a small group.

The strange name of the course that I taught last August in the Village is mentioned above: Three groups every mathematician has to know. The groups were the three most famous forms of SL_2: $SO_3(\mathbb{R})$, $PGL_2(\mathbb{R})$, and $PSL_2(\mathbb{C})$. For our projects, I needed to refresh and sharpen my understanding of these groups, and bring it into a usable state; what better way to do so than to give, from first principles, relaxed and free flowing lectures on these groups, and to make them as accessible to listeners as possible? Can you quickly explain—and in the simplest possible way—why the cross-product of vectors in $\mathbb{R}^3$ is the Lie algebra of $SO_3(\mathbb{R})$? Or Dirac's cup trick? Of course, I gave due attention to geometries of the groups, and paid tributes to glorious names associated with them: Euclid, Lobachevsky, Minkowski.

When you teach to absolute novice learners, you learn, too. Perhaps occasionally I slipped into the entertainment mode and used juicy historical morsels, such, say, as polishing of spherical stone vases in Egypt during the Old Dynasty (or, in mathematical terms, classification of 3-dimensional subalgebras in the Lie algebra of
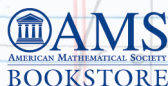
A high school student solves a problem on the blackboard while lecturer Mübe Kanuni looks on.

"sliding vectors", that is, infinitesimal isometries of the 3-dimensional Euclidean space)—but for me it was a way to relax after intensive research sessions.

I do not know any other mathematical establishment in the world where you may find this level of fusion of research and enlightenment."

Future Plans for the Mathematics Village

Some events are already planned for the upcoming year, apart from the usual summer school: for example, the CIMPA Research School on Leavitt Path Algebras and Graph C^*-algebras or the 2nd Colloquium on Existentialism.

Due to extensive interest from departments of philosophy, one of the new projects at the Mathematics Village is to build an attached Philosophy Village on the new land purchased. Housing is already being built there, although for now it mostly houses the overflow from the Mathematics Village. Eventually, it may be possible to construct an Arts Village as well, planned as a communal area providing (mostly plastic) artists with studios, to be used as a kind of artist's retreat.

Apart from this, construction at the Mathematics Village itself is still very much in progress. More housing is being built in the hopes that eventually all students will be able to stay in dorms rather than tents.

Ambitious plans are not lacking at the Mathematics Village! Neither are enthusiastic and generous volunteers who do their best to bring them to life and without which the Village could not survive. But more plans, more volunteers, and more input are always welcome, and its residents are always eager to share their pride in the Village with any visitors.[1]

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[1]*For more information, visit the Village's webpage* matematikkoyu.org/eng/.

About the Cover

The Polyface of Polymath

The June/July cover was suggested by John Friedlander's article "Prime Numbers: A Much Needed Gap Is Finally Found" in this issue. The photographs portray thirteen of the fifteen people credited on the webpage michaelnielsen.org/polymath1/index.php?title= Polymath8_grant_acknowledgments as being primary participants of the Polymath8 project that improved dramatically the twin prime gap of Yitang Zhang, through cooperative effort on the Internet.

No significance is to be attributed to sizing or placement of the photographs which, like participation in the project itself, had a largely random component.

The Polymath8 project is the subject of an article in the December 2014 issue of the *Newsletter of the European Mathematical Society.* D. H. J. Polymath is the article's author (!) and it includes extensive comments by several of the participants. Among other things, this article outlines the history of the project. As it indicates, there are many polymath projects, but none apparently quite so successful as this one. We have to ask, what does the future hold along these lines?

The main webpage of polymath is: michaelnielsen.org/polymath1/index.php?title= Main_Page

Most of the photographs were taken by friends, wives, or colleagues: that of Tao was taken by Reed Hutchinson of UCLA, that of Kowalski is an official photograph credited to ETHZ DMATH 2014, that of Sutherland was taken by Nikki Dedekian of Catchlight Images. We thank everybody for supplying pictures.
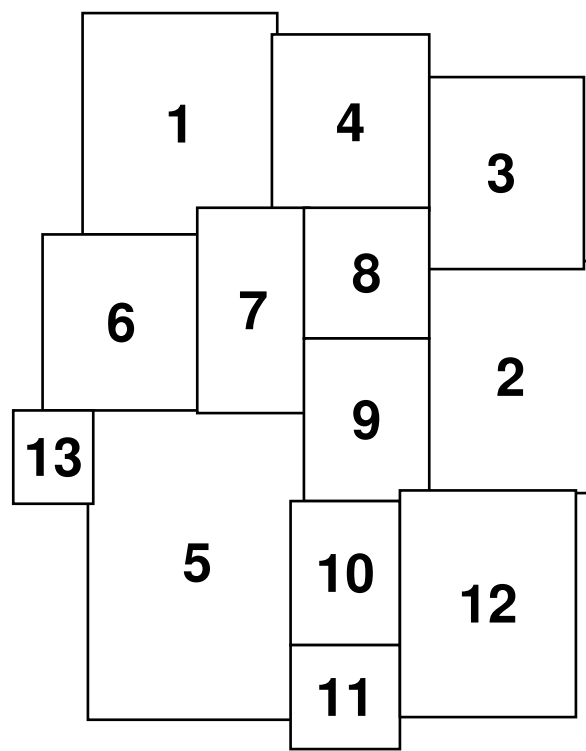
The cover key above identifies those Polymath8 participants featured on the June/July cover:

[1] Gergely Harcos, Rényi Institute
[2] Xiao-Feng Xie, Carnegie Mellon University
[3] Emmanuel Kowalski, ETH Zürich
[4] Janos Pintz, Rényi Institute
[5] Terry Tao, University of California at Los Angeles
[6] Paul Nelson, École Polytechnique Fédérale de Lausanne
[7] Andrew Sutherland, Massachusetts Institute of Technology
[8] Pace Nielsen, Brigham Young University
[9] Philippe Michel, École Polytechnique Fédérale de Lausanne
[10] James Maynard, Oxford University
[11] Aubrey de Grey, SENS (Strategies for Engineered Negligible Senescence) Research Foundation
[12] Étienne Fouvry, Université Paris-Sud
[13] Wouter Castryck, Katholieke Universiteit Leuven

—Bill Casselman
Graphics Editor
notices-covers@ams.org

Prime Numbers: A Much Needed Gap Is Finally Found

John Friedlander

In May of 2013 the *Annals of Mathematics* accepted a paper [Z], written by Yitang Zhang and showing "bounded gaps for primes," that is, the existence of a positive constant (specifically mentioned was 70 million) with the property that infinitely many pairs of primes differ by less than that constant. Zhang's result created a sensation in the number theory community, but much more broadly as well.

I don't know what it says about the current state of the world or of mathematics or maybe just of me, but I began writing these words by going to Google and typing in "zhang, primes, magazine." Among the first 10 out of more than 74,000 hits, I found references to articles on this topic by magazines with the names *Nautilus, Quanta, Nature, Discover, Business Insider*, and *CNET*. (Within a week of my beginning this, there has appeared a long article [W] in the *The New Yorker*.) I can't begin to guess how many more there have been. I understand that there is also a movie and, I guess, probably television interviews as well. Zhang has since won a number of prizes, including a MacArthur Fellowship, the Ostrowski Prize, the Rolf Schock Prize of the Royal Academy of Sciences (Sweden), and a share of the Cole Prize of the American Mathematical Society. There have also been quite a number of professional papers written about the mathematics and its ensuing developments.

Thus, when I was invited by Steven Krantz to write this article and I requested a few days to think it over, my overriding concern naturally was: "What can I possibly write that is not simply covering well-trodden ground?" This is my excuse for what

follows being (I hope) somewhat of a compromise between "folksy gossip" and "bounded gaps for nonspecialists." Perhaps that is what such a *Notices* article should be.

One aspect of this saga—one which presumably should have no place at all—concerns the refereeing of the paper. Both before and after the acceptance of the paper there has been an unseemly amount of attention paid to this, and I admit to being in the process of exacerbating that here. However, the recent article in the *New Yorker* magazine has now driven the final nail in the coffin of confidentiality, the adherence to which has, from the beginning, been what might most charitably be described as tenuous.

As I understand it, the Zhang paper, although received a few days earlier, was first seen by the editor on April 22, 2013. On the morning of April 24, in response to his request of the previous day for a quick opinion, I wrote back, "At first glance this looks serious. I need a few days to think about it and shall write again after that."

A couple of days later I phoned my old friend Henryk Iwaniec to make arrangements regarding a joint project we were going to work on during my trip a few days later to the Institute for Advanced Study in Princeton. "The *Annals* sent me a paper," he mentioned. "I'll bet it's the same one they sent me," I replied. Within a few days, I was at IAS, and meanwhile it seemed the *Annals* had received a raft of quick opinions, all suggesting that there was a nontrivial chance of this being correct, but every one of them deflecting elsewhere the request by the editor to give the paper detailed refereeing.

After Henryk and I, independently and then jointly, had initially refused to do this, we wrote on May 4: "…have been further considering your

John Friedlander is university professor of mathematics at the University of Toronto. His email address is frdlndr@math.toronto.edu.

request that we referee this paper. The paper, if correct, would be of great importance and absolutely deserve to be published in the *Annals*. As the ideas appear to have a very good chance of succeeding, we have decided to accept your invitation to jointly referee it."

That message was well timed, for the next morning we received an email from a friend (initials P.S.) with the words: "…By the way, Katz tells me that he is dealing with a paper at the *Annals* which claims bounded gaps in primes and that all experts (e.g…) are simply passing the buck. That is, you guys are saying it looks like it may be correct (is that so?) but no one is willing to commit to look closely. I haven't seen the paper but if it is serious—it isn't a good sign if everyone suggests each other to referee." I was glad to be in a position wherein we were able to write back: "Before you bawl us out, you might want to talk to Nick again."

I should interrupt this narrative to stress that I am quite sure that almost any of the other "experts" referred to would have, if pressed a little bit harder, agreed to do this job. Henryk and I had the advantage of being on the scene and also of having each other for company.

As many will know, among visitors to the Institute, it can be only a truly monastic individual who is willing to pass up the lunches. So, as a welcome break from the very long hours of checking every line (we had already seen that the basic ideas could not be otherwise dismissed), we went to lunch and sat at the "math table." There were only a few people present there who did not know what we were doing. Our response to the questioning on Monday, "So far, so good." On Tuesday, "So far, so good." On Wednesday, the same. On Thursday, May 8, we were able to say, "It is correct." Two hours later, the report had been sent.

Meanwhile, emails enquiring about the paper's correctness had also been arriving from elsewhere; from D.G. in NY, from D.G. in SJ, from S-T. Y. in Cambridge. One I liked came from Zhang's Princeton namesake: "…I knew him very well even before I came to the US. It would be great if he proved such a theorem." Within a few days, Zhang had his referee report and was giving an invited lecture on his result at Harvard.

I won't write more than a few words about Zhang's history. I can add nothing to the many magazine articles that have been written. A young person raised during a turbulent period of Chinese history, captivated by mathematics but without easy access to library resources, the difficulty in obtaining an education, then even more so an academic position, but continuing to follow the dream—the dream about prime numbers and zeta-functions—then, after many years, finding a

stunning success which had evaded the experts. It's a storybook ending to a tale well suited to capturing the public fancy. In addition to showcasing this spectacular theorem, the publicity is of course a very good thing to happen to a discipline that seems not to advertise itself quite as well as do some others and which can be heard to not infrequently complain about the (evident, but perhaps not totally unrelated) inequities in research funding.

In any case, let's pass on to what is always the most beautiful part of the story, the mathematics. The intention here is to make the description brief and accessible to all potential readers. For those interested in a much more extensive introduction to the subject matter yet without forging into the original works, there is now the excellent treatment given in the *Bulletin* article [G] of Andrew Granville.

Everybody knows to whom we credit the origin of the Goldbach conjecture; the name tells you that. Just about as famous is the twin prime conjecture, that there be infinitely many pairs of primes differing by two, such as 3 and 5, 17 and 19, 41 and 43 (yes, I've left some out). Maybe somebody knows the origin of this very old problem, but not I. Although there seems to be no record to substantiate this, it would not be out of the question for Euclid to have speculated about it.

The prime number theorem states that if $\pi(x)$ denotes the number of primes up to x, then, as $x \to \infty$,

$$\pi(x) \sim x/\log x,$$

where the notation means that the quotient of the left side by the right side approaches one as x approaches infinity. This implies that if we are looking at integers, say between x and $2x$, with x large, then the average gap has size about $\log x$. A seemingly modest step beyond this would ask that, for some constants $0 < c < 1 < C$, there be, for arbitrarily large x, pairs of consecutive primes with a gap less than $c \log x$ as well as pairs for which the gap is greater than $C \log x$. A little less modest would be the request that the above hold for *all* c and C satisfying the above inequalities.

For large gaps C, the stronger request was, already in 1931, substantiated by a theorem of Westzynthius. For small gaps, progress came far more slowly, and although the existence of some acceptable $c < 1$ was proven by Erdős in 1940, and despite several highly nontrivial papers further lowering the known verifiable constant, the proof that the result holds for arbitrary positive c came only in the past few years, with the breakthrough paper [GPY] of Goldston, Pintz, and Yıldırım.

Successful approximations to the still unproven twin prime conjecture, as to many problems about prime numbers, start with sieve methods. Although extensively developed over the past century, such methods are, at root, elaborations of the ancient

sieve of Eratosthenes. One takes a finite sequence $\mathcal{A}$ of integers and a set $\mathcal{P}$ of (small) primes and tries to estimate the number of integers in $\mathcal{A}$ not divisible by any prime in $\mathcal{P}$. This is done by exclusion-inclusion and requires us to know, for many given d formed by taking products of subsets of the primes in $\mathcal{P}$, just how many of the integers of $\mathcal{A}$ are divisible by d. For many sequences $\mathcal{A}$ of arithmetic interest, this number has a smooth approximation apart from a small remainder r_d, and just how this "error" accumulates when summed over d determines the degree of success of the argument. In the case of the twin prime problem, one may begin with the set of integers

$$\mathcal{A} = \{p - 2 : p \leq x, \ p \ \text{prime}\}$$

and cast out multiples of odd integers d, as large as we can, subject to the summed remainder, say $R(D) = \sum_{d \leq D} |r_d|$, being acceptable. In this fashion, Renyi succeeded in being the first to prove that, for some fixed r, there are infinitely many primes p such that $p - 2$ has at most r prime factors. The smallest known value of r was eventually lowered to 2 by J-R. Chen, but the so-called parity phenomenon of sieve theory (see [FI2]) prevents one from reaching the goal along these lines.

Note that in the above scenario the number of multiples of a given integer d is just $\pi(x; d, a)$, the number of primes $p \leq x$ in the arithmetic progression a modulo d, specifically for $a = 2$. The prime number theorem for arithmetic progressions gives us an asymptotic formula for this quantity, but so far one has succeeded to prove this only for d very small compared to x, and as stated above, it is crucial to have information for many (and hence also for large) d. Fortunately, we need this information for the remainder only on average over d. The Bombieri-Vinogradov theorem tells us that this averaged remainder is small for d almost up to $x^{1/2}$. We have (slightly more than) the bound

$$\sum_{d < x^{\frac{1}{2} - \varepsilon}} \max_{\gcd(a, d) = 1} \left| \pi(x; d, a) - \pi(x)/\varphi(d) \right|$$
$$\ll x/(\log x)^A$$

holding for arbitrary fixed positive A and ε. Here, the Euler function $\varphi(d)$ counts the number of "reduced" residue classes modulo d, that is, those relatively prime to the modulus, and the symbol $\ll$ indicates that the left side is bounded by some constant multiple of the right side. The B-V theorem has played a key role in all attacks on the small gaps problem, and indeed Bombieri's work was motivated by an important step along the way [BD] jointly with H. Davenport.

The parity phenomenon tells us that we can't hope to succeed in proving, along these lines, that there are pairs of integers differing by two, both

of which are prime; we have to give something up. In the Renyi-Chen theorem we sacrifice one of the integers being prime, but get close to the result in that this integer is an "almost-prime." In the GPY method we insist on requiring both integers to be prime, but we give up the demand that they necessarily have a single prescribed difference, much less that the distance specifically be two. Indeed, such a sacrifice had already been conceded in all earlier attempts at the small gap problem, but GPY introduced ideas that went much further than previously and were the first to get close to the result. They begin with an "admissible" k-tuple of integers $\mathcal{H} = \{h_1, \ldots, h_k\}$. By this we mean that for every prime number p, at least one of the residue classes modulo p is missed by every one of the h_i. It is expected, but is presumably very far from our current reach, that every admissible k-tuple of integers $\mathcal{H}$ ought to possess infinitely many translates $n + \mathcal{H}$, *all* of whose integers are primes. (It is easy to see that admissibility is a necessary condition for such a result to hold. To take the simplest example, note that $\{0, 2\}$ is admissible, but $\{0, 1\}$ is not, and indeed every second integer is even.) The GPY approach asks for a more modest conclusion: it seeks to estimate the number of translates $n + \mathcal{H}$ of $\mathcal{H}$ which contain at least two primes. In addition to proving that there exist pairs of primes arbitrarily closer than the average, [GPY] proves, using an essential (to my knowledge not otherwise published) input from Granville and Soundararajan, that any improved exponent beyond $1/2$ in the Bombieri-Vinogradov theorem would imply the bounded gaps theorem.

There had already been in the 1980s in [Fo-I], [BFI] some results that went beyond the exponent $1/2$ in Bombieri–Vinogradov type estimates. However, these results lacked a certain uniformity in the residue class, one that had been present in the earlier B-V theorem. Specifically, as we noted above in connection with the Renyi approach, regardless of which modulus d was being considered, it was always the same initial term, 2 modulo d. For that approach, wherein the residue class is fixed, the results in [Fo-I], [BFI] were satisfactory. However, when one begins, as does GPY, with a more complicated set, a k-tuple of integers $\{h_1, \ldots, h_k\}$, then the relevant residue classes modulo d move around as d does and modifications to the arguments are required.

These modifications have now, several years after [GPY], been successfully implemented for three crucial reasons. In the first place, unlike in the original Bombieri-Vinogradov theorem, wherein every reduced class was permitted to enter, the number of residue classes involved in the k-tuple is not very large. In the second place, the movement of these classes is not arbitrary but occurs in a natural

arithmetic fashion; specifically, it is controlled by the Chinese Remainder Theorem. In the third place, Zhang is very talented. In addition to being completely at ease with all of the relevant earlier work (of which there was much), he succeeded in producing a number of crucial innovations of his own.

The full proof, especially when considered from first principles, is a beautiful intermingling of ideas from various parts of the subject: combinatorial, algebraic, analytic, geometric. Deligne's work makes an appearance in bounds for certain exponential sums (along the lines of [FI1], but only after one of Zhang's most significant improvements).

The excitement created by Zhang's result was by no means confined to the popular press. Very shortly after the news was out, a number of small improvements in Zhang's constant 70 million began to appear on the Number Theory arXiv. During that summer, Iwaniec and I had written up our own account of Zhang's work, originally not intended for publication, but later appearing in [FI4]. About the same time, a Polymath project, led by Terence Tao and attracting contributors, some young and some more established, systematically whittled away in far more substantial fashion, employing ever more delicate arguments, algebro-geometric, combinatorial, and computational. For months, on any given day it was dangerous to claim that one knew the latest value of this constant!

Then, in early autumn, things took a sudden turn. At Oberwolfach in October 2013 and on the arXiv two or three weeks later, James Maynard announced a further breakthrough. Simultaneously, Terence Tao found essentially the same results along closely related lines. Maynard's paper has since been published in [M]. In this, he re-proves Zhang's bounded gap result in both simpler and stronger quantitative form. Moreover, he succeeds in producing, for each given m, not just for $m = 2$, the existence of m primes in infinitely many intervals, each having a length bounded by a constant (depending only on m). Precisely, with p_n denoting the nth prime, one has

$$\liminf_n (p_{n+m} - p_n) < Cm^3 e^{4m}$$

for a universal positive constant C. Even after Zhang's result, it seemed amazing to think one would soon see even triples handled.

Maynard's method (as well as that of Tao) begins, as did Zhang's, with the GPY approach but then immediately takes off in a completely different direction. To describe this we need to say a fair bit more about GPY. The starting point for their method rests on consideration of the difference between two sums.

Let $\mathcal{H} = \{h_1, \ldots, h_k\}$, as before, be an "admissible" k-tuple of integers. We consider a sum

$$S = \sum_{x < n < 2x} \Big(\sum_{1 \le j \le k} \chi_p(n + h_j) - \nu \Big) \theta_n = S_1 - S_2$$

say, where χ_p is the characteristic function of prime numbers and θ_n is a certain nonnegative weight whose intelligent choice is key to the argument. Suppose we can prove for some positive ν that we have $S > 0$. Since θ_n is nonnegative, it follows for at least one n that the quantity in parentheses is positive and for that n, the number of primes $n + h_j$ is at least ν (or possibly better, the least integer greater than or equal to ν), and these primes all lie in an interval of length no greater than the diameter of $\mathcal{H}$.

To evaluate the sum S we deal with the two sums S_1, S_2 separately. To have any chance of success in making this difference positive, we are going to have to require the arithmetic function θ_n to have various properties which are impossible to justify in a brief account and which suggest that one look at Selberg sieve weights. One can find a rather full account of the Selberg sieve and the GPY argument, for example, in Chapter 7 of [FI3]. Suffice it to say here that GPY chose weights of the following type:

$$\theta_n = \Big(\sum_d \mu(d) f(d) \Big)^2 .$$

Here μ is the Möbius function, the sum goes over those $d < D$, $d | (n + h_1) \ldots (n + h_k)$, and f is of the form $f(d) = F(\log D/d)$ where F is a nice smooth function to be determined. To evaluate each of the sums S_i we open the square and interchange the order of summation, bringing us to the inner sum, now being over n. In the case of S_2 all goes well, but when it comes to S_1, because of the presence of χ_p, the inner sum counts primes in an arithmetic progression, and we need a Bombieri-Vinogradov type result. This limits the choice of D in that we require an acceptable B-V result with moduli up to level D^2 (because of the square in our choice of θ_n). The final problem is to choose F well. GPY actually made a choice not quite optimal but just about as good for the application.

The innovation which allows so much progress in [M] is simply the attachment of a k-dimensional version of the sieve weight used by GPY, one which gives separate individual treatment to each of the elements of the k-tuple. Roughly speaking, his weights look like

$$\theta_n = \Big(\sum_{\mathbf{d}} \Big(\prod_{1 \le i \le k} \mu(d_i) \Big) f(d_1, \ldots, d_k) \Big)^2 ,$$

where the sum goes over k-tuples $\mathbf{d} = (d_1, \ldots, d_k)$ with $d_i | n + h_i$, $1 \le i \le k$, and $\prod_{1 \le i \le k} d_i \le D$.

Selberg had many years ago briefly introduced this multidimensional version of his weight but did not make much use of it, and certainly it was not responsible for any of his great advances in the subject. This new weight leads, in the analytic evaluation of the two sums being compared, to some complications vis-à-vis the one-dimensional version in GPY, in particular in the optimal choice of f, but Maynard overcomes these in elegant fashion.

As a result of this new approach, Maynard is able to dispense with all of the most advanced results on the distribution of primes in arithmetic progressions, such as those which form the centerpiece of innovation in Zhang's proof. The Bombieri-Vinogradov theorem is amply sufficient for the qualitative statement of Maynard's results, and I expect, but do not know if anybody has checked, that even the somewhat complicated-looking precursors of the B-V theorem dating back to Renyi might be sufficient. However, for explicit bounds on these gaps, strong statements of Zhang type are important, with the happy consequence being a new Polymath project [P], including Maynard's incorporation into the enterprise and resulting in further quantitative improvements (for twins, we are now down into the hundreds) by a combination of the two approaches. One particularly striking achievement is a result in [P] which is conditional on the assumption of a very strong Generalized Elliott-Halberstam Conjecture (of a type introduced in [BFI]) and concerning the average distribution in arithmetic progressions to very large moduli (d running up to $x^{1-\varepsilon}$) of certain arithmetic functions. As a consequence of this conjecture, the authors of [P] deduce the existence of infinitely many pairs of primes differing by no more than six.

Meanwhile, there have also been further developments in other directions. The Maynard weights offer various possibilities for future research and, especially following the availability of the preprint form of [M], there quickly followed a dozen or more inventive uses of the new ideas to attack different problems, questions on number fields, on polynomials, on primitive roots, on cluster points of normalized prime gaps, on elliptic curves, on large gaps between primes....One can find more information on these in Section 12 and Appendix B of [G], the electronic version of which became available a few days before I wrote these words. Those few pages, although near the end of Granville's paper, can be read without having gone through the heavier work of the immediately preceding sections and are highly recommended to the readers of this article. Moreover, all of these works can be located through the very extensive list of references in [G].

I enjoyed having had the opportunity to co-organize, with D. Goldston and K. Soundararajan, a November 2014 workshop at the American Institute of Mathematics shortly before its relocation from Palo Alto to San Jose. It was a particular pleasure to hear talks on many of these innovations and especially to see that a very high percentage of them are due to young mathematicians, young mathematicians of both genders.

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The connection between mathematics and art goes back thousands of years. Mathematics has been used in the design of Gothic cathedrals, Rose windows, oriental rugs, mosaics and tilings. Geometric forms were fundamental to the cubists and many abstract expressionists, and award-winning sculptors have used topology as the basis for their pieces. Dutch artist M.C. Escher represented infinity, Möbius bands, tessellations, deformations, reflections, Platonic solids, spirals, symmetry, and the hyperbolic plane in his works.

Mathematicians and artists continue to create stunning works in all media and to explore the visualization of mathematics--origami, computer-generated landscapes, tessellations, fractals, anamorphic art, and more.

> A mathematican, like a painter or poet, is a maker of patterns. If his patterns are more permanent than theirs, it is because they are made with ideas.
>
> —**G. H. Hardy,**
> ***A Mathematician's Apology***
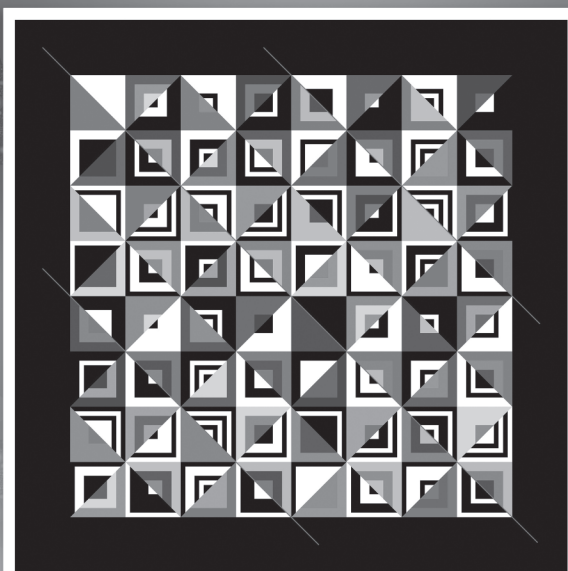
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"Basset Hound, opus 212," by Robert J. Lang
One uncut square of kozo paper with Inclusions, 8", composed 1988, folded 2012

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William Benter Prize in Applied Mathematics 2016

Call for NOMINATIONS

The Liu Bie Ju Centre for Mathematical Sciences of City University of Hong Kong is inviting nominations of candidates for the William Benter Prize in Applied Mathematics, an international award.

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The Prize recognizes outstanding mathematical contributions that have had a direct and fundamental impact on scientific, business, financial, and engineering applications.

It will be awarded to a single person for a single contribution or for a body of related contributions of his/her research or for his/her lifetime achievement.

The Prize is presented every two years and the amount of the award is US$100,000.

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Nomination is open to everyone. Nominations should not be disclosed to the nominees and self-nominations will not be accepted.

A nomination should include a covering letter with justifications, the CV of the nominee, and two supporting letters. Nominations should be submitted to:

Selection Committee
c/o Liu Bie Ju Centre for Mathematical Sciences
City University of Hong Kong
Tat Chee Avenue
Kowloon
Hong Kong

Or **by email to: lbj@cityu.edu.hk**

Deadline for nominations: 30 September 2015

Presentation of Prize

The recipient of the Prize will be announced at the **International Conference on Applied Mathematics 2016** to be held in summer 2016. The Prize Laureate is expected to attend the award ceremony and to present a lecture at the conference.

The Prize was set up in 2008 in honor of Mr William Benter for his dedication and generous support to the enhancement of the University's strength in mathematics. The inaugural winner in 2010 was George C Papanicolaou (Robert Grimmett Professor of Mathematics at Stanford University), the 2012 Prize went to James D Murray (Senior Scholar, Princeton University; Professor Emeritus of Mathematical Biology, University of Oxford; and Professor Emeritus of Applied Mathematics, University of Washington), the winner in 2014 was Vladimir Rokhlin (Professor of Mathematics and Arthur K. Watson Professor of Computer Science at Yale University).

The Liu Bie Ju Centre for Mathematical Sciences was established in 1995 with the aim of supporting world-class research in applied mathematics and in computational mathematics. As a leading research centre in the Asia-Pacific region, its basic objective is to strive for excellence in applied mathematical sciences. For more information, visit ***http://www.cityu.edu.hk/lbj/***

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What Is New in LaTeX?
## VII. The STIX Math Symbols

G. Grätzer

To Barbara Beeton:
who persevered with STIX for seventeen years.

We are like children, "I want more…" Except that we don't want more candy but more math symbols. Donald Knuth provided a number of them, Leslie Lamport some more, and the AMS hundreds more. In addition, we are given tools to put together new symbols from given ones, and scale, rotate, and raise them. But we are still not satisfied.

Now finally, the spoiled children of mathematics will be happy. We got an incredible number of new symbols, over 2,000 of them! And best of all, unbeknownst to you, you already have them. This article is the brief story of the STIX fonts and why we should all rejoice.

Swinging It

In a recent paper of mine (arXiv:1312.2537), I introduce the concept of a *swing*: a prime interval $\mathfrak{p}$ swings to another one, $\mathfrak{q}$, as exemplified by this diagram:
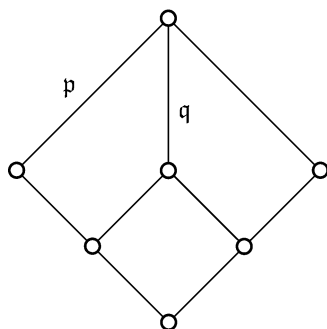
The AMS provides a nice curved arrow, `\curvearrowright`, typeset as ⌢; unfortunately, it is upside down (you don't swing that way).

G. Grätzer is Distinguished Professor of Mathematics, retired, at the University of Manitoba. His email address is `gratzer@me.com`.

I solved my problem, utilizing the `graphicx` package, by defining

```
\newcommand{\swing}
   {\mathbin{{\rotatebox{180}
       {$\curvearrowleft$}}}}
```

which turns `\curvearrowleft`, ↷, 180 degrees: $\mathfrak{p} \smile \mathfrak{q}$. (Raise it with `\raisebox`: $\mathfrak{p} \smile \mathfrak{q}$.)

A better way to solve the problem is by utilizing the 2,000 or so new math symbols offered by STIX.

The STIX Project

"The mission of the Scientific and Technical Information Exchange (STIX) font creation project is the preparation of a comprehensive set of fonts that serve the scientific and engineering community in the process from manuscript creation through final publication, both in electronic and print formats."

This is the mission statement of the STIX project. It all started in 1995. The project was proposed by Arie de Ruiter of Elsevier, a scientific publisher. In collaboration with four other scientific publishers/associations (AIP, ACS, IEEE, APS), the STI Pub consortium was formed. The AMS joined in 1997. For an outline of the project timeline, visit the site

`www.stixfonts.org/proj_timeline.html`

For the timeline of the AMS participation (up to 2006), go to `www.ams.org/STIX/`. The symbols were completed by 2006.

The LaTeX Version 2.0 was released for my birthday last year. I guess this momentous event needs some publicity. It received some in the *New York Times* back in 2002.

Installation and Usage

"Regularity is good," advised Maharishi Mahesh Yogi. I hope you are taking his advice, and you

have a TeX installation from 2014 (for instance, TeX Live, MacTeX, MiKTeX, proTeXt 2014). If you do, then you already have the STIX fonts installed.

Try to typeset the following tiny article:

```
\documentclass{article}
\usepackage{stix}
\begin{document}
Some text, and a math formula
    $\ccwundercurvearrow$.
\end{document}
```

This will typeset as

Some text, and a math formula ↶.

Once installed, using the STIX fonts with LaTeX is as simple as loading the STIX package, as in the example. There is only one catch. The STIX package has to be loaded *ahead of* the AMS packages. Easier said than done. If you use the `amsart` document class, it loads all the AMS packages. So use the unusual construct:

```
\RequirePackage{stix}
\documentclass{amsart}
\begin{document}
Some text, and a math formula
    $\ccwundercurvearrow$.
\end{document}
```

This typesets the same as the previous example.

If your installation is not up to date, it is simpler to update it than to try to install the STIX fonts yourself. However, if you insist, you can find the STIX fonts at

`https://sourceforge.net/projects/stixfonts`

Download the package; you get the folder STIXv2 (if you get STIXv2.zip, unzip it). In STIXv2, you find the folder Fonts. It contains:

(1) the fonts (inside the Fonts folder, there is a subfolder fonts, which contains a subfolder opentype, which contains a subfolder public; this contains a subfolder stix, containing the five font files);
(2) the style file stix.sty (inside the Fonts folder, there is a subfolder tex, which contains a subfolder latex; this contains a subfolder stix, containing a lot of files, including the style file);
(3) the documentation stix.pdf (inside the Fonts folder, there is a subfolder doc, which contains a subfolder fonts; this contains a subfolder stix, containing several files, including the document file).

Installing fonts to be used with LaTeX is so complicated that related questions take up a substantial portion of any TeX discussion group. This installation is no exception. Follow the steps appropriate for your operating system. Believe me, updating your LaTeX installation is simpler.

All the math symbols are listed in nineteen pages of stix.pdf (we located this document

in the third item above). The second of these nineteen pages is reproduced as the last page of this article (an * indicates that there is no bold version). These pages show all the symbols and the commands necessary to produce them. So \varcarriagereturn typesets as ⏎.

How to Find a Symbol?

With perseverance. The symbols are divided into twelve parts; the longest is Relations, about seven pages! Within a part, they are listed by their hexadecimal number.

"With so many symbols, however, the STIX fonts could be cumbersome to use. The developers are working to come up with a method that will make it relatively easy for users to find the symbols they want. Symbols will probably be organized by type or subject, with the user selecting a category (and possibly a subcategory) from drop-down menus. A grid of symbols in that category will then appear, from which the user can choose the appropriate one." So promised Tim Ingoldsby, speaking to the NYT in 2002 for the American Institute of Physics. Unfortunately, this promise went unfulfilled.

With sufficient resources, the task of finding the appropriate symbol can be made much easier. One approach can be found at `detexify.kirelabs.org` and at `shapecatcher.com`. Draw the symbol on the screen and they try to find the most similar symbols. Neither site supports the STIX fonts, but it would be nice to have such a tool available for them.

A different approach, a big table with links, is promised by Johannes Küster for his Minion Math font. He intends to make this available online.

There is a cheaper way to go: group the symbols and list related ones together. For instance, Relations could have Arrows as a subsection, with Straight Arrows, Curved Arrows, and Miscellaneous Arrows as further subsections.

Conclusion

I gave only two examples of the STIX math symbols; there are about 2,000. There are lots of arrows, for instance, ⇨ (\rightwhitearrow) is new, and here it is in bold ⇨ (\boldsymbol\rightwhitearrow). And if you want the old ≤ with =, you can have it; here are some variants: ≦, ≨, ≨ (\leqq, \lneqq, \lvertneqq).

We conclude this article with page 5 of stix.pdf, a broader list of STIX math symbols. Browse the list; find some symbols that you may want to use for your math.

‴	U+2037	\backtrprime	⇩	U+21E9	\downwhitearrow
‸	U+2038	\caretinsert	⇧	U+21EA	\whitearrowupfrombar
‼	U+203C	\Exclam	∀	U+2200	\forall
⁃	U+2043	\hyphenbullet*	∁	U+2201	\complement
⁇	U+2047	\Question	∃	U+2203	\exists
⁗	U+2057	\qprime	∄	U+2204	\nexists
◯	U+20DD	\enclosecircle	∅	U+2205	\varnothing
☐	U+20DE	\enclosesquare*	∅	U+2205	\emptyset
◇	U+20DF	\enclosediamond*	∆	U+2206	\increment
△	U+20E4	\enclosetriangle	∎	U+220E	\QED*
ℇ	U+2107	\Eulerconst	∞	U+221E	\infty
ℏ	U+210F	\hbar*	∟	U+221F	\rightangle
ℏ	U+210F	\hslash	∠	U+2220	\angle
ℑ	U+2111	\Im	∡	U+2221	\measuredangle
ℓ	U+2113	\ell	∢	U+2222	\sphericalangle
℘	U+2118	\wp	∴	U+2234	\therefore
ℜ	U+211C	\Re	∵	U+2235	\because
℧	U+2127	\mho	∿	U+223F	\sinewave
℩	U+2129	\turnediota	⊤	U+22A4	\top
Å	U+212B	\Angstrom	⊥	U+22A5	\bot
Ⅎ	U+2132	\Finv	⊹	U+22B9	\hermitmatrix
ℵ	U+2135	\aleph	⊾	U+22BE	\measuredrightangle
ℶ	U+2136	\beth	⊿	U+22BF	\varlrtriangle
ℷ	U+2137	\gimel	⋯	U+22EF	\cdots
ℸ	U+2138	\daleth	⌀	U+2300	\diameter*
⅁	U+2141	\Game*	⌂	U+2302	\house
⅂	U+2142	\sansLturned*	⌐	U+2310	\invnot
⅃	U+2143	\sansLmirrored*	⌑	U+2311	\sqlozenge*
⅄	U+2144	\Yup*	⌒	U+2312	\profline*
℔	U+214A	\PropertyLine*	⌓	U+2313	\profsurf*
↕	U+21A8	\updownarrowbar	⌗	U+2317	\viewdata*
⏎	U+21B4	\linefeed	⌙	U+2319	\turnednot
↵	U+21B5	\carriagereturn	⌬	U+232C	\varhexagonlrbonds*
↖	U+21B8	\barovernorthwestarrow	⌲	U+2332	\conictaper*
⇹	U+21B9	\barleftarrowrightarrowbar	⌶	U+2336	\topbot
↺	U+21BA	\acwopencirclearrow	⍀	U+2340	\APLnotbackslash*
↻	U+21BB	\cwopencirclearrow	⍓	U+2353	\APLboxupcaret*
⇞	U+21DE	\nHuparrow*	⍰	U+2370	\APLboxquestion*
⇟	U+21DF	\nHdownarrow*	⍼	U+237C	\rangledownzigzagarrow*
⇠	U+21E0	\leftdasharrow*	⎔	U+2394	\hexagon*
⇡	U+21E1	\updasharrow*	⎶	U+23B6	\bbrktbrk
⇢	U+21E2	\rightdasharrow*	⏎	U+23CE	\varcarriagereturn*
⇣	U+21E3	\downdasharrow*	⏠	U+23E0	\obrbrak
⇦	U+21E6	\leftwhitearrow	⏡	U+23E1	\ubrbrak
⇧	U+21E7	\upwhitearrow	⏢	U+23E2	\trapezium*
⇨	U+21E8	\rightwhitearrow	⏣	U+23E3	\benzenr*

Nash and Nirenberg Awarded 2015 Abel Prize

Editor's Note: *This article was written before the sudden loss of John Forbes Nash Jr. on May 23. Nash and his wife Alicia were killed in a traffic accident in New Jersey on the final leg of their journey home from Norway where he had just received the 2015 Abel Prize. "We at the American Mathematical Society join our colleagues and friends all over the world in expressing our deep sorrow over the tragic passing of John and Alicia Nash, and we send our most heartfelt condolences to their family."—AMS President Robert Bryant.*
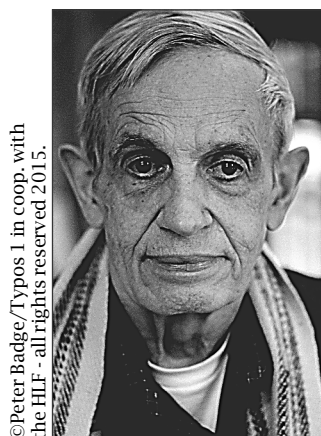
John F. Nash Jr.
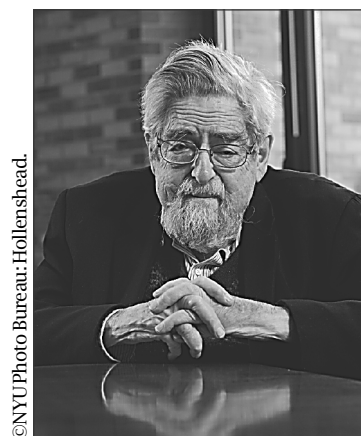
Louis Nirenberg

The Norwegian Academy of Science and Letters has awarded the Abel Prize for 2015 to JOHN F. NASH JR. of Princeton University and LOUIS NIRENBERG of the Courant Institute of Mathematical Sciences, New York University, "for striking and seminal contributions to the theory of nonlinear partial differential equations and its applications to geometric analysis." The Abel Prize recognizes contributions of extraordinary depth and influence to the mathematical sciences and has been awarded annually since 2003. It carries a cash award of 6,000,000 Norwegian kroner (approximately US$750,000). Nash and Nirenberg received the Abel Prize in an award ceremony in Oslo, Norway, on May 19, 2015.

Citation

Partial differential equations are used to describe the basic laws of phenomena in physics, chemistry, biology, and other sciences. They are also useful in the analysis of geometric objects, as demonstrated by numerous successes in the past decades.

John Nash and Louis Nirenberg have played a leading role in the development of this theory by the solution of fundamental problems and the introduction of deep ideas. Their breakthroughs have developed into versatile and robust techniques, which have become essential tools for the study of nonlinear partial differential equations. Their impact can be felt in all branches of the theory, from fundamental existence results to the qualitative study of solutions, both in smooth and nonsmooth settings. Their results are also of interest for the numerical analysis of partial differential equations.

Isometric embedding theorems, showing the possibility of realizing an intrinsic geometry as a submanifold of Euclidean space, have motivated some of these developments. Nash's embedding theorems stand among the most original results in geometric analysis of the twentieth century. By proving that any Riemannian geometry can be smoothly realized as a submanifold of Euclidean space, Nash's smooth (C^∞) theorem establishes the equivalence of Riemann's intrinsic point of view with the older extrinsic approach. Nash's nonsmooth (C^1) embedding theorem, improved by Kuiper, shows the possibility of realizing embeddings that at first seem to be forbidden by geometric invariants such as Gauss curvature; this theorem is at the core of Gromov's whole theory of convex integration and has also inspired recent spectacular advances in the understanding of the regularity of incompressible fluid flow. Nirenberg, with his fundamental embedding theorems for the sphere S^2 in R^3, having prescribed Gauss curvature or Riemannian metric, solved the classical problems of Minkowski and Weyl (the latter being also treated, simultaneously, by Pogorelov). These solutions were important, both because the problems were representative of a developing area and because the methods created were the right ones for further applications.

Nash's work on realizing manifolds as real algebraic varieties and the Newlander-Nirenberg

theorem on complex structures further illustrate the influence of both laureates in geometry.

Regularity issues are a daily concern in the study of partial differential equations, sometimes for the sake of rigorous proofs and sometimes for the precious qualitative insights that they provide about the solutions. It was a breakthrough in the field when Nash proved, in parallel with De Giorgi, the first Hölder estimates for solutions of linear elliptic equations in general dimensions without any regularity assumption on the coefficients; among other consequences, this provided a solution to Hilbert's nineteenth problem about the analyticity of minimizers of analytic elliptic integral functionals. A few years after Nash's proof, Nirenberg, together with Agmon and Douglis, established several innovative regularity estimates for solutions of linear elliptic equations with L^p data, which extend the classical Schauder theory and are extremely useful in applications where such integrability conditions on the data are available. These works founded the modern theory of regularity, which has since grown immensely, with applications in analysis, geometry, and probability, even in very rough, nonsmooth situations.

Symmetry properties also provide essential information about solutions of nonlinear differential equations, both for their qualitative study and for the simplification of numerical computations. One of the most spectacular results in this area was achieved by Nirenberg in collaboration with Gidas and Ni: They showed that each positive solution to a large class of nonlinear elliptic equations will exhibit the same symmetries as those that are present in the equation itself.

Far from being confined to the solutions of the problems for which they were devised, the results proved by Nash and Nirenberg have become very useful tools and have found tremendous applications in diverse contexts. Among the most popular of these tools are the interpolation inequalities due to Nirenberg, including the Gagliardo-Nirenberg inequalities and the John-Nirenberg inequality. The latter governs how far a function of bounded mean oscillation may deviate from its average and expresses the unexpected duality of the BMO space with the Hardy space H^1. The Nash-De Giorgi-Moser regularity theory and the Nash inequality (first proven by Stein) have become key tools in the study of probabilistic semigroups in all kinds of settings, from Euclidean spaces to smooth manifolds and metric spaces. The Nash-Moser inverse function theorem is a powerful method for solving perturbative nonlinear partial differential equations of all kinds. Though the widespread impact of both Nash and Nirenberg on the modern toolbox of nonlinear partial differential equations cannot be fully covered here, the Kohn-Nirenberg theory of pseudodifferential operators must also be mentioned.

Besides being towering figures as individuals in the analysis of partial differential equations, Nash and Nirenberg influenced each other through their contributions and interactions. The consequences of their fruitful dialogue, which they initiated in the 1950s at the Courant Institute of Mathematical Sciences, are felt more strongly today than ever before.

Biographical Sketch: John F. Nash Jr.

John Forbes Nash Jr. was born in 1928 in Bluefield, West Virginia. He entered the Carnegie Institute of Technology (now Carnegie Mellon University) in Pittsburgh with a full scholarship, originally studying for a major in chemical engineering before switching to chemistry and finally changing again to mathematics.

At Carnegie, Nash took an elective course in economics, which gave him the idea for his first paper, "The Bargaining Problem," which he wrote in his second term as a graduate student at Princeton University. This paper led to his interest in the new field of game theory, the mathematics of decision making. Nash's PhD thesis, "Noncooperative games," is one of the foundational texts of game theory. It introduced the concept of an equilibrium for noncooperative games, the "Nash equilibrium," which has had a great impact in economics and the social sciences. While at Princeton Nash also made his first breakthrough in pure mathematics. He described it as "a nice discovery relating to manifolds and real algebraic varieties." In essence the theorem shows that any manifold, a topological object like a surface, can be described by an algebraic variety, a geometric object defined by equations, in a much more concise way than had previously been thought possible. The result was already regarded by his peers as an important and remarkable work.

In 1951 Nash left Princeton to take an instructorship at the Massachusetts Institute of Technology. Here he became interested in the Riemann embedding problem, which asks whether it is possible to embed a manifold with specific rules about distance in some n-dimensional Euclidean space such that these rules are maintained.

Nash provided two theorems that proved it was true: the first when smoothness was ignored and the second in a setting that maintained smoothness. In order to prove his second embedding theorem, Nash needed to solve sets of partial differential equations that hitherto had been considered impossible to solve. He devised an iterative technique, which was then modified by Jürgen Moser, and is now known as the Nash-Moser theorem.

In the early 1950s Nash worked as a consultant for the RAND Corporation, a civilian think tank funded by the military in Santa Monica, California. He spent a few summers there, where his work on

game theory found applications in United States military and diplomatic strategy.

Nash won one of the first Sloan Fellowships in 1956 and chose to take a year's sabbatical at the Institute for Advanced Study in Princeton. Basing himself in New York, he spent much of his time at Richard Courant's fledgling Institute for Applied Mathematics at New York University. There he met Nirenberg, who suggested that Nash work on a major open problem in nonlinear theory concerning inequalities associated with elliptic partial differential equations. Within a few months Nash had proved the existence of these inequalities. Unknown to him, the Italian mathematician Ennio De Giorgi had already proved this fact using a different method, and the result is known as the Nash-De Giorgi theorem.

In 1957 Nash married Alicia Larde, a physics major whom he met at MIT. In 1959 when Alicia was pregnant with their son, he began to suffer from delusions and extreme paranoia and as a result resigned from the MIT faculty. For the next three decades Nash was only able to do serious mathematical research in brief periods of lucidity. He improved gradually, and by the 1990s his mental state had recovered.

Nash has received many honors for his work. In 1994 he shared the Nobel Prize in economic sciences with John C. Harsanyi and Reinhard Selten. In 1999 he won the American Mathematical Society's Steele Prize for Seminal Contribution to Research for his 1956 embedding theorem, sharing it with Michael G. Crandall. He has been a member of the National Academy of Sciences since 1996.

Biographical Sketch: Louis Nirenberg

Louis Nirenberg was born in Hamilton, Canada, in 1925 and grew up in Montreal, where his father was a Hebrew teacher. His first interest in mathematics came from his Hebrew tutor, who introduced him to mathematical puzzles. He studied mathematics and physics at McGill University, graduating in 1945.

The summer after graduating Nirenberg worked at the National Research Council of Canada on atomic bomb research. One of the physicists there was Ernest Courant, the elder son of New York University professor Richard Courant. Nirenberg asked Ernest's wife, who was a friend of his from Montreal, to ask her father-in-law for advice about where to do graduate studies in theoretical physics. Richard Courant responded that he should study mathematics at his department at NYU.

Nirenberg began his PhD research under James J. Stoker, who suggested to him an open problem in geometry that had been stated by Hermann Weyl three decades previously: Can one embed isometrically a two-dimensional sphere with positive curvature into three Euclidean dimensions as a convex surface? In order to prove

that one can, he reduced the problem to one about nonlinear partial differential equations. The equations in question were elliptic, a class of equations that have many applications in science.

Nirenberg's subsequent work has been largely concerned with elliptic partial differential equations, and over the following decades he developed many important theorems about them. After receiving his PhD from NYU in 1949, he stayed on as a research assistant. He was a member of the faculty of the Courant Institute of Mathematical Sciences for his entire career, becoming a full professor in 1957. Between 1970 and 1972 he was the Institute's director; he retired in 1999.

Nirenberg has written important collaborative papers with August Newlander on complex structures (1957), with Shmuel Agmon and Avron Douglis on regularity theory for elliptic equations (1959), with Fritz John introducing the function space of functions with bounded mean oscillation (1961), with David Kinderlehrer and Joel Spruck developing regularity theory for free boundary problems (1978), and with Basilis Gidas and Wei Ming Ni about the symmetries of solutions of PDEs in 1979. A paper on solutions to the Navier-Stokes equations, coauthored with Luis A. Caffarelli and Robert V. Kohn, won the American Mathematical Society's 2014 Steele Prize for Seminal Contribution to Research.

Nirenberg's awards and honors include the Bôcher Memorial Prize of the AMS (1959), the Crafoord Prize (with Vladimir Arnold, 1982), the Steele Prize for Lifetime Achievement from the AMS (1994), the National Medal of Science (1995), and the first Chern Medal for Lifetime Achievement (2010). He has been a member of the National Academy of Sciences since 1969.

About the Prize

The Niels Henrik Abel Memorial Fund was established in 2002 to award the Abel Prize for outstanding scientific work in the field of mathematics. The prize is awarded by the Norwegian Academy of Science and Letters, and the choice of Abel Laureate is based on the recommendation of the Abel Committee, which consists of five internationally recognized mathematicians.

Previous recipients of the Abel Prize are: Jean-Pierre Serre (2003), Michael Atiyah and I. M. Singer (2004), Peter Lax (2005), Lennart Carleson (2006), S. R. S. Varadhan (2007), John G. Thompson and Jacques Tits (2008), Mikhail L. Gromov (2009), John Tate (2010), John Milnor (2011), Endre Szemerédi (2012), Pierre Deligne (2013), and Yakov Sinai (2014).

—From an announcement of the Norwegian
Academy of Science and Letters

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The beginning and ending month and year of terms are given.

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Mathematics People

2015–2016 AMS Centennial Fellowships Awarded

The AMS has awarded its Centennial Fellowships for 2015-16 to KYUNGYONG LEE and CHRISTIAN SCHNELL. The fellowship carries a stipend of US$87,000, an expense allowance of US$8,700, and a complimentary Society membership for one year.

Kyungyong Lee
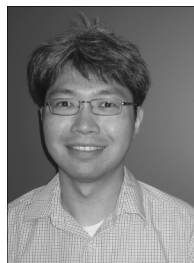
Kyungyong Lee

Kyungyong Lee received his PhD in 2008 from the University of Michigan at Ann Arbor under the direction of Robert Lazarsfeld. He has held postdoctoral positions at Purdue University and the University of Connecticut. He has been an assistant professor at Wayne State University since 2011 and will be an assistant professor at the University of Nebraska–Lincoln starting in 2016. Lee's research focuses on problems at the intersection of algebra, combinatorics, geometry, and topology. In particular, he is currently interested in cluster algebras. He will use the Centennial Fellowship to visit the University of Michigan and the University of Connecticut for several months during 2015-16.

Christian Schnell

Christian Schnell

Christian Schnell was born in Germany in 1979. He received his PhD from the Ohio State University in 2008 under the direction of Herb Clemens and held postdoctoral positions at the University of Illinois at Chicago, the Kavli Institute for the Physics and Mathematics of the Universe, and the University of Bonn. Since 2012 he has been an assistant professor at Stony Brook University. Schnell's research is in the field of algebraic geometry and Hodge theory. He is interested in global properties of variations of Hodge structure, in the structure of *D*-modules on Abelian varieties, and, more broadly, in applications of Hodge theory to questions in algebraic geometry. He plans to use the fellowship to participate in a program about Hodge theory at the Simons Center for Geometry and Physics, to visit the École Polytechnique in Paris and the Research Institute for Mathematical Sciences in Kyoto, and to work with Claude Sabbah on a book about mixed Hodge modules.

Please note: Information about the competition for the 2016–17 AMS Centennial Fellowships will be published in the "Mathematics Opportunities" section of an upcoming issue of the *Notices.*

—Allyn Jackson

Barry Simon Awarded Bolyai Prize

BARRY SIMON of the California Institute of Technology has been awarded the 2015 International János Bolyai Prize in Mathematics for his 2005 book *Orthogonal Polynomials on the Unit Circle.* According to the prize citation, the book "is a monumental treatise that connects two important fields of mathematics: the theory of orthogonal polynomials and operator theory. This connected view has turned out to be extremely fertile in both areas, leading to applications in various directions from stochastic processes to theoretical physics. Barry Simon's monograph contains the classical theory, all the new developments, as well as many of their applications. The book became an instant success—a worthy successor [to] the Hungarian mathematician Gábor Szegő's classic treatise on orthogonal polynomials written in 1939."

The Bolyai Prize is awarded every five years in recognition of internationally outstanding mathematics work. It carries a cash award of US$25,000.

—From a Hungarian Academy of Sciences announcement

Stewart and Strogatz Receive Lewis Thomas Prize

IAN STEWART of Warwick University and STEVEN STROGATZ of Cornell University have been awarded the 2015 Lewis Thomas Prize for Writing about Science.

Ian Stewart is an active research mathematician with more than 180 published papers. He has published over eighty books, including *Mathematics of Life, Why Beauty Is Truth, What Shape Is a Snowflake?*, and *In Pursuit of the Unknown.* He is also coauthor of the bestselling series *The Science of Discworld I, II, III*, and *IV* and two science fiction novels, *Wheelers* and *Heaven.* Stewart's *Letters to a Young Mathematician* won the Peano Prize, and *The Symmetry Perspective* (written jointly with Martin Golubitsky) won the Ferran Sunyer i Balaguer Prize. A member of the Royal Society, he is also the recipient of the Royal Society's Faraday Medal, the Gold Medal of the Institute for

Mathematics and Its Applications, and the Public Understanding of Science Award from the American Association for the Advancement of Science.

Steven Strogatz is a renowned teacher and one of the world's most highly cited mathematicians. He has blogged about math for the *New York Times* and has been a frequent guest on RadioLab. He is the author of *Nonlinear Dynamics and Chaos, Sync, The Calculus of Friendship*, and *The Joy of x*. His honors include a Presidential Young Investigator Award; the E. M. Baker Award for Excellence in Undergraduate Teaching, the Massachusetts Institute of Technology's highest teaching prize; the Joint Policy Board for Mathematics Communications Award; the AAAS Public Engagement with Science Award; and membership in the American Academy of Arts and Sciences.

The Lewis Thomas Prize was established in 1993 by the trustees of Rockefeller University. The prize honors the rare individual who bridges the worlds of science and the humanities—whose voice and vision can tell us about science's aesthetic and philosophical dimensions, providing not merely new information but cause for reflection, even revelation. It was named after its first recipient, writer, educator, and physician-scientist Lewis Thomas, renowned author of *The Lives of a Cell*. Past recipients of the prize include Abraham Pais, Freeman Dyson, Steven Weinberg, and Martin Rees.

—From a Rockefeller University announcement

Fischer and Ruzhansky Awarded Sunyer Prize

VERONIQUE FISCHER and MICHAEL RUZHANSKY of Imperial College, London, have been awarded the 2014 Ferran Sunyer i Balaguer Prize for their monograph *Quantization on Nilpotent Lie Groups*. The prize citation reads: "The theory of quantization was initiated at the end of the 1920s in mathematical physics. The mathematical aspect of this theory concerned with the analysis of operators has been intensively developed during the past fifty years. Nowadays, it is widely accepted and used as a powerful tool to study different questions in the theory of partial differential equations. However, the settings of these studies have been mainly Euclidean and commutative in nature. This monograph presents the recent advances of the theories of quantization and pseudodifferential operators on compact and nilpotent Lie groups. It also contains applications to noncommutative global analysis and to partial differential equations, in particular on the Heisenberg group. The prize carries a cash award of 15,000 euros (approximately US$16,000). It is awarded for a mathematical monograph of an expository nature presenting the latest developments in an active area of research in mathematics in which the recipient has made important contributions. The winning monograph will be published by Birkhäuser Verlag in the series Progress in Mathematics.

—From a Ferran Sunyer i Balaguer Foundation announcement

Megiddo Awarded von Neumann Prize

NIMROD MEGIDDO of the IBM Corporation Research Division has been awarded the 2014 John von Neumann Theory Prize, the highest prize given in the field of operations research and management science. According to the prize citation, he has had a "profound impact on the theory of linear programming. His work on the probabilistic analysis of the simplex method, alone and with Adler, established some of the most important results in the area, including the best (quadratic) bound for the complexity of a complete parametric pivoting method and an explanation of why this is possible for the lexicographic version but not the standard Lemke perturbation. He also established a quadratic lower bound for this method. This, along with work of Smale, Borgwardt, and Haimovich, together with independent proofs of the quadratic result by Adler-Karp-Shamir and Todd, provided the first theoretical justification for the success of the simplex method." Megiddo has done important work in the theory of interior-point methods and algorithmic game theory and has studied the question of whether there is a strongly polynomial algorithm for linear programming. The von Neumann Prize carries a cash award of US$5,000.

—From an INFORMS announcement

Prizes of the Canadian Mathematical Society

The Canadian Mathematical Society (CMS) has awarded a number of prizes for 2015.

DONG LI of the University of British Columbia has been awarded the Coxeter-James Prize for his work in mathematical fluid dynamics, nonlinear dispersive equations, and mathematical physics. The prize honors young mathematicians who have made outstanding contributions to mathematical research.

ALEJANDRO ADEM of the University of British Columbia has been awarded the Jeffery-Williams Prize for Research Excellence for his work in group cohomology and the geometry of group actions. According to the prize citation, he "is fascinated by the deep mathematics and beauty associated to symmetry groups, which manifest themselves both in nature and across a variety of scientific disciplines." He is managing editor of both *Memoirs* and *Transactions of the AMS* and is a Fellow of the AMS. The prize is awarded to mathematicians who have made outstanding contributions to mathematical research.

JANE YE of the University of Victoria has been awarded the Krieger-Nelson Prize for her work in optimization, optimal control theory, and variational analysis and its application in economics, engineering, management science, operations research, and statistics. According to the prize citation, in her work as an applied mathematician, she develops powerful theoretical tools and designs algorithms to attack some complicated optimization questions. The

prize is awarded for outstanding research by a woman mathematician.

Jamie Mulholland of Simon Fraser University has been awarded the Excellence in Teaching Award for his innovative teaching techniques. According to the prize citation, he "records calculus lectures and combines these videos with other online and traditional teaching resources.... [His] approach to math education produces a student population that is more engaged, confident and successful." In more advanced math courses, "he uses puzzles and hands-on activities to teach concepts in group theory and discrete mathematics." He is currently a Senior Lecturer in the Department of Mathematics at SFU, where he balances his teaching responsibilities with researching teaching methodology and participating in the direction of undergraduate mathematics education. The prize recognizes sustained and distinguished contributions in teaching at the postsecondary undergraduate level at a Canadian institution.

—From CMS announcements

Pramanik Awarded Michler Prize

Malabika Pramanik of the University of British Columbia has been awarded the 2015–16 Ruth I. Michler Prize of the Association for Women in Mathematics (AWM). Pramanik was chosen for "her wide range of mathematical talent and the close connection of her work with the research of the analysis group at Cornell University." Her research spans several areas, including Euclidean harmonic analysis, geometric measure theory, several complex variables, partial differential equations, and inverse problems. At Cornell she will be working with Camil Muscalu and Robert Strichartz, whose research in harmonic analysis, specifically the theory of multilinear singular integrals and convergence of Fourier series and spectral analysis of fractal sets, is of special interest to Pramanik in her work.

Pramanik received her PhD in mathematics from the University of California Berkeley in 2001 under the direction of F. Michael Christ. She has been a Fairchild Senior Research Fellow at the California Institute of Technology, a visiting assistant professor at the University of Rochester, and Van Vleck Assistant Professor at the University of Wisconsin–Madison before joining the University of British Columbia in 2006, where she is currently an associate professor in the Department of Mathematics. She is currently an adjunct visiting faculty member at the Centre for Applicable Mathematics of the Tata Institute of Fundamental Research in Bangalore, India.

The Michler Prize grants a midcareer woman in academia a residential fellowship in the Cornell University mathematics department without teaching obligations.

—From an AWM announcement

Allen Awarded Kovalevsky Lectureship

Linda J. S. Allen of Texas Tech University has been chosen as the AWM-SIAM Sonia Kovalevsky Lecturer for 2015 by the Association for Women in Mathematics (AWM) and the Society for Industrial and Applied Mathematics (SIAM). She was honored "for her outstanding contributions in ordinary differential equations, difference equations, and stochastic models, which have significant applications in the areas of infectious diseases and ecology." Her work has had a large impact in the fields of mathematical epidemiology and ecological modeling.

Allen received her PhD from the University of Tennessee in 1981 under the direction of T. G. Hallam. She joined the faculty at Texas Tech in 1985. In 2010 she was recognized with the Paul Whitfield Horn Professorship in Mathematics and Statistics, which she still holds. She also holds an adjunct professorship at the Institute of Environmental and Human Health at Texas Tech and has done research at the Mathematical Bioscience Institute of Ohio State University. She serves on the editorial boards of four prestigious journals and is the author of ninety research articles and two books. She will deliver the Kovalevsky Lecture, titled "Predicting population extinction, disease outbreaks, and species invasions using branching processes," at the 2015 International Congress on Industrial and Applied Mathematics (ICIAM) in Beijing, China, in August 2015. The Sonia Kovalevsky Lectureship honors significant contributions by women to applied or computational mathematics.

—From an AWM-SIAM announcement

Hrimiuc Awarded PIMS Education Prize

Dragos Hrimiuc of the University of Alberta has been awarded the 2015 PIMS Education Prize of the Pacific Institute for the Mathematical Sciences (PIMS). In addition to receiving "outstanding assessments from students who praise both his dedication and ability to inspire in them a love and understanding of mathematics", he is committed to mathematical outreach. He is the president of the Alberta High School Mathematics Competition (AHSMC), the first province-wide high school mathematics competition in Canada. He is also one of the founders of *Pi in the Sky*, a PIMS publication intended for high school teachers and their students, and is a regular contributor to the magazine, writing articles on problem-solving strategies, as well as editing the "Math Challenges" section.

The annual prize recognizes individuals in western Canada and Washington State who have played a major role in encouraging activities that enhance public awareness and appreciation of mathematics, as well as fostering communication among various groups concerned with mathematical education at all levels.

—From a PIMS announcement

Bohun Awarded CAIMS-Fields Prize

SEAN BOHUN of the University of Ontario Institute of Technology has been awarded the 2015 CAIMS-Fields Prize in Industrial Mathematics by the Fields Institute and the Canadian Applied and Industrial Mathematics Society (CAIMS) for "exciting and valuable insights into problems ranging from mineral processing to tissue engineering and scheduling," which have led to "new theoretical developments in the theory of PDE models for thermoelasticity and free boundary problems."

The CAIMS-Fields annual industrial mathematics prize is awarded to a researcher in recognition of exceptional research conducted primarily in Canada in any branch of industrial mathematics, interpreted broadly.

—From a Fields Institute press release

Curien and Miller Awarded Davidson Prize

NICOLAS CURIEN of Université Paris-Sud and JASON MILLER of the Massachusetts Institute of Technology have been awarded the 2015 Rollo Davidson Prize. Curien was honored for "outstanding work on random planar maps and related processes." Miller was recognized for "far-reaching results on the geometry of the continuum Gaussian free field."

The Rollo Davidson Trust was founded in 1975 and awards the annual prize to young mathematicians working in the field of probability.

—From a Rollo Davidson Trust announcement

Ramond Awarded Heineman Prize

PIERRE RAMOND of the University of Florida has been awarded the 2015 Dannie Heineman Prize in Mathematical Physics for his "pioneering foundational discoveries in supersymmetry and superstring theory, in particular the dual model of fermions and the theory of the Kalb-Ramond field."

The Heineman Prize is awarded annually in recognition of outstanding publications in the field of mathematical physics. The prize consists of US$10,000 and a certificate. It was established by the Heineman Foundation for Research, Educational, Charitable, and Scientific Purposes, Inc., and is administered jointly by the American Physical Society and the American Institute of Physics.

—From a Heineman Foundation announcement

Recht Receives Baker Award for Initiatives in Research

BENJAMIN RECHT of the University of California Berkeley has been awarded the William O. Baker Award for Initiatives in Research of the National Academy of Sciences (NAS), presented in 2015 in the field of statistics and machine learning. He was honored for "his significant contributions to the field of data science, an area of research that combines statistics (the analysis of large amounts of numerical data), computer science, and mathematics. His work has been particularly valuable in a broad area of mathematics that uses assumptions to reconstruct data-matrix completion and nuclear normal minimization." The award recognizes innovative young scientists and encourages research likely to lead toward new capabilities for human benefit. It is to be given to a resident of the United States preferably no older than thirty-five years of age. The prize carries a cash award of US$15,000.

—From an NAS announcement

2015 Guggenheim Fellowship Awards to Mathematical Scientists

The John Simon Guggenheim Memorial Foundation has announced the names of 175 scholars, artists, and scientists who were selected as Guggenheim Fellows for 2015. Selected as fellows in mathematics and applied mathematics were: EMERY N. BROWN, Harvard Medical School and Massachusetts Institute of Technology; MICHAEL DOEBELI, University of British Columbia; JORDAN S. ELLENBERG, University of Wisconsin–Madison, and TATIANA TORO, University of Washington. Guggenheim Fellows are appointed on the basis of impressive achievement in the past and exceptional promise for future accomplishment.

—From a Guggenheim Foundation announcement

Simons Fellows in Mathematics

The Simons Foundation Mathematics and Physical Sciences (MPS) division supports research in mathematics, theoretical physics, and theoretical computer science. The MPS division provides funding for individuals, institutions, and science infrastructure. The Fellows Program provides funds to faculty for up to a semester-long research leave from classroom teaching and administrative obligations. The mathematical scientists who have been awarded Simons Fellowships for 2015 are: ANTHONY BLOCH, University of Michigan; LILIANA BORCEA, University of Michigan; NIGEL BOSTON, University of Wisconsin–Madison; TED CHINBURG, University of Pennsylvania; OCTAV CORNEA, University of Montreal; HENRI DARMON, McGill University; LAURA DEMARCO, Northwestern University; TYRONE DUNCAN, University of Kansas; JOHN ETNYRE,

Georgia Institute of Technology; ALAN FRIEZE, Carnegie Mellon University; DENNIS GAITSGORY, Harvard University; ALLAN GREENLEAF, University of Rochester; DANIEL GROVES, University of Illinois at Chicago; SAMUEL GRUSHEVSKY, Stony Brook University; MARCO GUALTIERI, University of Toronto; YAN GUO, Brown University; ELENY IONEL, Stanford University; KREŠIMIR JOSIĆ, University of Houston; ROWAN KILLIP, University of California Los Angeles; SERGIU KLAINERMAN, Princeton University; NICOLAI KRYLOV, University of Minnesota; THOMAS LAM, University of Michigan; AARON LAUDA, University of Southern California; TAO LI, Boston College; HANS LINDBLAD, Johns Hopkins University; GUOZHEN LU, Wayne State University; MITCHELL LUSKIN, University of Minnesota–Twin Cities; ROBERT MCCANN, University of Toronto; CURTIS MCMULLEN, Harvard University; LENHARD NG, Duke University; MARTIN OLSSON, University of California Berkeley; BJORN POONEN, Massachusetts Institute of Technology; FLORIAN POP, University of Pennsylvania; MIHNEA POPA, Northwestern University; CRISTIAN POPESCU, University of California San Diego; NICOLAI RESHETIKHIN, University of California Berkeley; TIMO SEPPÄLÄINEN, University of Wisconsin–Madison; ALEXANDER VARCHENKO, University of North Carolina at Chapel Hill; W. HUGH WOODIN, Harvard University; and HONG-KUN ZHANG, University of Massachusetts, Amherst.

—From a Simons Foundation announcement

Putnam Prizes Awarded

The winners of the seventy-fifth William Lowell Putnam Mathematical Competition have been announced. The Putnam Competition is administered by the Mathematical Association of America (MAA) and consists of an examination containing mathematical problems that are designed to test both originality and technical competence. Prizes are awarded to both individuals and teams.

The six highest ranking individuals, listed in alphabetical order, were: RAVI JAGADEESAN, Harvard University; ZIPEI NIE, Massachusetts Institute of Technology; MARK A. SELLKE, Massachusetts Institute of Technology; BOBBY C. SHEN, Massachusetts Institute of Technology; DAVID H. YANG, Massachusetts Institute of Technology; and LINGFU ZHANG, Massachusetts Institute of Technology. Each received a cash award of US$2,500.

Institutions with at least three registered participants obtain a team ranking in the competition based on the rankings of three designated individual participants. The five top-ranked teams (with members listed in alphabetical order) were: first place, Massachusetts Institute of Technology (MITCHELL M. LEE, ZIPEI NIE, DAVID H. YANG); Harvard University (CALVIN DENG, MALCOLM GRANVILLE, XIAOYU HE), Rensselaer Polytechnic Institute (THEERAWAT BHUDISAKSANG, OWEN GOFF, WIJIT YANGJIT); University of Waterloo (KANGNING CHEN, SAM EISENSTAT, DANIEL SPIVAK); Carnegie Mellon University (LINUS U. HAMILTON, THOMAS E. SWAYZE, SAMUEL ZBARSKY). The first-place team receives an award of US$25,000, and each member of the team receives US$1,000. The awards for second place are US$20,000 and US$800; for third place, US$15,000 and US$600; for fourth place, US$10,000 and US$400; and for fifth place, US$5,000 and US$200.

—From an MAA announcement

Intel Science Talent Search Winners Announced

Three students whose work involves the mathematical sciences won first-, second-, and third-place scholarship awards in the 2015 Intel Science Talent Search. NOAH GOLOWICH, seventeen, of Lexington, Massachusetts, was awarded the First Place Medal of Distinction for Basic Research, which recognizes finalists who demonstrate exceptional scientific potential through depth of research and analysis. In his project, "Resolving a conjecture on degree of regularity, with some novel structural results," he developed a proof in the area of Ramsey theory, a field of mathematics based on finding types of structure in large and complicated systems. He received a scholarship award of US$150,000. BRICE HUANG, seventeen, of Princeton Junction, New Jersey, was awarded the Second Place Medal of Distinction for Basic Research and a scholarship award of US$75,000. In his project, "Monomization of power ideals and generalized parking functions," he extended previous mathematical research on power ideals-linear functions of variables raised to some power and was able to calculate the power ideal's series of dimension for a larger class of ideals than has previously been possible. SHASHWAT KISHORE, eighteen, of West Chester, Pennsylvania, received the Third Place Medal of Distinction for Basic Research and a scholarship award of US$35,000 for his math project, "Multiplicity space signatures and applications in tensor products of SL_2 representations," which focused on representing abstract algebras using matrices. His work developed a new relationship between these matrices and topology. The Intel Science Talent Search is administered by the Society for Science and the Public (SSP).

—From an SSP announcement

NSF Graduate Research Fellowships Awarded

The National Science Foundation (NSF) has awarded a number of Graduate Research Fellowships for fiscal year 2015. Further awards may be announced later in the year. This program supports students pursuing doctoral study in all areas of science and engineering and provides a stipend of US$30,000 per year for a maximum of three years of full-time graduate study. Following are the names of the awardees in the mathematical sciences selected so far in 2015, followed by their undergraduate institutions (in parentheses) and the institutions at which they plan to pursue graduate work.

LEONARDO ABBRESCIA (Columbia University), Columbia University; AMOL AGGARWAL (Massachusetts Institute of Technology), Massachusetts Institute of Technology; OLIVIA BECKWITH (Harvey Mudd College), Emory

University; Claire McKay Bowen (Idaho State University), University of Notre Dame; Amanda Bower (University of Michigan), University of Michigan, Ann Arbor; Madeline Brandt (Virginia Reed College), Reed College; David J. Bruce (University of Michigan, Ann Arbor), University of Wisconsin, Madison; Katherine E. Cai (Arizona State University), Arizona State University; Orsola Capovilla-Searle (Bryn Mawr College), Bryn Mawr College; Ryan P. Caulfield (University of Delaware), University of Delaware; Julian C. Chaidez (Massachusetts Institute of Technology), Massachusetts Institute of Technology; Lorin A. Crawford (Clark Atlanta University), Duke University; Maricela F. Cruz (Pomona College), University of California Irvine; Irving F. Dai (Harvard College), Princeton University; Sheela Devadas (Massachusetts Institute of Technology), Massachusetts Institute of Technology; Steven M. Diamond (Stanford University), Stanford University; Hannah M. Director (University of Washington), Harvard University; Stephanie Dodson (University of Massachusetts, Amherst), Brown University; Alexander J. Dunlap (University of Chicago), University of Chicago; Mitchell Faulk (University of Notre Dame), Columbia University; Agustin Flores (Northeastern Illinois University), William Marsh Rice University; Jesse B. Freeman (Williams College), Williams College; Benjamin G. Gammage (University of Chicago), University of California Berkeley; Xavier E. Garcia (University of Minnesota, Twin Cities), Northwestern University; Stephanie Kwang-Yu Ger (Boston College), Northwestern University; Gautam C. Goel (Georgia Institute of Technology), Georgia Institute of Technology; Benjamin Z. Green (Yale University), Harvard University; Mark J. Greenfield (California Institute of Technology), California Institute of Technology; Samuel F. Hopkins (Reed College), Massachusetts Institute of Technology; Eaman Jahani (University of Michigan, Ann Arbor), Massachusetts Institute of Technology; William B. Jamieson (East Tennessee State University), University of Nebraska, Lincoln; Rachael T. Keller (Louisiana State University Agricultural Center), Louisiana State University Agricultural Center; Carson R. Kent (Colorado School of Mines), Colorado School of Mines; Anna E. Kirkpatrick (University of South Carolina, Columbia), University of South Carolina, Columbia; Michael Landry (University of California Berkeley), Yale University; Caleb Lareau (University of Tulsa), University of Tulsa; Carl F. Lian (Massachusetts Institute of Technology), Massachusetts Institute of Technology; Martin L. Lindsey (Massachusetts Institute of Technology), Stanford University; Erin M. Linebarger (Eckerd College), University of Utah; Michelle D. Maiden (Meredith College), University of Colorado, Boulder; Devlin D. Mallory (University of California Berkeley); Matthew B. McDermott (Harvey Mudd College); Shaina Joan-Alexandria Mitchell (Carnegie Mellon University), University of North Carolina, Chapel Hill; Nishant Nangia (University of Illinois, Urbana-Champaign), Northwestern University; Amy L. Nesky (Boston College), University of Michigan, Ann Arbor; Alex J. Ocampo (University of Michigan, Ann Arbor), Harvard University; Bertrand J. Ottino-Loffler (California Institute of Technology), Cornell University; Joshua W. Pfeffer (Harvard University), Harvard University; Ante Qu (Princeton University), Princeton University; Arpon P. Raksit (Harvard University), Harvard University; Nicolas Z. Reyes (University of Massachusetts, Amherst), University of Texas, Austin; Ryan Thorngren (California Institute of Technology), University of California Berkeley; Shreyas S. Tikare (University of North Carolina, Chapel Hill), Princeton University; Brandon V. Tran (Massachusetts Institute of Technology), Massachusetts Institute of Technology; Daniel R. Vitek (Duke University), Princeton University; Abigail R. Ward (University of Chicago), University of Chicago; Ryan S. Warnick (Baylor University), William Marsh Rice University; Allen Yuan (Harvard University), Harvard University.

—From an NSF announcement

SIAM Fellows Elected

The Society for Industrial and Applied Mathematics (SIAM) has elected thirty-one new fellows for 2015. Their names and institutions follow.

Charu C. Aggarwal, IBM T. J. Watson Research Center; Ann S. Almgren, Lawrence Berkeley Laboratory; Aharon Ben-Tal, Technion–Israel Institute of Technology; Vincent D. Blondel, Université Catholique de Louvain; Stephen P. Boyd, Stanford University; Fred Brauer, University of British Columbia, University of Wisconsin, Madison; Franco Brezzi, Istituto Universitario di Studi Superiori di Pavia; Tyrone E. Duncan, University of Kansas; Charles M. Elliott, University of Warwick; Fan Chung Graham, University of California San Diego; Anne Greenbaum, University of Washington; William W. Hager, University of Florida; Per Christian Hansen, Technical University of Denmark; Tamara G. Kolda, Sandia National Laboratories; Petros Koumoutsakos, ETH Zurich; Miroslav Krstic, University of California San Diego; Rachel Kuske, University of British Columbia; Charles E. Leiserson, Massachusetts Institute of Technology; Qun Lin, Chinese Academy of Sciences; Esmond G. Ng, Lawrence Berkeley National Laboratory; Hinke M. Osinga, University of Auckland; Christopher C. Paige, McGill University; Rodolphe Sepulchre, University of Cambridge; Halil Mete Soner, ETH Zurich; Panagiotis E. Souganidis, University of Chicago; Ping Tak Peter Tang, Intel Corporation; Moshe Y. Vardi, Rice University; Charles W. Wampler, General Motors Company; Clarence E. Wayne, Boston University; Henry Wolkowicz, University of Waterloo; and Gang George Yin, Wayne State University.

—From a SIAM announcement

Samuel Gitler (1933–2014)

Samuel Gitler was born on July 14, 1933, in Mexico City, soon after his parents emigrated from Poland, fleeing from the Nazi regime. At the age of twelve, he was sent by his father to San Antonio, Texas, to attend junior high school, where his mathematical skills quickly impressed his teachers. He returned to attend high school in Mexico in 1947 at the prestigious Escuela Nacional Preparatoria of the National University of Mexico (UNAM). Later, in 1952, he enrolled in UNAM's Escuela Nacional de Ingenieros, graduating in 1956 with two BSc degrees, one in engineering and another in mathematics. Motivated by Solomon Lefschetz, a regular visitor to Mexico starting in 1944, Samuel enrolled in Princeton's PhD program under the supervision of Norman Steenrod. Samuel graduated in January 1960 and got a postdoctoral position at Brandeis University, where he first met Edgar H. Brown. In 1961, Samuel returned to Mexico to found, together with José Ádem, a Mathematics Department at Cinvestav. Under their joint leadership, this research center quickly gained a world-class reputation, thus establishing the basis of the modern Mexican school in algebraic topology.

Samuel started a brilliant mathematical career by attacking with extraordinary success the Euclidean immersion problem for real projective spaces. His joint work with Ádem and Mahowald initiated an authentic explosion of new results in the field. They quickly established three of the seven optimal families of immersions known to date for those manifolds. During the first decade of accomplishments, Samuel was also interested in the topology of projective Stiefel manifolds due to their role in the immersion problem. His results on the subject led to two very influential papers: one published in *Topology* in 1968, and then another published in 1986 in his beloved *Mexican Bulletin*, where the parallelizability properties of those manifolds are settled with a single exception. These ideas launched a flurry of results around the vector field problem for projective Stiefel manifolds.

The end of the fruitful first decade of activities witnessed the development by Gitler and Mahowald of a modified version of the Moore-Postnikov method of decomposing a fibration in terms of the homotopy groups of the fiber. As in Adams's work on the unitary Hopf invariant, the new approach utilized homological algebra to filter the homotopy groups of the fiber. This resulted in a highly manageable technique to compute higher order cohomology operations.

The ground was thus prepared in the early 1970s for a seminal collaboration of Samuel and Edgar Brown: the construction of the Brown–Gitler spectra, objects that became a fundamental tool in modern homotopy theory. Not only were these spectra crucial in Ralph Cohen's argument in 1985 for proving the immersion conjecture for manifolds, but they have played an important role in many of the most spectacular developments of homotopy theory. The most representative examples are Mahowald's counterexample in the 1970s to the Doomsday Conjecture, in which he constructed an infinite family of Adams filtration 2 elements in the cohomology of the Steenrod algebra that detect nontrivial elements in the stable homotopy groups of spheres, and Haynes Miller's solution of the Sullivan Conjecture, one of the most significant problems in homotopy theory during the 1980s dealing with the homotopy possibilities for mapping the classifying space of a finite group into a finite complex. The Brown–Gitler work was cited in George W. Whitehead's historical survey of the one hundred most relevant papers in homotopy theory up to 1980, featuring the Brown–Gitler paper as one of the high points of homotopy theory. Indeed, Brown–Gitler spectra were popping up as basic building blocks of classical spaces and, in 1985, the AMS organized a symposium on that subject.

Throughout his mathematical life, Samuel always maintained a wide range of mathematical interests. He worked on the generalized vector first problem, the homotopy classification of stunted projective spaces, supermanifolds, the Riemann–Hurwitz formula, configuration spaces and, near the end of his career, toric topology. He showed an incredible intuition that always resulted in the finest mathematics due to a tireless attitude toward work and an extraordinary ability to go right to the essence of the problem under consideration.

Samuel had a wise vision to create leading research groups. While he was the chairman of the Rochester mathematics department, Doug Ravenel and Fred Cohen joined the faculty, thus consolidating one of the world's leading groups in homotopy theory.

Samuel received many prizes and honors; in particular, he received the National Prize of Science from the hands of the Mexican president in 1976; he was president of the Mexican Mathematical Society for the period 1967–1969, an Inaugural Fellow of the AMS (2012) and, since 1986, a member of El Colegio Nacional, an elite institution grouping the most distinguished artists, scientists, and writers of Mexico.

Samuel died on September 9, 2014, at the age of 81, leaving a rich legacy in the field of algebraic topology.

—Jesus Gonzalez
Center for Research
and Advanced Studies of the National
Polytechnic Institute
(CINVESTAV-IPN) Mexico

Mathematics Opportunities

NSF Postdoctoral Research Fellowships

*Announcement rerun with updated URL

The National Science Foundation (NSF) awards Mathematical Sciences Postdoctoral Research Fellowships (MSPRF) for appropriate research in areas of the mathematical sciences, including applications to other disciplines. Awardees are permitted to choose research environments that will have maximal impact on their future scientific development. Awards are made in the form of either Research Fellowships or Research Instructorships. The Research Fellowship option provides full-time support for any eighteen academic-year months in a three-year period, in intervals not shorter than three consecutive months. The Research Instructorship option provides either two academic years of full-time support or one academic year of full-time and two academic years of half-time support. Under both options, the award includes six summer months; however, no more than two summer months of support may be received in any calendar year. Under both options, the stipend support for twenty-four months (eighteen academic-year months plus six summer months) will be provided within a forty-eight-month period.

The deadline for proposals is **October 21, 2015**. See `www.nsf.gov/funding/pgm_summ.jsp?pims_id=5301&org=DMS&from=home`.

—From an NSF announcement

Research Training Groups in the Mathematical Sciences

*Announcement rerun with updated URL

The National Science Foundation (NSF) Research Training Groups in the Mathematical Sciences (RTG) program provides funds for the training of US students and postdoctoral researchers in the mathematical sciences. Proposals are solicited from groups of researchers based in a subarea of the mathematical sciences or linked by a multidisciplinary theme to support training at educational levels from undergraduate to postdoctoral within that focus. RTG awards are intended to support training programs that have strong potential to increase the number of well-prepared US citizens, nationals, and permanent residents who pursue careers in the mathematical sciences and in other NSF-supported disciplines. The deadline for full proposals is **June 2, 2015**. For more information see `www.nsf.gov/funding/pgm_summ.jsp?pims_id=5732&org=DMS&from=home`.

—From an NSF announcement

NSF Enriched Doctoral Training in Mathematical Sciences

The National Science Foundation's (NSF) Enriched Doctoral Training in the Mathematical Sciences (EDT) program is intended to strengthen the nation's scientific competitiveness by increasing the number of well-prepared US citizens, nationals, and permanent residents who pursue careers in the mathematical sciences and in other professions in which expertise in the mathematical sciences plays an increasingly important role. The program supports efforts to enrich research training in the mathematical sciences at the doctoral level by preparing PhD students to recognize and find solutions to mathematical challenges arising in other fields and in areas outside today's academic setting. The deadline for proposals is **July 8, 2015**. For more information, see `www.nsf.gov/funding/pgm_summ.jsp?pims_id=505083`.

—From an NSF announcement

Call for Nominations for 2016 Heineman Prize

The American Physical Society (APS) and the American Institute of Physics (AIP) are seeking nominations for the

2016 Dannie Heineman Prize for Mathematical Physics. The prize recognizes outstanding publications in the field of mathematical physics. The prize carries a cash award of US$10,000, an award certificate, and travel expenses to the meeting at which the prize is given. The deadline for nominations for the 2016 prize is **July 1, 2015**. For more information, see the APS website at `www.aps.org/programs/honors/prizes/heineman.cfm`.

—From an APS announcement

Call for Nominations for the 2015 SASTRA Ramanujan Prize

The Shanmugha Arts, Science, Technology, Research Academy (SASTRA) is seeking nominations for the 2015 SASTRA Ramanujan Prize. The prize is given annually to a mathematician, not over the age of thirty-two, for outstanding contributions in an area of mathematics influenced by the late Indian mathematical genius Srinivasa Ramanujan. The prize carries a cash award of US$10,000 and an invitation to give a talk at the SASTRA conference in December 2015. The deadline for nominations is **July 31, 2015**. For more information see the website `www.ams.org/opportunities/view/listing?listing_id=491165`.

—Krishnaswami Alladi, University of Florida

Call for Nominations for Sloan Research Fellowships

Nominations of candidates for Sloan Research Fellowships, sponsored by the Alfred P. Sloan Foundation, are due by **September 15, 2015**. A candidate must be a member of the regular faculty at a college or university in the United States or Canada and must have received their PhD or equivalent within the six years prior to the nomination. For information, write to: Sloan Research Fellowships, Alfred P. Sloan Foundation, 630 Fifth Avenue, Suite 2550, New York, NY 10111-0242, or consult the foundation's website: `www.sloan.org/sloan-research-fellowships/`.

—From a Sloan Foundation announcement

Fulbright Postdoctoral Fellowships in Israel

The United States–Israel Educational Foundation (USIEF), the Fulbright commission for Israel, will award eight fellowships to US postdoctoral researchers in support of work to be carried out at Israeli universities during the course of the 2016–17 academic year. The fellowships will support study for at least two academic years with an award of US$20,000 per academic year. The deadline for 2016/2017–2017/2018 Fellowships is **August 1, 2015**. For more information, see the website `fulbright.org.il/en/?page_id=1024&utm_source=AmericanMathematicalSociety&utm_medium=www&utm_campaign=postdoc`.

—From a USIEF announcement

IMA Prize in Mathematics and its Applications

The Institute for Mathematics and its Applications (IMA) awards the annual Prize in Mathematics and its Applications to an individual who has made a transformative impact on the mathematical sciences and their applications. This prize can recognize either a single notable achievement or acknowledge a body of work. Nominees should have received the PhD degree within ten years of the nomination year. Nominations of persons who have visited and conducted research at the IMA are especially encouraged. The prize consists of a certificate and a cash award of US$3,000. The deadline for nominations is **July 17, 2015**. For more information see `www.ima.umn.edu/prize/`.

—From an IMA announcement

The John Riordan Prize

The *On-Line Encyclopedia of Integer Sequences* (OEIS) Foundation is offering US$1,000 for the best solution in 2015 to an open problem in the OEIS. Readers are invited to solve an open problem in an entry in the OEIS (`https://oeis.org`). After adding your solution to the OEIS entry, notify `secretary@oeisf.org` with the subject line "Riordan Prize Nomination." It is acceptable to nominate your own work. The deadline for submission is **December 1, 2015**. The decision will be made by a special prize committee and will be announced at the Joint Mathematics Meetings in Seattle in January 2016.

To find problems to work on, search in the OEIS for the words "conjecture," "empirical," "evidence suggests," "it would be nice," "would like," etc. Or find a formula or recurrence (with proof, of course) for a sequence that currently has no formula. Your proof should be mentioned in the appropriate OEIS entry but (especially if it is long) may be published elsewhere, for example, on the arXiv.

The prize is named after John Riordan (1903–1988; Bell Labs, 1926–1968), author of the classic books *An Introduction to Combinatorial Analysis* (1958) and *Combinatorial Identities* (1968), which were the source for hundreds of early entries in the OEIS. Additional information may be found at `oeis.org/wiki/RiordanPrize`. The OEIS Foundation hopes that this competition will lead to the resolution of many open questions in the OEIS.

—Neil J. A. Sloane, President
The OEIS Foundation

News from the Clay Mathematics Institute

The Clay Mathematics Institute (CMI) will hold the 2015 Clay Research Conference and Workshops from September 28 through October 2, 2015, at the Mathematical Institute of the University of Oxford. The speakers will be Charles Fefferman (Princeton University), Mike Hopkins (Harvard University), Maryam Mirzakhani (Stanford University), Andrei Okounkov (Columbia University), and Peter Scholze (University of Bonn).

The recipient of the 2015 Clay Research Award will be announced at the conference. Presented annually, the Clay Research Award celebrates outstanding achievements in mathematical research.

The following workshops will be held throughout the week of the conference: Algebraic Topology: Manifolds Unlocking Higher Structures, Mike Hopkins and Ulrike Tillmann; Geometry and Dynamics on Moduli Spaces, Alex Eskin, Giovanni Forni, and Anton Zorich; Motives and Automorphic Forms, Minhyong Kim and Peter Scholze; Water Waves and Related Fluid Models, Alex Ionescu and Steve Shkoller.

Registration for the Clay Research Conference is free and required. Participation in the workshops is by invitation; a limited number of additional places are available. For more information, email Naomi Kraker at `admin@claymath.org`. For full details, including the schedule, titles, and abstracts when they become available, see `www.claymath.org`.

—From a CMI announcement

Mathematical Sciences Research Institute Fall Workshops, 2015, Berkeley, CA

With funding from the National Science Foundation, the National Security Agency, and the Clay Mathematics Institute, the Mathematical Sciences Research Institute (MSRI) will hold three workshops during the fall of 2015 in New Challenges in PDE: Deterministic Dynamics and Randomness in High and Infinite Dimensional Systems.

Established researchers, postdoctoral fellows, and graduate students are invited to apply for funding. It is the policy of MSRI to actively seek to achieve diversity in its workshops. Thus, a strong effort is made to remove barriers that hinder equal opportunity, particularly for those groups that have been historically underrepresented in the mathematical sciences. MSRI has a resource to assist visitors with finding childcare in Berkeley.

The workshops are as follows:

August 19–21, 2015
Connections for women: Dispersive and stochastic PDE
`www.msri.org/workshops/759`

August 24–28, 2015
Introductory workshop: Randomness and long time dynamics in nonlinear evolution differential equations
`www.msri.org/workshops/760`
October 19–30, 2015
New challenges in PDE: Deterministic dynamics and randomness in high and infinite dimensional systems
`www.msri.org/workshops/761`

For more information, please contact Sanjani Varkey at `sanjani@msri.org`.

Corrections

The *Notices* editors regret the following errors that appeared in the 2015 April and May issues:

On page 373 of the April issue, the introductory text preceding the article by Pierre Cartier cited an incorrect date for the death of Alexander Grothendieck. Grothendieck died November 13, 2014.

On page 475 of the May issue, contributing editor Wai-Mee Ching's affiliations should have read: "Wai-Mee Ching is a retired professor of computer science, Zhejiang Normal University and former research staff member for the IBM Thomas J. Watson Research Center."

On page 518 of the May 2015 issue, in my review of Walter Hayman's book *My Life and Functions*, I erroneously stated that Fields Medalist Klaus Roth is deceased. He is still living and is in his 90th year.

—David Drasin

On page 565 of the May issue, the Mathematics People obituary for Virginia Halmos should have been attributed to Gerald Alexanderson of Santa Clara University.

On page 579 of the May issue, the photo caption should have read: "Erik Demaine, Arnold Ross Lecture, 2013 at Museum of Math."

Inside the AMS

Fan China Exchange Program Awardees

The Society's Fan China Exchange Program awards grants to support collaborations between Chinese and US or Canadian researchers. Institutions in the United States or Canada apply for the funds to support a visitor from China or vice versa. This funding is made possible through a generous gift made to the AMS by Ky and Yu-Fen Fan in 1999. The awardees for 2015 follow.

MICHIGAN STATE UNIVERSITY received a grant of US$4,748 to support a visit from Lianzhang Bao of Jilin University.

RUTGERS UNIVERSITY received a grant of US$5,000 to support a visit from Xuezhang Chen of Nanjing University.

NORTHWESTERN UNIVERSITY received a grant of US$5,000 to support a visit from Peng Sun of the Central University of Finance and Economics.

Each visitor's own department will receive a grant of US$1,000 after the visit.

For information about the Fan China Exchange Program, visit the website www.ams.org/programs/travel-grants/china-exchange/china-exchange or contact the AMS Membership and Programs Department, email: chinaexchange@ams.org, telephone 401-455-4170 (within the US call 800-321-4267, ext. 4170).

—AMS Membership and Programs Department

Erdős Memorial Lecture

The Erdős Memorial Lecture is an annual invited address named for the prolific mathematician Paul Erdős (1913–1996). The lectures are supported by a fund created by Andrew Beal, a Dallas banker and mathematics enthusiast. The Beal Prize Fund, now US$100,000, is being held by the AMS until it is awarded for a correct solution to the Beal Conjecture (www.math.unt.edu/~mauldin/beal.html).

At Mr. Beal's request, the interest from the fund is used to support the Erdős Memorial Lecture.

The 2015 Erdős Memorial Lecturer for 2015 will be PETER SARNAK of the Institute for Advanced Study and Princeton University. The lecture will be held on October 3, 2015, at the 2015 Fall Central Section Meeting at Loyola University Chicago, Chicago, Illinois. The title of the lecture will be announced on the website www.ams.org/meetings/lectures/meet-erdos-lect#sthash.q6ktbI6I.dpuf.

From the AMS Public Awareness Office
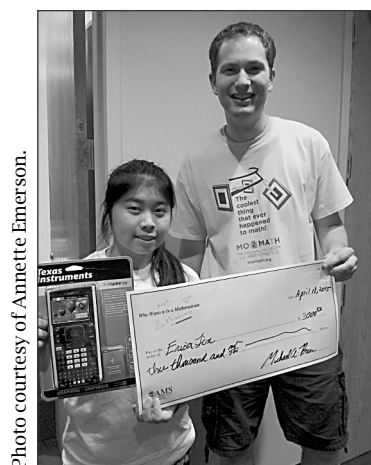
Erica Lin and her teacher, John Chase.

***Who Wants to Be a Mathematician* at the National Math Festival and in Rhode Island**. Who Wants to Be a Mathematician celebrated Mathematics Awareness Month with two games in April. On April 14, at Providence College, more than 250 students and teachers watched John Perino, a junior at Westerly High School, win US$3,000 from the AMS. A few days later, on the 18th, at the inaugural National Math Festival in Washington, DC, Erica Lin, a sophomore at Richard Montgomery High School, Maryland, won US$3,000. Read about the games at www.ams.org/programs/students/wwtbam/ri-2015 and www.ams.org/programs/students/wwtbam/nmf-2015.

2015 Mathematical Art Exhibition album. A collection of selected works from the exhibition is on Mathematical Imagery at `www.ams.org/mathimagery/thumbnails.php?album=42`.

***Really Big Numbers* Receives Mathical Award**. *Really Big Numbers* won the first Mathical: Books for Kids from Tots to Teens book prize in two categories: Grades 3–5 and Grades 6–8. The book, written by Richard Evan Schwartz of Brown University and published by the AMS, received the prize in Washington, DC, on April 17 as part of the National Math Festival. The Mathical: Books for Kids from Tots to Teens book prize, presented by the Mathematical Sciences Research Institute (MSRI) and the Children's Book Council (CBC), recognizes the most inspiring math-related fiction and nonfiction books for young people of all ages. See a video of Schwartz reading from his book at www.`youtube.com/watch?v=aOhsNP48AtQ`.

Awards, Fellowships, and Other Opportunities. Visitors to the page can search, browse, share, and post calls for fellowship and grant applications, prize and award nominations, and meeting and workshop proposals in the mathematical sciences on this new online resource. The page serves mathematics faculty/scientists, institutions, programs, postdocs/early-career mathematicians, graduate students, undergraduate students, and high school students and teachers. We invite you to disseminate this information to your members and submit calls for opportunities to this new site. Once a submission is approved, users can respond directly to the contact or website provided in the call. See `www.ams.org/opportunities`.

—Annette Emerson and Mike Breen
AMS Public Awareness Officers
`paoffice@ams.org`

Deaths of AMS Members

STEPHEN E. BOWSER, professor, Allegheny College, died on January 12, 2015. Born on April 12, 1949, he was a member of the Society for 41 years.

OLA BRATTELI, professor, University of Oslo, Norway, died on February 8, 2015. Born on October 24, 1946, he was a member of the Society for 43 years.

WILLIAM E. CHRISTILLES, of San Antonio, Texas, died on July 30, 2014. Born on June 16, 1931, he was a member of the Society for 53 years.

RICHARD A. DUKE, professor, Georgia Institute of Technology, died on February 19, 2015. Born on August 23, 1937, he was a member of the Society for 51 years.

MIKHAIL GORDIN, of St. Petersburg, Russia, died on March 17, 2015. Born on September 9, 1944, he was a member of the Society for 22 years.

ERIK HEMMINGSEN, of Kennett Square, Pennsylvania, died on December 30, 2012. Born on September 16, 1917, he was a member of the Society for 70 years.

J. HORVATH, of Silver Spring, Maryland, died on March 12, 2015. Born on July 30, 1924, he was a member of the Society for 57 years.

LOUIE C. HUFFMAN, of Amarillo, Texas, died on December 13, 2014. Born on December 29, 1926, he was a member of the Society for 43 years.

WOLFGANG P. KAPPE, professor, SUNY at Binghamton, died on February 20, 2015. Born on March 11, 1930, he was a member of the Society for 52 years.

J. HALCOMBE LANING, of San Diego, California, died on May 29, 2012. Born on February 14, 1920, he was a member of the Society for 67 years.

DONALD J. LEWIS, of Ann Arbor, Michigan, died on February 15, 2015. Born on January 25, 1926, he was a member of the Society for 69 years.

HENRYK MINC, professor, University of California Santa Barbara, died on July 15, 2013. Born on November 12, 1919, he was a member of the Society for 54 years.

ALBERT NIJENHUIS, of Seattle, Washington, died on February 13, 2015. Born on November 21, 1926, he was a member of the Society for 62 years.

D. A. QUARLES JR., of Eastham, Massachusetts, died on June 7, 2014. Born on May 8, 1922, he was a member of the Society for 66 years.

SYLVESTER REESE, of New York, New York, died on May 21, 2014. Born on November 18, 1933, he was a member of the Society for 54 years.

HANS I. RIESEL, of Sweden, died on December 21, 2014. Born on May 28, 1929, he was a member of the Society for 60 years.

CHARLES D. ROBINSON, of Abilene, Texas, died on December 10, 2014. Born on July 16, 1932, he was a member of the Society for 51 years.

LEIBA RODMAN, of Williamsburg, Virginia, died on March 2, 2015. Born on June 9, 1949, he was a member of the Society for 35 years.

TIMOTHY MICHAEL SEYMOUR, of Houston, Texas, died on January 15, 2015. Born on July 3, 1954, he was a member of the Society for 37 years.

JOHN C. SHEPHERDSON, of the United Kingdom, died on January 8, 2015. Born on June 7, 1926, he was a member of the Society for 60 years.

JOHN J. SOPKA, of Boston, Massachusetts, died on January 20, 2014. Born on December 27, 1919, he was a member of the Society for 67 years.

PATRICK SUPPES, professor, Stanford University, died on November 17, 2014. Born on March 17, 1922, he was a member of the Society for 61 years.

TOMA TONEV, professor, University of Montana-Missoula, died on February 22, 2015. Born on April 5, 1945, he was a member of the Society for 38 years.

WOLFGANG L. WALTER, of Germany, died on June 26, 2010. Born on May 2, 1927, he was a member of the Society for 46 years.

Reference and Book List

*The **Reference** section is intended to provide readers with frequently sought information in an easily accessible format. New information is printed as it becomes available and is referenced after its first printing.*

Contacting the *Notices*

The preferred method for contacting the *Notices* is e-mail.

The **editor-in-chief**, **Steven G. Krantz**, should be contacted about articles for consideration. Articles include features, memorials, communications, opinion pieces, and book reviews. The editor is also the person to whom to send news of unusual interest about other people's mathematics research. Contact the **editor-in-chief** at: notices@math.wustl.edu.

The **managing editor**, **Rachel L. Rossi**, should be contacted for additions to "Mathematics People", "Mathematics Opportunities", "For Your Information", and for any corrections. Contact the **managing editor** at: notices@ams.org.

Letters to the editor should be sent to: notices-letters@ams.org.

Permissions requests should be sent to: reprint-permission@ams.org.

Advertising requests should be sent to: notices-ads@ams.org.

Math Calendar additions should be sent to: mathcal@ams.org.

Book List additions should be sent to: notices-booklist@ams.org.

For full contact information, including postal addresses, see: www.ams.org/notices/contact.html.

Upcoming Deadlines

July 1, 2015: Nominations for 2016 Dannie Heineman Prize for Mathematical Physics. See "Mathematics Opportunities" in this issue.

July 8, 2015: Proposals for NSF Enriched Doctoral Training in the Mathematical Sciences program. See www.nsf.gov/pubs/2014/nsf14589/nsf14589.htm.

July 10, 2015: International Mathematics Competition for University Students. See www.imc-math.org.uk/.

July 20, 2015: Applications for Math for America Master Teacher Fellowships in New York City. See www.mathforamerica.org/web/guest/apply.

July 17, 2015: Nominations for IMA Prize in Mathematics and Its Applications. See "Mathematics Opportunities" in this issue.

July 23, 2015: Proposals for NSF Faculty Early Career Development (CAREER) Awards. See "Mathematics Opportunities" in this issue.

July 31, 2015: Nominations for 2015 SASTRA Ramanujan Prize. See "Mathematics Opportunities" in this issue.

Where to Find It

A brief index to information that appears in this and previous issues of the *Notices.*

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AMS Governance 2015—*June/July 2015, p. 673*

Contact Information for Mathematical Institutes—*August 2014, p. 786*

Conference Board of the Mathematical Sciences—*September 2014, p. 916*

IMU Executive Committee—*December 2014, p. 1370*

Information for *Notices* Authors—*June/July 2014, p. 646*

National Science Board—*March 2015, p. 290*

NRC Board on Mathematical Sciences and Their Applications—*March 2014, p. 305*

NSF Mathematical and Physical Sciences Advisory Committee—*May 2015, p. 571*

Program Officers for Federal Funding Agencies—*October 2013, p. 1188 (DoD, DoE); December 2014, p. 1369 (NSF Mathematics Education)*

Program Officers for NSF Division of Mathematical Sciences—*November 2014, p. 1264*

August 1, 2015: Applications for Fulbright Postdoctoral Fellowships in Israel. See "Mathematics Opportunities" in this issue.

August 1, 2015: Applications for August review for National Academies Research Associateship programs. See `sites.nationalacademies.org/PGA/RAP/PGA_050491` or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone: 202-334-2760; fax: 202-334-2759; email: `rap@nas.edu`.

September 15, 2015: Nominations for Sloan Research Fellowships. See "Mathematics Opportunities" in this issue.

September 15, 2015: Applications for 2016 semester of Math in Moscow. See `www.mccme.ru/mathinmoscow`, or write to: Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax: +7095-291-65-01; email: `mim@mccme.ru`. Information and application forms for the AMS scholarships are available on the AMS website at `www.ams.org/programs/travel-grants/mimoscow`, or by writing to: Math in Moscow Program, Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence RI 02904-2294; email: `student-serv@ams.org`.

October 1, 2015: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See `https://sites.google.com/site/awmmath/programs/travel-grants`; telephone: 703-934-0163; or email: `awm@awm-math.org`; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 21, 2015: Proposals for NSF Postdoctoral Research Fellowships. See `www.nsf.gov/pubs/2012/nsf12496/nsf12496.htm`.

November 1, 2015: Applications for November review for National Academies Research Associateship programs. See `sites.nationalacademies.org/PGA/RAP/PGA_050491` or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001;

telephone: 202-334-2760; fax: 202-334-2759; email: `rap@nas.edu`.

December 1, 2015: Submissions for the John Riordan Prize of the OEIS Foundation. See "Mathematics Opportunities" in this issue.

Book List

The Book List highlights recent books that have mathematical themes and are aimed at a broad audience, potentially including mathematicians, students, and the general public.

An * indicates a new edition to the book list.

Alan M. Turing: Centenary Edition, by Sara Turing. Cambridge University Press, April 2012. ISBN-13: 978-11070-205-80. (Reviewed September 2014.)

Alan Turing: The Enigma, The Centenary Edition, by Andrew Hodges. Princeton University Press, May 2012. ISBN-13: 978-06911-556-47. (Reviewed September 2014.)

Alan Turing: His Work and Impact, edited by S. Barry Cooper and J. van Leeuwen. Elsevier, May 2013. ISBN-13: 978-01238-698-07. (Reviewed September 2014.)

Alan Turing's Electronic Brain: The Struggle to Build the ACE, the World's Fastest Computer, by B. Jack Copeland et al. Oxford University Press, May 2012. ISBN-13: 978-0-19-960915-4. (Reviewed September 2014.)

André-Louis Cholesky: Mathematician, Topographer and Army Officer, by Claude Brezinski and Dominique Tournès. Birkhäuser, August 2014. ISBN-13: 978-33190-813-42.

Arnold: Swimming Against the Tide, edited by Boris A. Khesin and Serge L. Tabachnikov. AMS, September 2014. ISBN-13: 978-14704-169-97.

Automate This: How Algorithms Took Over Our Markets, Our Jobs, and the World, by Christopher Steiner. Portfolio Trade August 2013. ISBN-13: 978-15918-465-29.

Baroque Science, by Ofer Gal and Raz Chen-Morris. University of Chicago Press, March 2013. ISBN-13: 978-02262-129-82.

Beating the Odds: The Life and Times of E. A. Milne, by Meg Weston. Imperial College Press, June 2013. ISBN-13: 978-18481-690-74.

Beautiful Geometry, by Eli Maor and Eugen Jost. Princeton University Press, January 2014. ISBN-13: 978-06911-509-94.

Beyond Banneker: Black Mathematicians and the Paths to Excellence, by Erica N. Walker. State University of New York Press, June 2014. ISBN-13: 978-14384-521-59.

Combinatorics: Ancient and Modern, by Robin Wilson and John J. Watkins. Oxford University Press, August 2013. ISBN-13: 978-01996-565-92.

The Computing Universe: A Journey through a Revolution, by Tony Hey and Gyuri Pápay. Cambridge University Press, December 2014. ISBN-13: 978-05211-501-87.

**Constitutional Calculus: The Math of Justice and the Myth of Common Sense,* by Jeff Suzuki. Johns Hopkins University Press, January 2015. ISBN-13: 978-14214-159-56.

A Curious History of Mathematics: The Big Ideas from Early Number Concepts to Chaos Theory, by Joel Levy. Andre Deutsch, February 2014. ISBN-13: 978-02330-038-56.

Doing Data Science: Straight Talk from the Frontline, by Rachel Schutt and Cathy O'Neil. O'Reilly Media, November 2013. ISBN-13: 978-1-449-35865-5. (Reviewed October 2014.)

Doing Mathematics: Convention, Subject, Calculation, Analogy, by Martin H. Krieger. World Scientific, Second Edition, 2015. ISBN-13: 978-981-4571-83-8.

Einstein's Dice and Schrödinger's Cat: How Two Great Minds Battled Quantum Randomness to Create a Unified Theory of Physics, by Paul Halpern. Basic Books, April 2015. ISBN-13: 978-04650-757-13.

Electricity and Magnetism for Mathematicians: A Guided Path from Maxwell's Equations to Yang-Mills, by Thomas A. Garrity. Cambridge University Press, January 2015. ISBN-13: 978-11074-351-62.

Enlightening Symbols: A Short History of Mathematical Notation and Its Hidden Powers, by Joseph Mazur. Princeton University Press, March 2014. ISBN-13: 978-06911-546-33. (Reviewed February 2015.)

Experiencing Mathematics: What Do We Do, When We Do Mathematics?, by Reuben Hersh. AMS,

February 2014. ISBN-13: 978-0-8218-9420-0.

The Fascinating World of Graph Theory, by Arthur Benjamin, Gary Chartrand, and Ping Zhang. Princeton University Press January 2015. ISBN-13: 978-06911-638-19.

Fifty Visions of Mathematics, edited by Sam Parc. Oxford University Press, July 2014. ISBN-13: 978-0-19-87-018-11.

Finding Zero: A Mathematician's Odyssey to Uncover the Origins of Numbers, by Amir D. Aczel. Palgrave Macmillan Trade, January 2015. ISBN-13: 978-11372-798-42.

The Formula: How Algorithms Solve All Our Problems—And Create More, by Luke Dormehl. Perigee Trade, November 2014. ISBN-13: 978-03991-705-39.

From Mathematics in Logic to Logic in Mathematics: Boole and Frege, by Aliou Tall. Docent Press, July 2014, ISBN-13: 978-0-9887449-7-4.

The Goddess of Small Victories, by Yannick Grannec. Other Press, October 2014. ISBN-13: 978-15905-163-62.

The Grapes of Math: How Life Reflects Numbers and Numbers Reflect Life, by Alex Bellos. Simon and Schuster, June 2014. ISBN: 978-14516-400-90.

Great Mathematics Books of the Twentieth Century: A Personal Journal, by Lizhen Ji. International Press of Boston, April 2014. ISBN-13: 978-15714-628-31.

A History in Sum: 150 Years of Mathematics at Harvard (1825–1975), by Steve Nadis and Shing-Tung Yau. Harvard University Press, October 2013. ISBN-13: 978-06747-250-03. (Reviewed June/July 2014.)

How to Bake Pi: An Edible Exploration of the Mathematics of Mathematics, by Eugenia Cheng. Basic Books, May 2015. ISBN: 978-04650-517-17.

The Improbability Principle: Why Coincidences, Miracles, and Rare Events Happen Every Day, by David J. Hand. Scientific American/Farrar, Straus and Giroux, February 2014. ISBN-13: 978-03741-753-44. (Reviewed December 2014.)

James Clerk Maxwell: Perspective on his Life and Works, edited by Raymond Flood, Mark McCartney, and Andrew Whitaker. Oxford University Press, March 2014. ISBN-13: 978-0-19-96-643-75.

Levels of Infinity: Selected Writings on Mathematics and Philosophy, by Hermann Weyl (edited and with an introduction by Peter Pesic). Dover Publications, January 2013. ISBN: 978-04864-890-32.

Love and Math: The Heart of Hidden Reality, by Edward Frenkel. Basic Books, October 2013. ISBN-13: 978-04650-507-41. (Reviewed October 2014.)

*The Math Book: From Pythagoras to the 57th Dimension, 250 Milestones in the History of Mathematics, by Clifford A. Pickover. Sterling, February 7, 2012. ISBN-13: 978-14027-882-91. (Reviewed April 2015.)

Mathematical Expeditions: Exploring Word Problems Across the Ages, by Frank J. Swetz. Johns Hopkins University Press, June 2012. ISBN: 978-14214-043-87.

Mathematical Understanding of Nature: Essays on Amazing Physical Phenomena and Their Understanding by Mathematicians, by V. I. Arnold. AMS, September 2014. ISBN-13: 978-1-4704-170-17.

The Mathematician's Shiva, by Stuart Rojstaczer. Penguin Books, September 2014. ISBN-13: 978-0-14-312-631-7.

Mathematics and the Making of Modern Ireland: Trinity College Dublin from Cromwell to the Celtic Tiger, by David Attis. Docent Press, October 2014, ISBN-13: 978-0-9887449-8-1.

Mathematics and the Real World: The Remarkable Role of Evolution in the Making of Mathematics, by Zvi Artstein. Prometheus Books, September 2014. ISBN-13: 978-16161-409-15.

The Mathematics Devotional: Celebrating the Wisdom and Beauty of Mathematics, by Clifford Pickover. Sterling, November 2014. ISBN-13: 978-14549-132-21.

*The Mathematics of Love: Patterns, Proofs, and the Search for the Ultimate Equation, by Hannah Fry. Simon & Schuster/TED, February 2015. ISBN: 978-14767-848-85.

Mathematics without Apologies: Portrait of a Problematic Vocation, by Michael Harris. Princeton University Press, January 2015. ISBN-13: 978-06911-542-37.

A Mind For Numbers: How to Excel at Math and Science (Even If You Flunked Algebra), by Barbara Oakley. Tarcher, July 2014. ISBN-13: 978-03991-652-45.

My Life and Functions, by Walter K. Hayman. Logic Press, October 2014. Hardcover ISBN-13: 978-13260-322-41. Paperback ISBN-13: 978-1-326-03020-9. (Reviewed May 2015.)

On Leibniz: Expanded Edition, by Nicholas Rescher. University of Pittsburgh Press, June 2013. ISBN-13: 978-08229-621-82.

Origins of Mathematical Words: A Comprehensive Dictionary of Latin, Greek, and Arabic Roots, by Anthony Lo Bello. Johns Hopkins University Press, November 2013. ISBN-13: 978-14214-109-82.

Parables, Parabolas and Catastrophes: Conversations on Mathematics, Science and Philosophy, by René Thom. Translated by Roy Lisker and edited by S. Peter Tsatsanis. Thombooks Press, November 2014 (distributed only by `amazon.ca` or `amazon.com`). ISBN-13: 978-09939-269-07.

Pearls from a Lost City: The Lvov School of Mathematics, by Roman Duda (translated by Daniel Davies). AMS, July 2014. ISBN-13: 978-1-4704-107-66.

Probably Approximately Correct: Nature's Algorithms for Learning and Prospering in a Complex World, by Leslie Valiant. Basic Books, June 2013. ISBN-13: 978-04650-327-16. (Reviewed November 2014.)

Professor Stewart's Casebook of Mathematical Mysteries, by Ian Stewart. Basic Books, October 2014. ISBN-13: 978-04650-549-78.
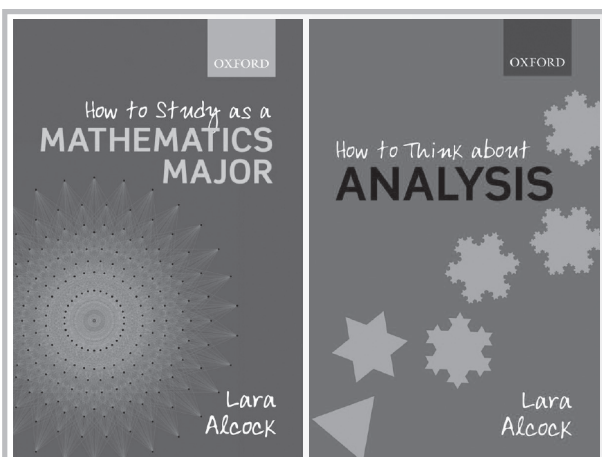
Quantum Computing since Democritus, by Scott Aaronson. Cambridge University Press, March 2013. ISBN-13: 978-0-521-1-995-68. (Reviewed November 2014.)

Ramanujan's Place in the World of Mathematics: Essays Providing a Comparative Study, by Krishnaswami Alladi. Springer, 2013. ISBN-13: 978-81322-076-65.

The Simpsons and Their Mathematical Secrets, by Simon Singh. Bloomsbury, October 2013. ISBN-13: 978-14088-353-02. (Reviewed January 2015.)

Struck by Genius: How a Brain Injury Made Me a Mathematical Marvel, by Jason Padgett and Maureen Ann

Seaberg. Houghton Mifflin Harcourt, April 2014. ISBN-13: 978-05440-456-06.

Synthetic Philosophy of Contemporary Mathematics, by Fernando Zalamea. Urbanomic/Sequence Press, January 2013. ISBN-13: 978-09567-750-16.

Taming the Unknown: A History of Algebra from Antiquity to the Early Twentieth Century, by Victor J. Katz and Karen Hunger Parshall. Princeton University Press, July 2014. ISBN-13: 978-06911-490-59.

The Tower of Hanoi: Myths and Maths, by Andreas M. Hinz, Sandi Klavzar, Uros Milutinovic, and Ciril Petr. Birkhäuser, January 2013. ISBN-13: 978-303-48023-69.

Turing: Pioneer of the Information Age, by Jack Copeland. Oxford University Press, January 2013. ISBN-13: 978-0-19-96-397-93. (Reviewed September 2014.)

Turing's Cathedral: The Origins of the Digital Universe, by George Dyson. Pantheon/Vintage, December 2012. ISBN-13: 978-14000-759-97. (Reviewed August 2014.)

The War of Guns and Mathematics: Mathematical Practices and Communities in France and Its Western Allies Around World War I, by David Aubin and Catherine Goldstein. AMS, October 2014. ISBN-13: 978-1-4704-146-96.

What's Math Got to Do with It?: How Teachers and Parents Can Transform Mathematics Learning and Inspire Success, by Jo Boaler. Penguin Books, revised edition, March 2015. ISBN-13: 978-0-14-31-282-98.

Why Is There Philosophy of Mathematics At All?, by Ian Hacking. Cambridge University Press, April 2014. ISBN-13: 978-11070-501-74. (Reviewed December 2014.)

Zombies and Calculus, by Colin Adams. Princeton University Press, September 2014. ISBN-13: 978-06911-619-07.

Mathematics Calendar

Please submit conference information for the Mathematics Calendar through the Mathematics Calendar submission form at www.ams.org/cgi-bin/mathcal-submit.pl. The most comprehensive and up-to-date Mathematics Calendar information is available on the AMS website at www.ams.org/mathcal/.

June 2015

1–4 **6th Symposium on Analysis and PDEs**, Purdue University, West Lafayette, Indiana.

* 1–5 **Actual problems of mathematics and mathematical modeling (APMMM-2015)**, Institute of Mathematics and Mathematical Modeling of Education and Science Ministry of the Republic of Kazakhstan, Almaty, Kazakhstan.

Description: Institute of Mathematics and Mathematical Modeling of Education and Science Ministry of the Republic of Kazakhstan organizes the international conference "Actual problems of mathematics and mathematical modeling", dedicated to the 50th anniversary of the foundation of the Institute of Mathematics and Mechanics. The Organizing Committee invite researchers on differential equations, analysis, algebra, geometry, mathematical logic, mathematical physics, mathematical modeling, numerical mathematics, mechanics, and information technology to participate in the conference.

Location: www.math.kz/conf

1–5 **AIM Workshop: Stochastic Methods for Non-Equilibrium Dynamical Systems**, American Institute of Mathematics, Palo Alto, California. (Sept. 2014, p. 985)

1–5 **Asymptotic Problems: Elliptic and Parabolic Issues**, Vilnius, Lithuania.

1–5 **Integrability in Mechanics and Geometry: Theory and Computations**, Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, Rhode Island. (Nov. 2014, p. 1275)

1–5 **MAMERN VI-2015: 6th International Conference on Approximation Methods and Numerical Modeling in Environment and Natural Resources**, University of Pau, Pau, France.

1–5 **Moduli Spaces in Symplectic Topology and in Gauge Theory**, CIRM, Marseille Luminy, France.

1–5 **Nordic Summer School in Algebra and Geometry**, The Sven Loven Centre for Marine Sciences of the University, Gothenburg, Sweden.

1–5 **Representation Theory, Number Theory and Invariant Theory**, Yale University, New Haven, Connecticut.

* 1–5 **School JISD 2015**, Facultat de Matemàtiques i Estadística (FME), Universitat Politècnica de Catalunya (UPC), Barcelona, Spain

Description: 13th Workshop on Interactions Between Dynamical Systems and Partial Differential Equations (Jisd2015)

Information: www.ma1.upc.edu/recerca/jisd/jisd2015

* 1–5 **XVIII International Conference on Waves and Stability in Continuous Media 2015—WASCOM 2015**, Grand Hotel San Michele, Loc. Bosco, 8/9—87022 Cetraro (CS), Italy

Description: The International Conference on Waves and Stability in Continuous Media (WASCOM), now in its XVIII edition, is a biennial international conference on Mathematical Physics. Since its first edition organized in 1981, this meeting aimed at gathering Italian and foreign researchers interested in stability and wave propagation problems in continuous media. The meeting will encompass different fields concerning wave propagation, stability problems and modeling problems such as acceleration and shock waves, diffusion processes in biology and in continuum mechanics, kinetics models, irreversible thermodynamics, stochastic processes, group methods, numerical techniques.

Information: galileo.cincom.unical.it/wascom2015/index.html.

1–19 **Dynamics of Multi-Level Systems**, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany.

1–July 31 **Networks in Biological Sciences**, Institute for Mathematical Sciences, National University of Singapore, Singapore. (Oct. 2014, p. 1107)

This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found in the Meetings & Conferences Section of each issue.

An announcement will be published in the *Notices* if it contains a call for papers and specifies the place, date, subject (when applicable), and the speakers; a second announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in every third issue until it has been held. Asterisks (*) mark those announcements containing new or revised information.

In general, announcements of meetings and conferences carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. If there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editors of the *Notices* at notices@ams.org or mathcal@ams.org. In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **eight months** prior to the scheduled date of the meeting. **The complete listing** of the Mathematics Calendar will be published only in the September issue of the *Notices*. New information about meetings and conferences that will occur beyond the current twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the given twelve-month period. **The Mathematics Calendar,** as well as Meetings and Conferences of the AMS, is now available through the AMS website: www.ams.org/.

2–5 **Frontiers of Singular Integrals**, University of Helsinki, Helsinski, Finland.

3–6 **International Conference on Recent Advances in Pure and Applied Mathematics (ICRAPAM 2015)**, Istanbul Commerce University, Sutluce, Istanbul, Turkey.

4–5 **French-Japanese Workshop on Teichmüller Spaces and Surface-Mapping Class Groups**, Institut de Recherche Mathématique Avancée, University of Strasbourg, France.

4–6 **International Conference on Recent Advances in Mathematical Biology, Analysis and Applications**, Department of Applied Mathematics, Aligarh Muslim University, Aligarh, India.

5–10 **XVII-th International Conference on Geometry, Integrability and Quantization**, Sts. Constantine and Elena resort, Varna, Bulgaria.

* 6–7 **The Third Annual Conference for the Exchange of Mathematical Ideas**, University of Mary Washington, located in Fredericksburg, Virginia.
Description: This is a conference jointly organized by ERAU-Prescott, University of Mary Washington, and University of Northern Iowa. The aim of the annual conference is to improve communication among mathematicians in different specializations in order to enhance and stimulate their research. Talks are therefore expected to focus on a general introduction to the speaker's current research, major open problems, and its future prospective.
Information: `noetherian.net/conference`

* 7 **Asymptotics in Integrable Systems, Random Matrices and Random Processes and Universality**, Centre de recherches mathématiques, Université de Montréal, Montréal, Canada.
Description: The principal goal of Random Matrix Theory (RMT) is the description of the statistical properties of the eigenvalues or singular values of ensembles of matrices with random entries subject to some chosen distribution, in particular when the size of the matrix becomes very large.
Information: `www.crm.umontreal.ca/2015/Deift15/index_e.php`.

8–12 **AIM Workshop: Mathematical Aspects of Physics with Non-self-adjoint Operators**, American Institute of Mathematics, Palo Alto, California. (Aug. 2014, p. 797)

8–12 **International Conference on Applied Analysis and Mathematical Modelling (ICAAMM2015)**, Yildiz Technical University, Davutpasa Campus, Istanbul, Turkey.

8–12 **Real Analytic Geometry and Trajectories of Vector Fields**, CIRM, Marseille Luminy, France.

* 8–12 **Workshop on Strategic Behavior and Phase Transitions in Random and Complex Combinatorial Structures**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: Phase Transitions has been lately an active multidisciplinary field of research bringing together physicists, computer scientists and mathematicians. The main theme in this area of research is how atomic agents that act locally and microscopically lead to discontinuous macroscopic changes. This point of view has proved to be especially useful in studying the evolution of random and usually complex or large combinatorial objects (like networks or logic formulas) with respect to discontinuous changes in global parameters like connectivity, satisfiability, etc. There is, of course, an obvious strategic element in the formation of a transition: The atomic agents seek "selfishly" to optimize a local parameter. However, this game-theoretic aspect of abrupt, locally triggered changes has not been extensively studied until now. The aim of the workshop is to bring together researchers who study phase transitions in various disciplines together with game theorists towards formulating a common language.
Information: `www.crm.cat/en/Activities/Curs_2014-2015/Pages/Strategic-Behaviour.aspx`

8–12 **WSCG 2015 - 23rd Int.Conf. on Computer Graphics, Visualization and Computer Vision Workshop: Meshless Methods in Computer Science and Engineering**, Primavera Congress Center (`www.primaverahotel.cz/`) Plzen [Pilsen] close to Praha, Prague, Czech Republic.

9–11 **Elementary, Analytic, and Algorithmic Number Theory: Research Inspired by the Mathematics of Carl Pomerance**, University of Georgia, Athens, Georgia.

10 **2015 PIMS Marsden Memorial Lecture**, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland.

10–12 **IMA International Conference on Barriers and Enablers to Learning Maths**, University of Glasgow, Glasgow, Scotland.

10–12 **Western International Workshop on Harmonic Analysis and PDE**, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

* 10–14 **2015 Georgia Topology Conference**, University of Georgia, Athens, Georgia.
Description: The University of Georgia has been hosting the annual Georgia Topology Conference since 1961. This year's conference will focus on symplectic topology and dynamics. Financial support is available for the participation of graduate students and new PhD's working in related areas; please apply at the conference website.
Speakers: Erkao Bao (UCLA); Olguta Buse (IUPUI); Dan Cristofaro-Gardiner (Harvard); Jean Gutt (Berkeley); Kristen Hendricks (UCLA); Ailsa Keating (Columbia); Michael Khanevsky (Chicago); Tian-Jun Li (Minnesota); Samuel Lisi (Mississippi); Cheuk-Yu Mak (Minnesota); Mark McLean (Stony Brook); Jo Nelson (IAS/Barnard); Andres Pedroza (Colima); Mohammed Tehrani (Stony Brook); Weiwei Wu (Montreal)
Information: `alpha.math.uga.edu/~topology/`

11–15 **Tenth Panhellenic Logic Symposium**, University of Aegean, Samos, Greece.

13–14 **International Conference on Computer Science, Engineering and Innovations (ICCSEI 2015)**, Strand Palace Hotel London, 372 Strand, London, England.

14–18 **PDEs, Potential Theory and Function Spaces**, Linköping, Sweden.

14–19 **BIOMATH 2015: International Conference on Mathematical Methods and Models in Biosciences**, University Centre Bachinovo, South-West University, Blagoevgrad, Bulgaria.

14–21 **Fifty-third International Symposium on Functional Equations (53rd ISFE)**, Hotel Pegaz, Krynica-Zdrój, Poland.

* 15–17 **Boise Extravaganza in Set Theory (BEST) 2015**, San Francisco State University, San Francisco, California.
Description: BEST 2015 will be hosted at San Francisco State University as a symposium of the annual meeting of the American Association for the Advancement of Science—Pacific Division (AAAS-PD). Contributed and invited talks will be held on June 15, 16 and 17.
Confirmed Plenary Speakers: Dr. Rodrigo Dias, University of Sao Paulo, Brazil; Dr. Mirna Džamonja, East Anglia University, U.K.; Dr. Aleksandra Kwiatkowska, UCLA; Dr. Spencer Unger, UCLA; Dr. Trevor Wilson, UC Irvine.
Description: BEST 2015 offers NSF supported funding to assist participation of a number of student-, post-doc and pre-tenure faculty speakers. The AAAS-PD provides up to $150.00 in travel funding for students on a competitive basis. For details on applying for a travel grant and deadlines, please visit the conference website. The AAAS-PD offers several symposia and workshops of interest, organized an evening at the California Academy of Sciences on June 15, and hosts a student award banquet on June 16.
Information: `diamond.boisestate.edu/~best/`

15–18 **Progress on Difference Equations 2015**, University of Beira Interior, Covilh, Portugal.

15–18 Summer School, Mathematics in Savoie, MIS 2015 on "Evolution Equations: Long Time Behavior and Control", Departement Mathematics, Laboratoire de Mathématiques, Université de Savoie, Campus scientifique, Chambéry, France

15–19 Connections in Discrete Mathematics, Simon Fraser University, Vancouver, Canada. (Jun/Jul 2014, p. 668)

15–19 MEGA 2015: Effective Methods in Algebraic Geometry, University of Trento, Povo (Trento), Italy. (Oct. 2014, p. 1107)

15–19 Nordfjordeid Summer School 2015 "Lie Groups and Pseudogroups Actions: From Classical to Differential Invariants", Sophus Lie Conference Center, Norfjordeid, Norway.

15–19 Probability and Biological Evolution, CIRM, Marseille Luminy, France.

15–26 Geometric and Computational Spectral Theory–Séminaire de mathématiques supérieures, Centre de recherches mathématiques, Montréal, Québec, Canada.

15–26 Summer Graduate School — Geometric Group Theory, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2014, p. 1275)

17–18 International Conference on High Performance Computing and Emerging Technology (ICHPCET 2015), Strand Palace Hotel London, 372 Strand, London, England.

17–19 Espalia, "Sapienza" Università di Roma, Rome, Italy.

18–19 2nd IMA Conference on Mathematics in Finance, University of Manchester, Manchester, United Kingdom.

* **18–19 BARCSYN 2015**, Institut d'Estudis Catalans, Barcelona, Spain.
Description: Barcsyn is about bringing together researchers from computational, systems and cognitive neuroscience. Our goal is to provide a forum for lively discussion and promote active collaboration between Barcelona-based research groups, especially between theorists and experimentalists. This is the fourth annual Barcsyn conference. Each day we will have 8–10 brief oral presentations from local researchers, a poster session and a longer keynote lecture from a renowned researcher from abroad.
Information: www.crm.cat/en/Activities/Curs_2014–2015/Pages/BARCSYN–2015.aspx

20–27 Physics and Mathematics of Nonlinear Phenomena, Gallipoli, close to Lecce, South of Italy.

22–24 3rd International Conference on "Graph Modelling in Engineering", University of Bielsko-Biala, Bielsko-Biala, Poland. (Jun/Jul 2014, p. 668)

22–25 2015 Computer Aided Modeling, Simulation and Analysis (CAMSA), Banff, Canada.

* **22–25 15th Haifa Workshop on Interdisciplinary Applications of Graph Theory, Combinatorics, and Algorithms**, The Caesarea Rothschild Institute at the University of Haifa, Room 570, 5th Floor, Education Building, Mount Carmel, Haifa, Israel.
Invited Speakers (alphabetically ordered): Andreas Brandstadt (Institut für Informatik, Rostock, Germany); Michel Habib (LIAFA, University Paris Diderot, France); Asaf Shapira (Tel-Aviv University, Israel); Christian Sohler (Technische Universität Dortmund, Germany); Maya Stein (Universidad de Chile, Santiago, Chile); Shira Zerbib (Technion, Haifa, Israel).
Lecture: The 6th Uri Natan Peled Memorial Lecture will be given by: Andreas Brandstadt (Institut für Informatik, Rostock, Germany) Title: TBD
Deadline: Call for Papers: Deadline for submission is May 1, 2015.
Workshop Information: Submissions for contributed talks are invited for this year's workshop, which emphasizes the diversity of the use of combinatorial algorithms and graph theory in application areas. Examples of such areas of interest include:

Randomized Algorithms, Networking, Graph Algorithms, Internet Congestion and Patterns, Computational Biology, Applied Combinatorics, Web Applications, Geometric Graphs and Computation, Optimization, and Graph Theoretic Models. The workshop is nonarchival and has no proceedings; accepted abstracts will be available online. Papers that have been accepted to recent top international conferences are particularly welcome, and should be so indicated in the submission.
Important Dates: Submission Deadline: May 1, 2015; Notification: May 11, 2014; Workshop: June 22-25, 2014. Please submit abstracts (1-2 pages) to HaifaGraphWorkshop2015@gmail.com.
Special Session: On "Sign matrices and patterns: Theory and applications" is being planned. For information and proposals, please contact Felix Goldberg felix.goldberg@gmail.com.
Registration: The registration site will open shortly after Pesach. Please visit www.cri.haifa.ac.il.
Workshop Committee: Martin Charles Golumbic, general chair (University of Haifa, Israel), Gila Morgenstern, program chair (Sapir College, Israel), Jasine Babu (University of Haifa, Israel), Shlomi Dolev (Ben Gurion University, Israel), Fedor Fomin (University of Bergen, Norway), Mathew Francis (Indian Statistical Institute, Chennai, India), Alain Hertz (Ecole des HEC et École Polytechnique, Montréal, Canada), Gil Kalai (Hebrew University, Israel), Ilan Newman (University of Haifa, Israel) Seffi Naor (Technion, Israel), Gaia Nicosia (University Roma Tre, Italy), Deepak Rajendraprasad (University of Haifa, Israel), Edward Scheinerman (Johns Hopkins University, USA), Gyorgy Turan (University of Illinois at Chicago, USA), and Shira Zucker (Sapir College, Israel). For further inquiries, please contact the CRI coordinator: Mrs. Danielle Friedlander dfridl1@univ.haifa.ac.il. Tel: +972-4-8288337.

22–26 Arithmetic Geometry, Representation Theory and Applications, CIRM, Marseille Luminy, France.

22–26 Conference "Singular Landscapes", Celebrating Bernard Teissier's 70th Birthday, Centre Paul-Langevin, Aussois, France.

22–26 International conference "Dynamical Systems and Their Applications", Institute of Mathematics of National Academy of Sciences of Ukraine, Kiyv, Ukraine. (Sept. 2014, p. 985)

* **22–26 Mini-courses in Mathematical Analysis 2015**, University of Padova, Padova, Italy.
Description: Following a long standing tradition, the University of Padova, Italy is organizing the meeting "Mini-courses in Mathematical Analysis 2015." The program consists of four lecture courses delivered by invited speakers and a limited number of short communications. The meeting aims at introducing the participants to important current research fields in Mathematical Analysis. The meeting is particularly indicated not only to graduate students, postdocs and young researchers but also to well-established experts in Mathematical Analysis.
Information: minicourses.dmsa.unipd.it/

22–28 Intuitive Geometry–László Fejes Tóth Centennial (LFT100), Budapest, Hungary.

25 7th National Dyscalculia & MLD Conference, The Cumberland Hotel, London.

* **25–26 Interdisciplinary Workshop on Quantitative Finance**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: In this workshop we aim to bring together academic researchers and professionals from financial institutions interested in quantitative finance, to interact and to discuss. We wish to focus on the underlying mathematical models as well as in advanced numerical solution techniques used for pricing financial contracts and risk measurement. Quantitative finance concerns the application of mathematical methods to solve problems in finance. The tools and techniques to tackle these problems cover a wide spectrum of fields,

like stochastic analysis, numerical analysis, partial differential equations, statistics and econometrics.
Information: www.crm.cat/en/Activities/Curs_2014-2015/Pages/Quantitative-Finance.aspx

25–27 **Thirty-Second Annual Workshop in Geometric Topology**, Texas Christian University, Fort Worth, Texas.

26–July 1 **The Eighth Congress of Romanian Mathematicians**, University A.I. Cuza, Iasi, Romania.

* 28–July 3 **Seventh Conference of the Euro-American Consortium for Promoting the Application of Mathematics in Technical and Natural Sciences (AMiTaNS'15)**, Black-Sea resort of Albena, Bulgaria.
Description: The conference is traditionally organized by The Euro-American Consortium for Promotion of the Application of Mathematics in Technical and Natural Sciences and will be held in the five-star Flamingo Grand hotel in the Northern Bulgarian Black Sea resort of Albena. This year it is organized in cooperation with SIAM. The event will be scheduled in plenary and keynote lectures followed by special and contributed sessions. The accents of the conference will be on Mathematical Physics, Solitons and Transport Processes, Numerical Methods, Scientific Computing, Continuum Mechanics, Applied Analysis, Applied Physics, Biomathematics, which can be complemented by some specific topics in contributed special sessions.
Currently Confirmed Speakers: S. Yoshida (USA), A. Samsonov (Russia), V. Shaydurov (Russia), P. Minev (Canada), N. Kolev (Germany), V. Pukhnachev (Russia), P. Vabishchevich (Russia), P. Radeva (Spain), J. Su (USA), N. Papanicolaou (Cyprus).
Information: 2015.eac4amitans.eu

28–July 4 **CNRS-PAN Mathematics Summer Institute in Krakow**, Krakow, Poland.

28–July 4 **Global Dynamics in Hamiltonian Systems (GDHAM15) Conference**, Santuari de Núria, Girona, Spain.

28–July 4 **The Fifth International Mathematical Conference on Quasigroups and Loops—LOOPS 2015**, Faculty of Computer Science and Engineering, UKIM University, Congress Center, Ohrid, R. Macedonia.

29–July 2 **9th Annual International Conference on Mathematics & Statistics: Education & Applications**, Athens, Greece.

29–July 2 **VI Jaen Conference on Approximation Theory, Computer Aided Geometric Design, Numerical Methods and Applications**, Ubeda, Jaen, Spain.

* 29–July 3 **Advanced Course on Combinatorial Matrix Theory**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: Combinatorial matrix theory is a rich branch of matrix theory concerned with the interplay of combinatorics/graph theory and matrix theory/linear algebra. It's a two way street, with linear algebra providing a means to prove combinatorial theorems, and combinatorics providing more detailed and refined information in linear algebra. Moreover, combinatorial properties of matrices are studied based on qualitative rather than quantitative information, so that the ideas developed can provide consistent information about a model even when the data is incomplete or inaccurate. The theory behind qualitative methods can also contribute to the development of effective quantitative matrix methods. Particular topics lectured in this summer school will include sign pattern matrices, minimum rank and its distribution, boundary value problems on finite networks, the group inverse for the Laplacian matrix of a graph and bounds on the spectral radius of the Laplacian matrix.
Information: www.crm.cat/en/Activities/Curs_2014-2015/Pages/Combinatorial-Matrix-Theory.aspx

29–July 3 **Geometry and Symmetry**, University of Pannonia, Veszprém, Hungary.

* 29–July 3 **Joint STAMP Conference and 9th ICMAT International GMC Summer School on Symplectic Geometry, Classical Mechanics and Interactions with Spectral Theory**, La Cristalera, Miraflores de la Sierra, Madrid, Spain.
Description: The format of this year's edition is different because it is a joint activity with the STAMP program at ICMAT on Spectral Theory and Mathematical Physics. That is why the topics of this summer school focus on Symplectic Geometry, Classical Mechanics and Interactions with Spectral Theory. The school is oriented to young researchers, PhD and postdoctoral students in Mathematics, Physics and Engineering, in particular those interested in symplectic geometry and mathematical physics. This activity consists of three courses (4 hours 30 minutes each) and around ten talks (40 minutes each) by invited guests. The courses will present an up-to-date view of some fundamental issues in the above-mentioned areas and bring to the participants attention some open problems, in particular, problems related to applications. The confirmed speakers this year are: Florin Diacu (University of Victoria, Canada). Chris Woodward (Rutgers University, USA). And poster session for young researchers!
Information: gmcnet.webs.ull.es/?q=activity-detaill/1338.

29–July 3 **School of Biology for Students in Mathematics and Informatics**, CIRM, Marseille Luminy, France.

29–July 3 **School and Workshop on Group Representations in Dynamical Systems and Geometry**, CIRM, Marseille Luminy, France.

29–July 10 **PIMS Symposium on the Geometry and Topology of Manifolds**, University of British Columbia, Vancouver, BC, Canada.

29–July 10 **Summer Graduate School — Mathematical Topics in Systems Biology**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2014, p. 1276)

29–July 10 **Winter School 2015 on Algebra, Geometry and Physics**, The University of Queensland, Queensland, Australia.

July 2015

1–3 **The 2015 International Conference of Applied and Engineering Mathematics**, Imperial College London, London, United Kingdom.

5–12 **24th International Conference on Nearrings, Nearfields and Related Topics**, Manipal Institute of Technology, Manipal University Manipal - 576 104, Karnataka, India.

6–10 **10th IMACS Seminar on Monte Carlo Methods**, Johannes Kepler University Linz and Radon Institute for Computational and Applied Mathematics, Linz, Austria. (Oct. 2013, p. 1205)

6–10 **29th Journées Arithmétiques**, University of Debrecen, Debrecen, Hungary.

* 6–10 **AdS/CFT, self-adjoint extension and the resolution of cosmological singularities**, Centre de recherches mathématiques, Université de Montréal, Montréal, Canada.
Description: In the context of Einstein gravity coupled to matter satisfying fairly general energy conditions, cosmological singularities are unavoidable, as was proven by Hawking and Penrose many years ago. One of the hopes for superstring theory is that a solution to this problem may be found.
Information: www.crm.umontreal.ca/2015/Extension15/index_e.php.

6–10 **Classical and Quantum Hyperbolic Geometry and Topology/ Topologie et géométrie hyperbolique classique et Quantique**, Université Paris-Sud, Orsay, France. (Jun/Jul 2014, p. 668)

6–10 **Computational Geometric Topology in Arrangement Theory**, The Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, RI.

6–10 **Dynamics and Geometry in the Teichmüller Space**, CIRM, Marseille Luminy, France.

6-10 **Equadiff 2015**, Université Claude Bernard Lyon 1, Lyon, France. (Oct. 2014, p. 1107)

6-10 **GAP XIII Pohang "Derived Geometry"—Geometry and Physics**, IBS Center for Geometry and Physics, Pohang, South Korea.

* 6-10 **IdeaLab 2015: Inverse Problems and Uncertainty Quantification**, Institute for Computational and Experimental Research in Mathematics (ICERM) Providence, Rhode Island.
Description: Idea-Lab is a one-week program aimed at fifteen early career researchers (within five years of their PhD) that will focus on a topic at the frontier of research. Participants will be exposed to a problem whose solution may require broad perspectives and multiple areas of expertise. Senior researchers will introduce the topic in tutorials and lead discussions. The participants will break into teams to brainstorm ideas, comprehend the obstacles, and explore possible avenues towards a solution. The teams will be encouraged to develop a research program proposal. On the last day, they will present their ideas to one another and to a small panel of representatives from funding agencies for feedback and advice. IdeaLab applicants should be at an early stage of their post-PhD career. A CV, research statement, and two reference letters are required. Applications are being accepted via `Mathjobs.org` (search under "Brown University"). The selection committee will begin review on March 1, 2015.
Information: `icerm.brown.edu/idealab/2015/`.

6-10 **International Workshop on Operator Theory and Applications, IWOTA 2015**, Tbilisi, Georgia.

6-10 **Second International Conference New Trends in the Applications of Differential Equations in Sciences (NTADES2015)**, Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, Sofia, Bulgaria.

6-10 **Stochastics & Computational Finance 2015: From Academia to Industry**, Lisbon, Portugal.

* 6-10 **Workshop on Classical and Quantum Integrable Systems (CQIS-2015)**, Institute for High Energy Physics, Protvino, Russia.
Description: This workshop continues the series of seminars which took place in Protvino, Dubna and Chernogolovka in 2000–2012. The workshop is supposed to consist of morning sessions, with invited plenary talks aimed to a detailed presentation of results obtained on the frontiers of the field, and afternoon sessions with original research talks.
Conference Topics: 1. Integrable probability and asymptotic representation theory; 2. Integrable systems in supersymmetric gauge theories; 3. Cluster algebras; 4. Conformal field theory and AGT correspondence; 5. Integrable models, Bethe ansatz and quantum groups.
Information: `sites.google.com/site/cqis2015/`

6-12 **Summer School in Geometric Analysis**, Northwestern University, Evanston, Illinois.

6-17 **CIMPA School: Random processes and optimal configurations in analysis**, Buenos Aires, Argentina.

7-10 **Fourth Summer School on Quantum Ergodicity and Harmonic Analysis. Eigenfunction Estimates and Related Topics**, University of Marburg, Marburg, Germany.

7-23 **Graduate Summer School: Games and Contracts for Cyber-Physical Security**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

8-10 **SIAM Conference on Control and Its Applications (CT15)**, Maison de la Mutualit, Paris, France. (Jun/Jul 2014, p. 668)

* 10-11 **International Workshop on Differential Geometry-Foundations and Developments**, Sri Sathya Sai institute Of Higher Learning, Prasanthinilayam, A.P., India.
Description: The Department of Mathematics and Computer Science is conducting an international workshop: Foundations and Current Developments in Differential Geometry. The workshop will be devoted to the foundations, current developments and future prospects in various branches of mathematics and physics. The primary purpose is to inspire post-graduate students and researchers to get acquainted with topics and methodologies in differential geometry, and to get motivated towards pursuing research. A number of overview and expository lectures will be delivered by experts in areas such as curves and surfaces, and Riemannian, Lorentzian, Symplectic and Contact geometries.
Information: `www.sssihl.edu.in`

11-14 **Workshop on New Directions for the Tutte Polynomial: Extensions, Interrelations, and Applications**, Royal Holloway University of London, Egham, United Kingdom.

12-16 **VI Annual International Conference of the Georgian Mathematical Union**, Batumi, Georgia.

* 12-17 **3rd Conference on Finite Dimensional Integrable Systems in Geometry and Mathematical Physics (FDIS2015)**, Mathematical Research and Conference Center, Bedlewo, Poland.
Description: The aim of the conference is to bring together specialists in mathematics and mathematical physics to exchange experience and knowledge about the most recent developments in the field of finite dimensional integrable classical and quantum systems.
Topics: Integrability criteria and obstructions to integrability: topological obstructions, dynamical obstructions, differential Galois obstructions; Integrable geodesic flows and natural Hamiltonian systems; Integrable systems on Lie algebras and symmetric spaces; Symplectic and Poisson geometry and integrability; Superintegrability; Lax representations, separation of variables; Rigid body dynamics; Nonholonomic mechanics; Quantum integrability and quantization procedures; Applications of finite dimensional integrable systems in mathematical physics, celestial mechanics and general relativity; Computer algebra methods in the theory of integrable systems.
Information: `fdis2015.wfa.uz.zgora.pl`

* 12-17 **BIOMATH 2015-S**, University of Pretoria, Pretoria, South Africa.
Description: This is an international conference on Mathematical Methods and Models in Biosciences. It is a satellite conference to the conference Biomath 2015 (Bulgaria). The Biomath conferences are devoted to recent research in life sciences based on applications of mathematics as well as mathematics applied to or motivated by biological studies. It is a multidisciplinary meeting forum for researchers who develop and apply mathematical and computational tools to the study of phenomena in the broad fields of biology, ecology, medicine, biotechnology, bioengineering, environmental science, etc. The Satellite Conference is organized by the NRF/DST SARChI Chair in Mathematical Methods and Models in Bioengineering and Biosciences in the Department of Mathematics and Applied Mathematics.
Information: `www.biomath.bg/2015-s/`

12-17 **Integrability in Algebra, Geometry and Physics: New Trends**, Congressi Stefano Franscini, Ascona, Switzerland.

12-24 **Summer Graduate School — Gaps between Primes and Analytic Number Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2014, p. 1276)

* 13-17 **Beyond integrability: The mathematics and physics of integrability and its breaking in low-dimensional strongly correlated quantum phenomena**, Centre de recherches mathématiques, Université de Montréal, Montréal, Canada.
Description: Strongly correlated quantum phenomena in low dimensions are particularly challenging to understand. In one and two dimensions strong quantum fluctuations lead the fundamental constituents of matter to organize in novel, often unpredictable ways. Phenomena such as non-abelian statistics, spin-charge separation, quantum number fractionalization, and topological states of matter can arise. These new forms of matter cannot be studied with the

perturbative approaches commonly used to understand the physics of weakly interacting systems.

Information: www.crm.umontreal.ca/2015/Quantum15/index_e.php.

13-17 Computational and Analytical Aspects of Image Reconstruction, Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, Rhode Island. (Nov. 2014, p. 1276)

13-17 12th International Conference on Finite Fields and Their Applications (Fq12), Skidmore College, Saratoga Springs, New York. (Feb. 2014, p. 214)

13-17 Impact of Geometric Group Theory, CIRM, Marseille Luminy, France.

* **13-17 Lluís Santaló Summer School "Number Theory and Arithmetic Geometry"**, Palacio de la Magdalena, Santander, Spain.
Description: Co-organized by the "Menéndez Pelayo" University and the Royal Spanish Mathematical Society, this conference aims to give an introduction to several topics of current active research in the areas of number theory and arithmetic geometry. It consists of four courses by experts of the highest level in these topics: Pilar Bayer (University of Barcelona), Loïc Merel (University Paris VII), Philippe Michel (École Polytechnique Fédérale de Lausanne) and Lenny Taelman (University of Amsterdam). The school is targeted to graduate students and young postdoctoral researchers who work on number theory and related topics and, more generally, to researchers in mathematics interested in these topics.
Information: www.imus.us.es/SANTALO15/

* **13-24 Post-grad ASI in Mathematical and Physical Sciences: Modelling, Numerical Analysis and Applications (CGPW01)**, Isaac Newton Institute for Mathematical Science, University of Cambridge, Cambridge, United Kingdom.
Description: Cellular migration depicts one of the most vital processes for complex life formation and is a major origin for devastating diseases upon malfunction. While hundreds of different migratory relevant molecules have been identified over the past decades, underlying mechanisms for cell migration including cell morphology and protein complex formation are only insufficiently understood and rarely rendered into mathematical models using theoretical as well as numerical methods. In order to accomplish these important scientific needs we will develop new 2D and 3D mathematical models for cell migration driven by experimental observations. At the same time, theoretical predictions can result in the development of completely new theories allowing new experimental approaches as well as hypothetical testing and validation in experimental laboratories.
Deadline for Applications: April 8, 2015
Information: www.newton.ac.uk/event/cgpw01

13-31 AMS Summer Institute in Algebraic Geometry, University of Utah, Salt Lake City, Utah.

13-December 18 Coupling Geometric PDEs with Physics for Cell Morphology, Motility and Pattern Formation, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Mar. 2014, p. 318)

14-17 International Conference on Nonlinear Operators, Differential Equations and Applications, ICNODEA-2015, Babes-Bolyai University, Cluj-Napoca, Romania. (Aug. 2014, p. 797)

15-17 International Conference on Applied Statistics 2015, Pattaya, Thailand. **15-22 International Workshop, Groups and Rings, Theory and Applications (GRiTA2015)**, Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences, Sofia, Bulgaria.

* **19-24 Semigroups for Dynamical Systems: Perturbation, Positivity, Networks**, University of Wuppertal, Wuppertal, Germany

Description: A one-week intensive course in Wuppertal with lectures by: Klaus-Jochen Engel (L'Aquila), $A + BC$: Variations on a theme; (Marjeta Kramar Fijavž (Ljubljana), The semigroup approach to transport and diffusion in networks; Rainer Nagel (Tübingen), What can positivity do for evolution equations?
Prerequisites: Solid background in functional analysis and in the theory of one-parameter semigroup of linear operators.
Information: www.fan.uni-wuppertal.de/aktivitaeten/summer-school.html

19-24 Summer School on Transport, Fluid and Mixing, Levico Terme, Trento, Italy.

20-23 ACA 2015: Applications of Computer Algebra, Kalamata, Greece.

* **20-23 Workshop: O-Minimality and Applications**, University of Konstanz, Kostanz, Germany.
Description: This event will bring together researchers from model theory, real geometry, number theory and related areas in order to examine the latest developments in the field of o-minimality and its applications to diophantine problems, dynamical systems, differential equations, analysis and algebra.
Information: www.math.uni-konstanz.de/~thomas/oma2015/

20-24 Frontiers of Mathematics and Applications IV - UIMP 2015, Palacio de la Magdalena, 39005, Santander, Spain.

20-24 ISIPTA'2015: 9th International Symposium on Imprecise Probability: Theories and Applications, Sea Lion Hotel, Pescara, Italy.

* **20-24 Summer School on Nonlinear PDE's and Applications to Image Analysis. A scientific tribute to Vicent Caselles**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: This event is an homage to the memory and scientific legacy of Vicent Caselles, aiming at the interplay between Image Processing and advanced mathematical techniques.
Information: www.crm.cat/en/Activities/Curs_2014-2015/Pages/SSNLPDE.aspx

20-24 The 11th International Conference on Fixed Point Theory and its Applications, Galatasaray University, Istanbul, Turkey. (Dec. 2013, p. 1497)

20-August 4 XVIII Summer Diffiety School on Geometry of PDEs, Piccolo Hotel Tanamalia, Lizzano in Belvedere (BO), Italy.

20-August 7 PI Summer Graduate Program: Modern Harmonic Analysis and Applications, University of Maryland, College Park, Maryland.

20-August 14 Metric and Analytic Aspects of Moduli Spaces, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Mar. 2014, p. 318)

* **27-31 Positive Grassmannians: Applications to integrable systems and super Yang-Mills scattering amplitudes**, Centre de recherches mathématiques, Université de Montréal, Montréal, Canada
Description: The discovery of cluster algebras by Fomin and Zelevinsky was in large part motivated by the study of the phenomenon of total positivity in reductive Lie groups. Grassmannians were among the first examples of varieties that support a natural cluster structure, that was arrived at in two ways: combinatorial, using Postnikov's work on parametrizing totally nonnegative cells in Grassmannians using directed planar networks, and geometric, that utilized properties of Grassmannians as Poisson homogeneous spaces.
Information: www.crm.umontreal.ca/2015/Amplitudes15/index_e.php.

27-August 1 XVIII International Congress on Mathematical Physics, ICMP 2015, Pontificia Universidad Catolica de Chile, Santiago de Chile, RM, Chile.

27–August 2 **22nd IMC (International Mathematics Competition for University Students)**, American University in Bulgaria, Blagoevgrad, Bulgaria.

27–August 7 **Stochastic Analysis and Applications Mongolia 2015**, National University of Mongolia, Ulan Bator, Mongolia.

27–August 7 **Summer Graduate School — Incompressible Fluid Flows at High Reynolds Number**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2014, p. 1276)

* 28–31 **7th International Workshop on Differential Equations and Applications**, Yasar University, Izmir, Turkey.
Description: The scope of the conference is to bring together members of the mathematical community whose interest lies in applied mathematics to assess new developments, ideas and methods. The conference will cover a wide range of topics of differential equations, difference equations, dynamic equations and stochastic differential equations.
Information: wdea2015.yasar.edu.tr.

28–30 **Mathematics in Data Science-Exploring the Role of the Mathematical Sciences in an Evolving Discipline**, Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, Rhode Island.

August 2015

2–7 **The International Conference "Mathematical and Computational Modeling in Science and Technology" (ICMCMST'15)**, Izmir University, Izmir, Turkey.

3–7 **AIM Workshop: First Passage Percolation and Related Models**, American Institute of Mathematics, Palo Alto, California. (Aug. 2014, p. 797)

3–7 **Differential and Combinatorial Aspects of Singularities**, TU Kaiserslautern, Germany. (Aug. 2014, p. 797)

3–7 **The 3rd Strathmore International Mathematics Conference Theme: Exploring Mathematics and its Applications**, Strathmore University, Nairobi, Kenya. (Oct. 2014, p. 1107)

3–7 **Symmetries of Discrete Systems and Processes**, Decin, Czech Republic.

3–8 **Logic Colloquium 2015**, Helsinki, Finland.

* 3–14 **Hidden Symmetries and Integrability Methods in Super Yang-Mills Theories and Their Dual String Theories**, Centre de recherches mathématiques, Université de Montréal, Montréal, Canada.
Description: Much of our current understanding of nonperturbative dynamics of quantum field theories, and in particular of AdS/CFT duality, derives from the use of integrability methods. Quantum integrability methods were first used to obtain exact solutions of certain 1+1 dimensional quantum spin chains and Quantum Field Theories.
Information: www.crm.umontreal.ca/2015/Symmetries15/index_e.php.

4–6 **ICNHBAS [I] Current Trends in Mathematics & its Applications**, Hurghada, Egypt.

* 9–15 **The International Conference and PhD Summer School (Groups and Graphs, Algorithms and Automata)**, All scientific activities will take place in one of recreation centers near Yekaterinburg (Russia). Yekaterinburg, Russia.
Description: The organizers of the confernce are N. N. Krasovskii Institute of Mathematics and Mechanics of Ural Branch of Russian Academy of Sciences and Ural Federal University named after the first President of Russia, B. N. Yeltsin. The conference aims to cover all branches of group theory, graph theory, automata and formal language theory and algorithm theory. The scientific program will include Lectures of Main Speakers, Short Contributions in Sections, and Minicourses in the Frame of the PhD school. The official language of the conference is English.

Information: g2a2.imm.uran.ru/

10–11 **Global Summit and Expo on Multimedia & Applications**, Hilton Metropole, Birmingham, United Kingdom.

* 10–21 **IMMERSION 2015: Summer camps featuring Virtual Reality (VR) and Minecraft**, Boston College High School, Boston, Massachusetts.
Description: The Immersive Education Initiative has announced the opening of two new "Creative Computing" summer camps in Boston USA this August. Hosted by Boston College High School, and taught by Boston College faculty, the 1- and 2-week summer camps are open to K–12 students, home schools, and the general public. Registration is now open for camp dates August 10 to August 21. During the Creative Computing camps attendees will: 1) Use fun and easy visual programming tools to learn the fundamentals of coding as they explore logic and reasoning, mathematical thinking, and creative computing concepts, 2) Use Minecraft to develop logical thinking and problem solving skills while creatively expressing themselves through 3D artistry, design and architecture, and 3) Create their very own Virtual Reality (VR) headset to explore the fundamentals of immersive VR and 3D computer graphics. Participants are also eligible to compete in upcoming Minecraft "Builder Bowl" competitions that conclude with championship rounds during IMMERSION 2015.
Information: Camp participants are eligible to compete in upcoming Minecraft "Builder Bowl" competitions that conclude with the championship rounds during IMMERSION 2015 this September. Building on the success of the previous nine years of Immersive Education conferences, IMMERSION 2015 addresses the personal and cultural impact of immersive technologies such as virtual reality, augmented reality, holograms, cybernetics, 3D printing, robotics, game-based learning and training systems, and fully immersive environments such as caves and domes.
Speakers and Exhibitors at Immersive Education Events: IMMERSION 2015 have included faculty, researchers, staff, administrators and professionals from Harvard University (Harvard Graduate School of Education, Berkman Center for Internet and Society at Harvard Law School, and Harvard Kennedy School of Government), Massachusetts Institute of Technology (MIT), MIT Media Lab, UNESCO (United Nations Educational, Scientific and Cultural Organization), Federation of American Scientists (FAS), United States Department of Education, National Aeronautics and Space Administration (NASA), Smithsonian Institution, Stanford University, Cornell University, Duke University, Walt Disney Company, Google, Intel, Microsoft, Oracle, Turner Broadcasting, Gates Planetarium, Computerworld, Stratasys, The MOFET Institute (Israel), Keio University (Japan), National University of Singapore (NUS), Coventry University (UK), Giunti Labs (Italy) and European Learning Industry Group, University of Glasgow (UK), Open University (UK), Universidad Carlos III de Madrid (Spain), University of Oulu (Finland), Royal Institute of Technology (Sweden), École Nationale Supérieure des Arts Décoratifs (EnsAD; France), Interdisciplinary Center Herzliya (Israel), Graz University of Technology (Austria), University of West of Scotland (UK), University of Essex (UK), Universidad Complutense de Madrid (Spain), University of Vienna (Austria), Government of New South Wales (Australia), Eötvös Loránd Tudományegyetem (Hungary), Universidade Federal do Rio Grande do Sul (UFRGS; Brazil) and many more world-class organizations detailed at summit.ImmersiveEducation.org.
Press Contact: Barbara Mikolajczak, Immersive Education Initiative, ImmersiveEducation.org, barbara.miko@ImmersiveEducation.org, +1 (617) 997-1017
Information: Camp details and registration are available at ImmersiveEducation.org/camp

* 14–18 **Lie Algebras, Vertex Operator Algebras, and Related Topics. A conference in honor of J. Lepowsky and R. Wilson**, University of Notre Dame, Notre Dame, IN.

Description: This conference will focus on Lie algebras, vertex algebras, quantum groups, and related structures from several different perspectives (algebraic, combinatorial and geometric), with some emphasis given to those fields of mathematics in which Lepowsky and Wilson made significant contributions. It is partially supported by a grant from the National Science Foundation. Junior researchers, postdocs, graduate students and participants from underrepresented groups will be given priority in funding. For registration deadline and information about accommodation etc. please refer to the website of the conference. For additional information or questions please contact Katrina Barron at kbarron@nd.edu; or any of the organizers.
Organizers: Katrina Barron (Chair), University of Notre Dame; Elizabeth Jurisich, College of Charleston; Haisheng Li, Rutgers University at Camden; Antun Milas, SUNY at Albany; Kailash C. Misra, North Carolina State University.
Information: www3.nd.edu/~conf/LieConf15/

16–18 **Mathematics for Nonlinear Phenomena: Analysis and Computation - International Conference in Honor of Professor Yoshikazu Giga on his Sixtieth Birthday**, Sapporo Convention Center, Sapporo, Japan.

* 17–19 **Stochastic Calculus and Applications Special Session MCSI–2015**, Sliema, Malta.

Description: CALL FOR PAPERS SPECIAL SESSION Stochastic Calculus and Applications
Organizer: Mounir Zili; Department of Mathematics, Faculty of sciences of Monastir, University of Monastir, Tunisia.
Aim: Stochastic calculus is a branch of mathematics that operates on stochastic processes. It focuses on analyzing and presenting solutions for a wide range of stochastic problems in engineering, hydrology, geology, biology, physics, economy and finance. The aim of this session is to bring together researchers and students from all over the world to exchange and share their experiences and research results about all aspects of Stochastic Calculus, and discuss the practical challenges encountered and the solutions adopted. Topics: Stochastic processes (Numerical, statistical and theoretical studies) Stochastic differential Equations, Modelling and applications.
Information: mcsi-conf.org/specialsession1.html

17–20 **The 8th International Conference on Lattice Path Combinatorics and Applications**, California State Polytechnic University, Pomona (Cal Poly Pomona), Pomona, California.

17–21 **AIM Workshop: Degenerations in algebraic geometry**, American Institute of Mathematics, San Jose, California.

17–21 **Combinatorial Constructions in Topology**, University of Regina, Regina, Saskatchewan, Canada.

17–21 **20th International Summer School on Global Analysis and Applications "General Relativity: 100 Years After Hilbert"**, Stara Lesna, High Tatras, Slovakia.

* 17–December 18 **New Challenges in PDE: Deterministic Dynamics and Randomness in High and Infinite Dimensional Systems (NCP)**, Mathematical Sciences Research Institute, Berkeley, CA
Description: The fundamental aim of this program is to bring together a core group of mathematicians from the general communities of nonlinear dispersive and stochastic partial differential equations whose research contains an underlying and unifying problem: quantitatively analyzing the dynamics of solutions arising from the flows generated by deterministic and non-deterministic evolution differential equations, or dynamical evolution of large physical systems, and in various regimes. In recent years there has been spectacular progress within both communities in the understanding of this common problem. The main efforts exercised, so far mostly in parallel, have generated an incredible number of deep results, that are not just beautiful mathematically, but are also important to

understand the complex natural phenomena around us. Yet, many open questions and challenges remain ahead of us. Hosting the proposed program at MSRI would be the most effective venue to explore the specific questions at the core of the unifying theme and to have a focused and open exchange of ideas, connections and mathematical tools leading to potential new paradigms. This special program will undoubtedly produce new and fundamental results in both areas, and possibly be the start of a new generation of researchers comfortable on both languages.
Information: www.msri.org/programs/287

18–21 **The 7th SEAMS-UGM 2015 International Conference on Mathematics and Its Applications**, Universitas Gadjah Mada, Yogyakarta, Indonesia.

* 19–21 **The 40th Sapporo Symposium on Partial Differential Equations**, Room 310, Faculty of Science Building #7, Hokkaido University, Sapporo, Hokkaido, Japan.
Description: The Sapporo Symposium on Partial Differential Equations has been held annually to present the latest developments on partial differential equations (PDE). The aim of the symposium is to help boost interaction and in-depth discussion among researchers working in mathematics, not limited to different branches of PDE.
Organizers: S. Ei (Hokkaido University), H. Takaoka (Hokkaido University). Program Committee: S. Ei (Hokkaido University), Y. Giga (The University of Tokyo), S. Jimbo (Hokkaido University), H. Kubo (Hokkaido University), T. Ozawa (Waseda University), T. Sakajo (Kyoto University), H. Takaoka (Hokkaido University), Y. Tonegawa (Tokyo Institute of Technology), K. Tsutaya (Hirosaki University) Contact (Symposium Secretariat): cri@math.sci.hokudai.ac.jp.
Information: www.math.sci.hokudai.ac.jp/sympo/sapporo/program150819_en.html

19–21 **Connections for Women: Dispersive and Stochastic Processes**, Mathematical Sciences Research Institute, Berkeley, California.

19–December 18 **Mathematical, Foundational and Computational Aspects of the Higher Infinite**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Sept. 2014, p. 987)

24–27 **11th International Symposium on Geometric Function Theory and Applications**, Congress Centre of Ss. Cyril and Methodius University, Ohrid, Republic of Macedonia.

24–28 **AIM Workshop: Mathematics inspired by immuno-epidemiology**, American Institute of Mathematics, San Jose, California.

24–28 **Introductory Workshop: Randomness and long time dynamics in nonlinear evolution differential equations**, Mathematical Sciences Research Institute, Berkeley, California.

* 24–28 K**-Theory,** $C*$**-Algebras and Topology of Manifolds III**, Harbin Institute of Technology, Harbin, China.
Description: This is the third conference of the series organized by Chern Institute of Mathematics (Nankai University, Tianjin) and Moscow State University. The two first conferences were held in Tianjin in 2009 and 2012.
Main Topics: $C*$-algebras, algebraic and topological K-theory, index theory, geometric group theory and group $C*$-algebras, noncommutative geometry and topology, pseudodifferential operators on singular manifolds, topological invariants of non-simply connected manifolds, deformation quantization.
Information: mech.math.msu.su/~manuilov/Harbin2015.html.

25–27 **7th International Conference on Research and Education in Mathematics (ICREM7)**, Kuala Lumpur, Malaysia.

* 25–28 **46th Annual Iranian Mathematics Conference**, Yazd University, Yazd, Iran.
Description: The Annual Iranian Mathematics Conference has been held since 1970. It is the oldest scientific gathering which takes

place regularly each year at one of Iranian universities. The 36th annual Iranian mathematics conference was held at Yazd University and now we are pleased to organize the 46th conference. The conference will provide a forum for mathematicians worldwide and scholar students to present their latest results about all aspects of pure and applied mathematics and a means to discuss their recent researches with each other. Interested scientists are warmly invited to propose their new ideas and recent researches for enhancing the scientific level of the conference. The language of the presentation may be English or Persian. We look forward to meeting you in the most beautiful and historical city of Iran, that is Yazd.
Information: `confs.yazd.ac.ir/AIMC46/?lang=2`

25–28 **International Conference on Pure and Applied Mathematics (ICPAM-2015)**, Department of Mathematics, Faculty of Sciences, Yuzuncu Yil University Kampus, 65080 Van, Turkey.

26–30 **Algebraic Combinatorics and Applications**, Michigan Technological University, Houghton, Michigan 49931.

27–29 **The 5th International Conference on Control and Optimization with Industrial Applications**, Baku, Azerbaijan.

* 30–September 4 **Mostly Markov Mixing**, Technion-Israel Institute of Technology, Haifa, Israel.
Description: The first four days of this event will constitute a workshop geared for graduate students (and post-docs and gutsy undergraduates). There will be three mini-courses, given by Persi Diaconis, Yuval Peres and Laurent Saloff-Coste, as well as several lectures by Pietro Caputo, Elchanan Mossel and Perla Sousi. The last day and a half will constitute a short research conference. It is expected that the students will remain for this.
Information: `www.math.technion.ac.il/Site/events/EvntOffices/view.php?oid=104`

31–September 3 **Finiteness Conditions in Topology and Algebra**, Queen's University, Belfast, United Kingdom.

31–September 3 **4th International Eurasian Conference on Mathematical Sciences and Applications (IECMSA-2015)**, President hotel, Athens, Greece.

31–September 4 **Conference on Topology, Geometry and Dynamics in Honour of François Lalonde**, Centre de recherches mathématiques, Université de Montréal Pavillon André-Aisenstadt 2920, Chemin de la tour, 5th floor, Montréal, Québec H3T 1J4, Canada.

31–September 4 **Cohomological Methods in the Theory of Algebraic Groups**, CIRM, Marseille Luminy, France.

31–September 4 **MathCompEPI 2015 International Conference on "Mathematical and Computational Epidemiology of Infectious diseases" the Interplay Between Models and Public Health Policies**, "Ettore Majorana Centre for Scientific Culture", Erice, Sicily, Italy.

31–September 4 **Numerical Methods for Large-Scale Nonlinear Problems and Their Applications**, The Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, RI.

September 2015

1–August 31 **Call for Research Programmes 2015-2016**, Centre de Recerca Matematica, Bellaterra, Barcelona, Spain. (Sept. 2014, p. 987)

1–4 **IMA Conference on Numerical Methods for Simulation**, Mathematical Institute, University of Oxford, UK. (Aug. 2014, p. 797)

* 6–19 **School and Conference: Analytic, Algebraic and Geometric Aspects of Differential Equations**, Mathematical Research and Conference Center, Bedlewo, Poland.
Description: The overall goal of the school and conference is to bring together the leading experts in the theory of differential and difference equations in the complex domain from different countries, to tackle and find approaches to open problems in the field,

exchange recent research results, learn new methods in the related areas (which is invaluable for young researchers) and identify new topics for future research.
Information: `bcc.impan.pl/15AAGA/`

* 7–9 **30th British Topology Meeting**, Pure Mathematics Research Centre, School of Mathematics and Physics, Queen's University Belfast, UK.
Description: The 30th British Topology Meeting, BTM30, will take place in the Pure Mathematics Research Centre of Queen's University Belfast, from Monday, September 7, to Wednesday, September 9, 2015.
List of Speakers: Carles Casacuberta (Barcelona, Spain), Eva Maria Feichtner (Bremen, Germany) and Andrew Tonks (Leicester, UK).
Main Focus: The meeting will be homotopy theory and its links to other areas such as geometry, combinatorics, higher category theory and homology. The meeting is supported by Queen's University Belfast and a conference grant of the London Mathematical Society.
Organisers: David Barnes and Thomas Huettemann
Information: `www.qub.ac.uk/puremaths/btm30/home.html`

7–11 **Additive Combinatorics in Marseille**, CIRM, Marseille Luminy, France.

7–11 **The Cauchy Problem in Kinetic Theory: Recent Progress in Collisionless Models**, Imperial College, London, United Kingdom.

7–11 **First Joint International Meeting of the Israel Mathematical Union and the Mexican Mathematical Society**, Instituto Tecnológico de Oaxaca, Oaxaca, Mexico.

7–11 **Workshop in Nonlinear PDEs**, Université libre de Bruxelles, Brussels, Belgium.

7–12 **Manifolds and Groups**, Ventotene (LT), Italy.

8–13 **International Conference on "Mathematical Analysis, Differential Equations and Their Applications" (MADEA 7)**, Baku, Azerbaijan.

8–December 11 **New Directions in Mathematical Approaches for Traffic Flow Management**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

9–11 **IMA Conference on Mathematics of Robotics**, St. Anne's College, Oxford, United Kingdom. (Sept. 2014, p. 987)

9–December 4 **ICERM Semester Program: Computational Aspects of the Langlands Program**, Brown University, Providence, Rhode Island. (Jun/Jul 2014, p. 669)

12–18 **International Conference "Harmonic Analysis and Approximations, VI"**, Tsaghkadzor, Armenia.

* 14–16 **Conference on D-modules and singularities**, Dipartimento di Matematica, Università di Padova, Padova, Italy.
Description: We are pleased to announce a conference "D-modules and singularities".
Invited Speakers: Tomoyuki Abe (University of Tokyo); *Alberto Castaño; Domínguez (TU Chemnitz); Valentina di Proietto (Freie Universität Berlin); María Cruz, Fernández Fernández (Universidad de Sevilla); Javier Fresan (ETH Zürich); Marco Hien (Universität Augsburg); Naofumi Honda (Hokkaido University); Thomas Krämer (École Polytechnique); Claude Sabbah (École Polytechnique); Christian Schnell (Stony Brook University); *Kiyoshi Takeuchi (Tsukuba University); Jean-Baptiste Teyssier (Freie Universität Berlin, Germany); *= to be confirmed.
Organizers: Andrea D'Agnolo, Francisco Jesús Castro Jimenez, Teresa Monteiro Fernandes, Luis Narvaez Macarro
Local Scientific Committee: Francesco Bottacin, Corrado Marastoni, Giovanni Morando, Pietro Polesello, Luca Prelli. For any questions, please contact the organizers: d-mod@math.unipd.it.
Information: `events.math.unipd.it/d-modules-and-singularities`

14–16 **International Conference on Signal Processing**, Embassy Suites Las Vegas; 4315 Swenson Street, Las Vegas, Nevada.

* 14–18 **AdS/CFT and Quantum Gravity**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal, Canada.

Description: Over the last fifteen years, our understanding of quantum gravity in string theory has been transformed by the discovery and exploitation of D-branes and the AdS/CFT correspondence in string theory. Many problems that were thought insuperably difficult have been solved, at least partially: (i) the entropy and thermodynamic properties of many extremal and near-extremal black holes have been precisely explained in terms of microscopic degrees of freedom, (ii) light has been shed on the physics of spacetime singularities, (iii) the holographic principle, positing massive reduction of the degrees of freedom in quantum gravity, has been understood precisely in spacetimes with a negative cosmological constant via a duality between gravity and gauge theory. This program of research has been so successful that it is now being used as a tool to shed light on otherwise intractable problems involving strongly coupled systems in other fields of physics.

Information: www.crm.umontreal.ca/2015/Gravity15/index_e.php.

* 14–18 **Cell Mechanics, Morphogenetics and Pattern Formation: Perspectives from the experimental and theoretical points of view (CGPW02)**, Isaac Newton Institute for Mathematical Sciences, University of Cambridge, Cambridge, UK.

Description: The mechanical characterisation of individual cells is complex and dynamic. Nonetheless, great progress has been made in understanding how the dynamics of subcellular structures leads to cell shape and motility. Static tissues have also been well characterised. It is at the level of morphogenesis where the bridging of scales between individual cell dynamics and tissue dynamics is least understood. This workshop aims to (1) present a framework for understanding what is already known about cell-level and tissue-level mechanics, (2) identify gaps in our understanding of how cells interact mechanically in tissues in order to actuate morphogenesis, (3) propose new collaborations to increase our understanding of the cell-tissue emergent dynamics. We will bring together experts in development, microscopy, image analysis, biomechanics, and modeling.

Information: www.newton.ac.uk/event/cgpw02

14–18 **GAGTA-9: Geometric, Asymptotic and Combinatorial Group Theory and Applications**, CIRM, Marseille Luminy, France.

* 14–18 **GraVisMa: Computer Graphics, Vision and Mathematics**, Primavera Congress Center (www.primaverahotel.cz) Plzen (The European City of Culture 2015), close to Prague (The Golden European City), Czech Republic.

Description: GraVisMa submissions are expected in all areas related to Computer Graphics, Visualization, Computer Vision and Mathematics related to (but not limited to) Projective Geometry, Geometrical Algebra, Conformal Geometry and its applications to "Computer Science fields". Mathematics: Numerical Computation, Geometry, Interpolation and Approximation, Meshless (meshfree) methods, Projective Geometry, Geometric Algebra, Conformal Algebra, Grassmann & Clifford Algebra, Other Mathematical Aspects, Influence Mathematics to Computer Science; Computer Science: Computer Graphics, Computer Vision, Algorithms and Data Structures, Human Computer Interaction, 3D Vision, 3DTV, Scientific and Medical Visualization, Image Processing, Scientific Computing, Parallel and Distributed Computing, Interesting applications: Computer Science inspiration to Mathematics Educational Aspects, History of Mathematics and Computer Science.

Information: www.GraVisMa.eu

14–18 **GraVisMa 2015: Computer Graphics, Visualization and Mathematics Workshop: Meshless Methods in Computer Science,** Engineering and Mathematics, Primavera Congress Center (www.primaverahotel.cz), Plzen [Pilsen], close to Praha, Prague, Czech Republic.

14–18 **The European Numerical Mathematics and Advanced Applications (ENUMATH) Conference**, Institute of Applied Mathematics, Middle East Technical University, Ankara, Turkey. (Dec. 2013, p. 1497)

14–18 **The Seventh Symposium on Nonlinear Analysis**, Faculty of Mathematics and Computer Sciences, Nicolaus Copernicus University, Toruń, Poland.

16–21 **13th International Conference of The Mathematics Education for the Future Project: Mathematics Education in a Connected World**, Grand Hotel Baia Verde, Catania, Sicily, Italy.

* 17–20 **The 8th edition of ICTAMI - International Conference on Theory and Applications in Mathematics and Informatics**, "1 Decembrie 1918" University of Alba Iulia, Alba Iulia, Romania.

Description: The aim of the conference is to bring together mathematicians and informaticians from all over the world and to attract original papers on the following topics: Topics in Operator Algebras, Algebraic Geometry and Algebraic Number Theory, Complex Analysis and Operator Theory, Differential Equations and Optimal Control, Probability and Statistics in Mathematical Modeling, Advances in the Theory and Applications of Computer Science, Artificial Intelligence, Product and Process Modeling-Embedded Systems, Knowledge Engineering.

Inforation: www.uab.ro/ictami

* 17–20 **The 23rd Conference on Applied and Industrial Mathematics CAIM 2015**, `Stefan cel Mare University', Suceava, Romania.

Description: The 23-rd Annual Conference of ROMAI, the Romanian Society of Applied and Industrial Mathematics, has the following sections: 1. Real, Complex, Functional and Numerical Analysis, 2. Partial Differential Equations with applications in Mechanics, Biology, etc., 3. Ordinary Differential Equations; Dynamical Systems, 4. Probability Theory, Mathematical Statistics, Operation Research, 5. Algebra, Logic, Geometry (with applications), 6. Mathematical Modeling, 7. Computer Science, 8. Education.

Information: www.romai.ro/conferintele_romai/caim2015_en.html

17–19 **The 96th Encounter Between Mathematicians and Theoretical Physicists: Geometry and Biophysics**, University of Strasbourg, Strasbourg, France.

18–20 **LMS-EMS Mathematical Weekend**, Birmingham University, Edgbaston Campus, Birmingham, United Kingdom.

18–20 **Workshop on Geometrical Analysis Dedicated to the 60th Birthday of Jan Maly**, Charles University, Prague, Czech Republic.

21–25 **AIM Workshop: Geometric flows and Riemannian geometry**, American Institute of Mathematics, San Jose, California.

21–25 **Elliptic Methods and Moduli Spaces**, CIRM, Marseille Luminy, France.

21–26 **International Conference in Mathematics Education**, Catania, Sicily, Italy. (Aug. 2014, p. 797)

21–26 **Master-Class on Finsler Geometry and Applications to Low-Dimensional Geometry and Topology and Moduli Spaces**, University of Cagliari, Sardinia, Italy.

27–October 2 **Mathematical Foundations of Traffic**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, CA.

28–October 2 **Frontiers of Operator Dynamics**, CIRM, Marseille Luminy, France.

28–October 3 **Semester Workshop: Modular Forms and Curves of Low Genus: Computational Aspects**, Institute for Computational

and Experimental Research in Mathematics (ICERM) at Brown University, Providence, Rhode Island.

* 29–October 1 **Workshop on Analysis and PDE**, Leibniz University Hannover, Hannover, Germany.
Description: This three-day workshop aims to bring together experts working on elliptic and parabolic equations, singular analysis, and geometric aspects of pdes. Limited support for young researchers is available. For further information see the workshop's website.
Main Speakers: Ugo Boscain, Eduard Feireisl, Kenro Furutani, Patrick Guidotti, Colin Guillarmou, Matthias Hieber, Matthieu Hillairet, Chisato Iwasaki, Rafe Mazzeo (tbc), Felix Otto, Gieri Simonett, Alexander Strohmaier, Tobias Weth, Jared Wunsch.
Information: www.math-conf.uni-hannover.de/anapde15

October 2015

3–4 **Central Fall Sectional Meeting**, Loyola University Chicago, Chicago, Illinois.

5–9 **Digital Humanities: Critical Edition of Diderot and D'Alembert's Encyclopedia**, CIRM, Marseille Luminy, France.

6–8 **Conference on Agricultural Statistics 2015**, Sarawak, Malaysia.

9–11 **Symposium on Biomathematics and Ecology: Education and Research (BEER-2015)**, Illinois State University, Normal, Illinois.

10–11 **35th Annual Southeastern-Atlantic Regional Conference on Differential Equations (SEARCDE 2015)**, The University of North Carolina at Greensboro, Greensboro, North Carolina.

12–14 **SIAM Conference on Geometric and Physical Modeling (GDSPM15)**, Sheraton Salt Lake City Hotel, Salt Lake City, Utah.

12–16 **Ordered Algebraic Structures and Related Topics**, CIRM, Marseille Luminy, France.

12–16 **Workshop II: Traffic Estimation**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

14–16 **International Conference "Stochastic Processes in Abstract Spaces"**, Taras Shevchenko National University of Kyiv; Institute of Mathematics, National Academy of Sciences of Ukraine; National Technical University of Ukraine "Kyiv Polytechnic Institute", Kyiv, Ukraine. See: matfiz.univ.kiev.ua/cmf2015

17–18 **Fall Southeastern Sectional Meeting**, University of Memphis, Memphis, Tennessee.

18–24 **Workshop on Almost Hermitian and Contact Geometry**, International Mathematics Conference Center in Bedlewo, near Poznan, Poland.

* 19–23 **Applications of AdS/CFT to QCD and Condensed Matter Physics**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal, Canada.
Description: One of the most important problems in mathematical physics is the study of strongly coupled field theories of the sort we use to describe the strong interactions (QCD) and condensed matter systems (CMT). Theorists have very few tools at their disposal, each of which accompanied by its attendant limitations. Perturbative (i.e., weak coupling) computations can probe a large part of the parameter space of QCD. However, these results are valid only at temperatures well above the deconfinement temperature, and at large values of the baryon number chemical potential μ in order for the QCD coupling to be small, and thus the perturbation theory valid. These exclusions limit the applicability to regions of parameter space explored in heavy ion collisions at RHIC and LHC.
Information: www.crm.umontreal.ca/2015/Applications15/index_e.php.

19–23 **Whitney Problems Workshop**, CIRM, Marseille Luminy, France.

19–24 **Semester Workshop: Explicit Methods for Modularity of K3 Surfaces and Other Higher Weight Motives**, Institute for Computational and Experimental Research in Mathematics (ICERM) at Brown University, Providence, Rhode Island.

19–30 **New challenges in PDE: Deterministic dynamics and randomness in high and infinite dimensional systems**, Mathematical Sciences Research Institute, Berkeley, California.

21–23 **International Conference in Modeling Health Advances 2015**, UC Berkeley, San Francisco Bay Area, California.

24–25 **Fall Western Sectional Meeting**, California State University, Fullerton, Fullerton, California.

26–30 **Moduli Spaces in Geometry**, CIRM, Marseille Luminy, France.

26–30 **Traffic Control**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, CA.

November 2015

2–5 **International Conference on Coding and Cryptography**, USTHB, University of Algiers, Algiers, Algeria.

2–6 **Conference in Noncommutative Geometry**, CIRM, Marseille Luminy, France.

* 3–5 **International Conference on Mathematical Modeling and Operations Research (ICMMOR 2015)**, X-Consultancy Organization - Online Conference, Sacramento, CA
Description: ICMMOR 2015 is inviting high quality, original papers that contribute (but not limited) to methodology and application of mathematical modeling, operations research, Statistics, Statistical Modeling, Optimization and to the practice of engineering, Simulation, modeling, Management and decision making. The papers are classified but not limited to one of the following headings:
　1. Applied Mathematics, Operations Research, Numerical Methods
　2. Applied Statistics, Survey Analysis
　3. Production, Manufacturing and Logistics
　4. Stochastic Processes, Simulation and Decision Support
　5. Mathematics and Statistics for Management & Engineering
　6. Interfaces with other disciplines.
Information: www.xconsultancy.org/ICMMOR.php

3–10 **SEAMS school: Algebras and Their Applications (Quantum Physics, Cryptography and Statistics)**, Institute for Mathematical Research, Universiti Putra, Malaysia.

5–7 **The 14th International Conference on Mathematics and its Applications-Icma 2015. Workshop on Mathematical Methods in Quantum Information Theory. Workshop on Dynamical Systems and their Application**, Department of Mathematics, Politehnica University of Timisoara, Romania.

9–13 **Controllability of Partial Differential Equations and Applications**, CIRM, Marseille Luminy, France.

9–13 **Semester Workshop: Computational Aspects of L-functions**, Institute for Computational and Experimental Research in Mathematics (ICERM) at Brown University, Providence, Rhode Island.

14–15 **Fall Eastern Sectional Meeting**, Rutgers University, New Brunswick, New Jersey.

16–20 **Decision Support for Traffic**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

16–December 25 **Stochastic Methods in Game Theory**, Institute for Mathematical Sciences, National University of Singapore, Singapore.

23–27 **Algebraic Geometry and Complex Geometry**, CIRM, Marseille Luminy, France.

26 **4th IMA Conference on Mathematics in Defence**, Satellite Applications Catapult, Harwell, Oxford, United Kingdom.

30–December 4 **AIM Workshop: Automorphic kernel functions**, American Institute of Mathematics, San Jose, California.

December 2015

1–5 **BioInfoSummer 2015: Summer Symposium in Bioinformatics**, Monash University (Caufield Campus), Melbourne, Australia. (Jun/Jul 2014, p. 669)

3–4 **Workshop on Integrable Systems**, School of Mathematics and Statistics, University of Sydney NSW, Australia.

6–11 **71st Annual Deming Conference on Applied Statistics**, Tropicana, Atlantic City, New Jersey.

7–11 **39th Australasian Conference on Combinatorial Mathematics and Combinatorial Computing**, The University of Queensland, Brisbane, Australia.

* 7–11 **New Mathematical and Computational Problems involved in Cell Motility, Morphogenesis and Pattern Formation (CGPW04)**, Isaac Newton Institute for Mathematical Sciences, University of Cambridge, Cambridge, UK.
Description: Cell motility, morphogenesis, and pattern formation are essential features of cell dynamics. The involved biochemical processes and biomechanical properties range from the intracellular level over cell surface dynamics, cell-cell and cell-tissue interactions up to the scale of cell population behaviour influencing organ formation and functioning. Mathematical models handling biological events taking place on one or several such scales can provide a powerful framework to understand these phenomena, test experimentally suggested conjectures, and make predictions about the behaviour of the studied system. Current modelling approaches are often continuous, involving systems of partial differential equations of various kinds (e.g., reaction-diffusion-transport, taxis, kinetic transport, population balance), possibly coupled to ordinary, random, or stochastic differential equations. For full description, see the website.
Information: www.newton.ac.uk/event/cgpw04

7–11 **Present Challenges of Mathematics in Oncology and Biology of Cancer**, CIRM, Marseille Luminy, France.

10–13 **Quasiweekend II - Ten Years After**, Helsinki, Finland.

13–15 **The 4th International Conference on Electrical Engineering**, Boumerdés, Algeria.

* 14–16 **International conference "Relativity and Geometry" in memory of André Lichnerowicz**, Institut Henri Poincaré, Paris, France.
Description: This conference, to celebrate the centenary of Lichnerowicz's birth, will conclude the trimester on "Mathematical General Relativity" organized at the Centre Emile Borel of the Institut Henri Poincaré. The lectures will present recent advances in Relativity, Riemannian and Poisson geometry, and quantization. A poster session for young researchers (doctoral students and post-docs) will be organized. Deadline for submissions: September 1, 2015.
Preliminary List of Speakers: Robert Bryant (Duke University), Pierre Cartier (I.H.E.S.), Thibault Damour (I.H.E.S.), Simon Donaldson (SUNY at Stony Brook & Imperial College), Michel Dubois-Violette (Université Paris-Sud), Jim Eisenberg (University of Oregon), Edward Frenkel (UC Berkeley), Simone Gutt (ULB), Sergiu Klainerman (Princeton University), Maxim Kontsevich (I.H.E.S.), Alan Weinstein (UC Berkeley).
Scientific Committee: Jean-Pierre Bourguignon (Chair); Michel Cahen, Yvonne Choquet-Bruhat, Ludwig Faddeev, Philippe G. LeFloch, Charles-Michel Marle, Giuseppe Marmo, Andrzej Trautman, Joseph Wolf.

Organizing Committee: Giuseppe Dito, Jean-Pierre Françoise, Paul Gauduchon, Richard Kerner, Yvette Kosmann-Schwarzbach, Daniel Sternheimer.
Information: monge.u-bourgogne.fr/gdito/lichnerowicz2015

14–17 **Geometric Aspects on Capillary Problems and Related Topics**, Granada, Spain.

14–18 **Geometric and Categorical Representation Theory**, Sunshine Coast, Australia.

14–18 **Semiclassical Analysis and Non-self-adjoint Operators**, CIRM, Marseille Luminy, France.

* 15–17 **15th IMA International Conference on Cryptography and Coding**, St. Catherine's College, University of Oxford, Oxford, UK.
Description: The mathematical theory and practice of cryptography and coding underpins the provision of effective security and reliability for data communication, processing and storage. Theoretical and practical advances in the fields of cryptography and coding are therefore a key factor in facilitating the growth of data communications and data networks of various types. Thus, this fifteenth International Conference in an established and successful IMA series on the theme of "Cryptography and Coding" is both timely and relevant. Original research papers on all technical aspects of cryptography and coding are solicited for submission. The proceedings will be published in Springer's Lecture Notes in Computer Science series, and will be available at the conference.
Important Dates: Submission Deadline: June 26, 2015; Author Notification: August 28, 2015; Proceedings Version Deadline: September 14, 2015; Conference: 15–December 17, 2015.
Information: www.cs.ucl.ac.uk/staff/j.groth/IMACC.html

16–20 **The 20th Asian Technology Conference in Mathematics (ATCM 2015)**, Leshan, China.

19–20 **4th International Conference on Mathematical and Computational Sciences**, Asian Institute of Technology Conference Center, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand.

* 21–23 **9th International Conference of IMBIC on "Mathematical Sciences for Advancement of Science and Technology (MSAST 2015)"**, IMBIC, Salt Lake City, Kolkata, India.
Description: The main objective of the conference is to bring specialized topics in mathematics, statistics, computer science, information technology, bioinformatics and closely related interdisciplinary areas to the forefront. Original full papers are invited. All papers are to be screened and accepted papers will be published in the Proceedings of IMBIC, Volume 4 (2015), having ISBN 978-81-925832-3-5, except for a few full scientific papers of high quality, which may be published in the highly acclaimed series of monographs of IMBIC. Many scientists from India, USA, Japan, Canada, Sweden, France, Germany, Finland, Australia, Russia, Egypt, Mexico, Algeria, Botswana, Korea, South Africa and many other countries participated in the earlier conferences.
Contact: All correspondences in respect to the conference are to be addressed to Dr. Avishek Adhikari, Convenor MSAST 2015 & Secretary, IMBIC; email: msast.paper@gmail.com; website: www.isical.ac.in/~avishek_r/.
Information: www.imbic.org/forthcoming.html

28–30 **Riemann Legacy Conference**, Sanya, Hainan, China.

31–January 4 **String Mathematics 2015**, Sanya, Hainan, China.

January 2016

*3–16 **New Challenges in Reverse Mathematics**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: The central theme of Reverse Mathematics is calibrating the strength of classical mathematical theorems in terms of the axioms needed to prove them; this calibration also takes into account recursion-theoretic complexity measures and consistency strength.
Topics: Collaborative Research and Workshop: January 3–16, 2016. There will be talks in the mornings and free discussions in the afternoons.
Location: www2.ims.nus.edu.sg/Programs/016reverse/index.php

5–9 **Conference on General Relativity**, Sanya, Hainan, China.

*9–13 **Moduli spaces, integrable systems, and topological recursions**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal, Canada.
Description: The computation and enumeration of invariants of moduli spaces took a sudden turn with the conjecture of Witten that they could be combined into a formal series that solved the KdV hierarchy. This conjecture, subsequently proven by Kontsevich, was motivated by considerations of quantum gravity.
Information: www.crm.umontreal.ca/2016/Moduli16/index_e.php.

10–12 **ACM-SIAM Symposium on Discrete Algorithms (SODA16), being held with Analytic Algorithmics and Combinatorics (ANALCO16) and Algorithm Engineering and Experiments (ALENEX16)**, Crystal Gateway Marriott, Arlington, Virginia.

11–15 **AIM Workshop: High and Low Forcing**, American Institute of Mathematics, San Jose, California.

*11–May 20 **Differential Geometry (DG)**, Mathematical Sciences Research Institute, Berkeley, CA
Description: Differential geometry is a subject with both deep roots and recent advances. Many old problems in the field have recently been solved, such as the Poincaré and geometrization conjectures by Perelman, the quarter pinching conjecture by Brendle-Schoen, the Lawson Conjecture by Brendle, and the Willmore Conjecture by Marques-Neves. The solutions of these problems have introduced a wealth of new techniques into the field. This semester-long program will focus on the following main themes: (1) Einstein metrics and generalizations, (2) Complex differential geometry, (3) Spaces with curvature bounded from below, (4) Geometric flows, and particularly on the deep connections between these areas.
Information: www.msri.org/programs/286

14–15 **Connections for Women: Differential Geometry**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul 2014, p. 669)

18–22 **Introductory Workshop: Modern Riemannian Geometry**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul 2014, p. 669)

*18–February 28 **Semidefinite and Matrix Methods for Optimization and Communication**, Institute for Mathematical Sciences, National University of Singapore.
Description: The program will cover topics in combinatorial optimization, approximation algorithms, and communication complexity and links connecting these areas. A common approach to hard combinatorial optimizations is to look at relaxations of these problems as linear or semidefinite programs. On the algorithmic side, one hopes to show that these relaxations can provide good approximations to the optimal value. On the hardness side, one hopes to show that (ever more complicated) relaxations are still far from the true value.
Workshops: Workshop 1 on Log Rank Conjecture: January 18–22, 2016; Workshop 2 on Positive Semidefinite Rank: February 1–5, 2016; Workshop 3 on Approximation Algorithms: February 15–19, 2016.
Information: www2.ims.nus.edu.sg/Programs/016semi/index.php

*25–29 **Partial Order: Mathematics, Simulations and Applications**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
Description: Partially ordered materials, between the conventional solid and liquid phases of matter, are ubiquitous in nature. Examples include liquid crystals and complex fluids, glassy matter, the cell cytoskeleton, and vibrated granular media. The theory of partial order not only presents cutting-edge mathematical challenges but can also be transformative for materials science and nano-technology. This workshop has three central themes: the mathematics, modeling, and simulation of (i) liquid crystals and complex fluids, (ii) bio-materials, and (iii) nano-materials and will feature invited talks in equilibrium and non-equilibrium phenomena for these materials, their singularities, numerical methods, and new experiments. As such, the workshop promises to be a unique platform for consolidating new and exciting ideas from different research communities in the field and formulate new plans for long-lasting collaboration.
Deadline: The application deadline for funding is November 30, 2015.
Information: www.ipam.ucla.edu/programs/workshops/partial-order-mathematics-simulations-and-applications/

26–28 **2nd International Conference on Mathematical Sciences and Statistics (ICMSS2016)**, Kuala Lumpur, Malaysia.

February 2016

1–6 **ICERM Semester Program on "Dimension and Dynamics"**, Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, Rhode Island.

15–19 **Ergodic, Algebraic and Combinatorial Methods in Dimension Theory**, Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, Rhode Island.

15–June 17 **Melt in the Mantle**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Apr. 2014, p. 433)

29–March 4 **AIM Workshop: Hereditary Discrepancy and Factorization Norms**, American Institute of Mathematics, San Jose, California.

March 2016

*6–31 **New Developments in Representation Theory**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Collaborative Research: March 6–31, 2016; Tutorial on Hecke Algebras: March 7–11, 2016, by Dan Ciubotaru, University of Oxford; Tutorial on Automorphic Descent: March 7–11, 2016, by Lei Zhang, National University of Singapore; Workshop on New Developments in Representation Theory: March 14–25, 2016.
Information: www2.ims.nus.edu.sg/Programs/016theory/index.php

7–June 10 **Culture Analytics**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

21–25 **Kähler Geometry, Einstein Metrics, and Generalizations**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2014, p. 797)

28–April 1 **AIM Workshop: Sheaves and modular representations of reductive groups**, American Institute of Mathematics, San Jose, California.

Mathematics Calendar

April 2016

4–8 **Semester Workshop: Computation in Dynamics**, Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, Rhode Island.

5–8 **SIAM Conference on Uncertainty Quantification (UQ16)**, SwissTech Convention Center, EPFL Campus, Lausanne, Switzerland.

May 2016

* 2–6 **AIM Workshop: Algebraic vision**, American Institute of Mathematics, San Jose, CA
Description: This workshop, sponsored by AIM and the NSF, will focus on multi-view geometry, the sub-discipline of computer vision that studies 3D scene reconstructions from images, and has deep foundations in projective geometry and linear algebra.
Information: `aimath.org/workshops/upcoming/algvision`

2–6 **Geometric Flows in Riemannian and Complex Geometry**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2014, p. 797)

* 9–13 **Cultural Patterns: Multi-scale Data-driven Models**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, CA.
Description: The proliferation of cultural data has given data-driven approaches a significant edge in modeling various cultural phenomena. This workshop focuses on such approaches that make use of mathematical tools in machine learning, data mining, network science, and computational social science. We are particularly interested in presenting methods, both normative and descriptive, that offer a gestalt or structure-first approach to culture analysis and that provide a multi-layered summarization of these phenomena suitable for exploration at multiple scales. These models are applied to various datasets such as social and information networks, social media, narrative and story detection in texts, group dynamics or behavior, and collaboration and competition leading to emergent behavior. The application deadline for funding is March 14, 2016.
Information: `www.ipam.ucla.edu/programs/workshops/` `workshop-iii-cultural-patterns-multi-scale-data-` `driven-models/`

* 16–20 **AIM Workshop: The Galois theory of orbits in arithmetic dynamics**, American Institute of Mathematics, San Jose, CA
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the study of Galois properties of points in orbits of algebraic maps.
Information: `aimath.org/workshops/upcoming/galarith-` `dyn`

* 22–25 **Fifteenth International Conference in Approximation Theory**, Menger Hotel, San Antonio, Texas.
Description: These triennial meetings have traditionally been the main general international conferences in Approximation Theory, and are designed to bring together students and researchers from all subareas of the subject.
Confirmed Invited Speakers: Josef Dick (New South Wales), Simon Foucart (Georgia), Elisabeth Larsson (Upssala), Doron Lubinsky (Georgia Tech), Carla Manni (Rome), Mike Neamtu (Vanderbilt), and Ulrich Reif (Darmstadt). A plenary lecture will also be given by the recipient of the eighth Vasil A. Popov Prize in Approximation Theory, see `imi.cas.sc.edu/popov-prize-description`. To organize a minisymposium on a topic of your choice, please submit a proposal via the website by April 1, 2016. Titles and abstracts for contributed talks or posters are due by April 30, 2016. Students, postdocs, and members of under-represented groups from the US and overseas are especially welcome, and are encouraged to apply for travel support. The deadline is April 1, 2016.

Information: `www.math.vanderbilt.edu/~AT15`

* 23–28 **The Eighth International Conference "Inverse Problems: Modeling and Simulation"**, In the distinguished hotels of the Mediterranean Region, in Liberty Hotels, Lykia, Ölüdeniz, Fethiye, Turkey
Description: The objective of this meeting is to be multidisciplinary and international, bringing together scientists working on various topics of inverse problems in diverse areas of mathematical, engineering, physical and computer sciences.
Information: `www.ipms-conference.org/`

June 2016

* 13–17 **AIM Workshop: Equivariant derived algebraic geometry**, American Institute of Mathematics, San Jose, CA.
Description: This workshop, sponsored by AIM and the NSF, will explore computations and examples that will help guide the development of the fledgling field of "equivariant derived algebraic geometry".
Information: `aimath.org/workshops/upcoming/equider-` `alggeom`

* 13–24 **Algebraic, Enumerative, and Geometric Combinatorics - ECCO 2016**, Universidad de Antioquia, Medellin, Colombia.
Description: Combinatorics is at the center of many areas in pure and applied mathematics. This summer school will focus on the versatility of combinatorics to shed light on problems in algebra, geometry, optimization, and mathematical physics. We will also discuss how algebraic and geometric perspectives can help us understand purely combinatorial objects. The main goal of the school is to bring young mathematicians from Colombia and other Latin American countries into close contact with each other and with world experts in various fields of combinatorics. This is part of a long term goal to build a strong regional community of mathematicians in combinatorics and related fields.
Information: `www.cimpa-icpam.org/ecoles-de-recher-` `che/ecoles-de-recherche-2016/liste-chronologique-` `des-ecoles-de/article/algebraic-enumerative-and-` `757?lang=fr`

The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.

July 2016

* 4–31 **Mathematics of Shapes and Applications**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Tutorial on Applications: Shapes in Multiples Disciplines: July 4–8, 2016; Summer School on Mathematics of Shapes: July 11–22, 2016; Workshop on State-of-the-Art Shape Research and its Applications: July 25–29, 2016.
Information: `www2.ims.nus.edu.sg/Programs/016shape/` `index.php`.

* 25–29 **Twelfth Symposium on General Topology and its Relations to Modern Analysis and Algebra - TOPOSYM 2016**, Prague, Czech Republic.
Description: The TOPOSYM is a conference series held in Prague, running in a five-year cycle since 1961, serving as a traditional meeting point for general topological audience. TOPOSYM 2016 will be organized by the Institute of Mathematics of the Czech Academy of Sciences and the Faculty of Mathematics and Physics of the Charles University in Prague. The following mathematicians have agreed to present an invited talk: Alexander Arhangel'skii, Leandro Aurichi, Dikran Dikranjan, Alan Dow, Michael Hrušák, Ondrej Kalenda, Alexander Kechris*, Piotr Koszmider, Mikolaj Krupski, Wieslaw Kubis,

Mathematics Calendar

Aleksandra Kwiatkowska, Jordi Lopez-Abad, Veronica Martinez de la Vega, Julien Melleray, Jan van Mill, Arnold Miller, Justin Moore, Chris Mouron, Lionel Nguyen Van Thé, Lex Oversteegen, Christian Rosendal, Marcin Sabok, Slawomir Solecki, Lajos Soukup, Mikhail Tkachenko, Stevo Todorcevic**, Toshimichi Usuba, Benjamin Weiss.*
* provisionally confirmed ** to be confirmed.
Information: `www.toposym.cz`

August 2016

* 15–December 16 **Geometric Group Theory (GGT2)**, Mathematical Sciences Research Institute, Berkeley, CA.
Description: The field of geometric group theory emerged from Gromov's insight that even mathematical objects such as groups, which are defined completely in algebraic terms, can be profitably viewed as geometric objects and studied with geometric techniques. Contemporary geometric group theory has broadened its scope considerably, but retains this basic philosophy of reformulating in geometric terms problems from diverse areas of mathematics and then solving them with a variety of tools. The growing list of areas where this general approach has been successful includes low-dimensional topology, the theory of manifolds, algebraic topology, complex dynamics, combinatorial group theory, algebra, logic, the study of various classical families of groups, Riemannian geometry and representation theory. The goals of this MSRI program are to bring together people from the various branches of the field in order to consolidate recent progress, chart new directions, and train the next generation of geometric group theorists.
Information: `www.msri.org/programs/278`

September 2016

* 19–30 **Workshop on Mathematics of Information–Theoretic Cryptography**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: Our workshop is the third in a series of workshops on Mathematics of Information-Theoretic Cryptography. Activities: Tutorials: September 19–23, 2016 Workshop: September 26–30, 2016.
Information: `www2.ims.nus.edu.sg/Programs/016wcrypto/index.php`

December 2016

* 13–22 **Recent Advances in Operator Theory and Operator Algebras 2016 (OTOA 2016)**, Indian Statistical Institute, Bangalore, India.
Description: Recent advances in Operator Theory and Operator Algebras–2016 (OTOA-2016) to be held at Indian Statistical Institute, Bangalore, during December 13–22, 2016. This conference is a continuation of the earlier conferences and workshops on Operator theory and Operator algebras held in Indian Statistical Institute, Bangalore. OTOA-2016 aims bringing experts and researchers from around the world, including postdocs and advanced doctoral students, to share their recent findings related to the various fields of Functional Analysis, Operator Theory, Operator Algebras and related fields. The meeting will start with a workshop during December 13–17, 2016 followed by a conference during December 19–22, 2016.
Programme: (i) Workshop part — December 13 till December 17, 2016. (ii) Conference part — December 19 till December 22 noon, 2016. The Conference encourages and promotes excellence in young mathematicians.
Information: `www.isibang.ac.in/~jay/OTOA/OTOA16/otoa16.html`
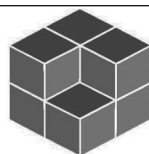
Institute for Computational and Experimental Research in Mathematics

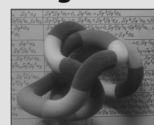### SEMESTER PROGRAM: FALL 2016

Topology in Motion
September 6 – December 9, 2016

Organizing Committee:
Yuliy Baryshnikov, *University of Illinois*
Fred Cohen, *Rochester University*
Matthew Kahle, *The Ohio State University*
Randall Kamien, *University of Pennsylvania*
Sayan Mukherjee, *Duke University*
Igor Pak, *UCLA*
Ileana Streinu, *Smith College*
Rade Zivaljevic, *Belgrade University*

Program Description:
This program aims at exploring those areas of topology where the research challenges stem from scientific and engineering problems and computer experiments rather than the intrinsic development of the topology proper. In this context, topology is a toolbox of mathematical results and constructions which impacts and inspires developments in other areas. Born as a supporting discipline, aimed at creating a foundation of intuitive notions immensely useful in differential equations and complex analysis, algebraic topology remains indispensable in many disciplines.

Associated Workshops:
- Unusual Configuration Spaces
  September 12 - 16, 2016
- Stochastic Topology and Thermodynamic Limits / *October 17 - 21, 2016*
- Topology and Geometry in a Discrete Setting / *November 28 - December 2, 2016*

Program and participant details:
http://icerm.brown.edu

ICERM welcomes applications for long- and short-term visitors. Support for local expenses may be provided. Decisions about online applications are typically made 1-3 months before each program, as space and funding permit. ICERM encourages women and members of underrepresented minorities to apply.
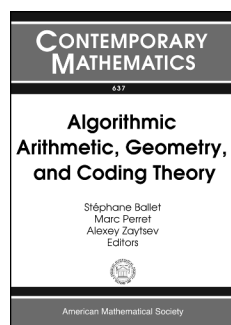
About ICERM: The Institute for Computational and Experimental Research in Mathematics is a National Science Foundation Mathematics Institute at Brown University in Providence, RI.

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Algebra and Algebraic Geometry

Algorithmic Arithmetic, Geometry, and Coding Theory

Stéphane Ballet, *Aix-Marseille University, France*, **Marc Perret**, *Université de Toulouse II Le Mirail, France*, and **Alexey Zaytsev**, *Immanuel Kant Baltic Federal University, Kaliningrad, Russia*, Editors

This volume contains the proceedings of the 14th International Conference on Arithmetic, Geometry, Cryptography, and Coding Theory (AGCT), held June 3–7, 2013, at CIRM, Marseille, France.

These international conferences, held every two years, have been a major event in the area of algorithmic and applied arithmetic geometry for more than 20 years.

This volume contains 13 original research articles covering geometric error correcting codes, and algorithmic and explicit arithmetic geometry of curves and higher dimensional varieties. Tools used in these articles include classical algebraic geometry of curves, varieties and Jacobians, Suslin homology, Monsky–Washnitzer cohomology, and *L*-functions of modular forms.

This item will also be of interest to those working in applications.

Contents: *Geometric error correcting codes:* **H. Randriambololona**, On products and powers of linear codes under componentwise multiplication; **M. Datta** and **S. R. Ghorpade**, Higher weights of affine Grassmann codes and their duals; *Algorithmic: Special varieties:* **D. Kohel**, The geometry of efficient arithmetic on elliptic curves; **I. Boyer**, 2-2-2 isogenies between Jacobians of hyperelliptic curves; **B. Smith**, Easy scalar decompositions for efficient scalar multiplication on elliptic curves and genus 2 Jacobians; *Algorithmic: Point counting:* **C. Gonçalves**, A point counting algorithm for cyclic covers of the projective line; **Y.-D. Shieh**, Point counting on non-hyperelliptic genus 3 curves with automorphism group $\mathbb{Z}/2\mathbb{Z}$ using Monsky-Washnitzer cohomology; **M. Q. Kawakita**, Wiman's and Edge's sextic attaining Serre's bound II; *Algorithmic: General:* **J. Guàrdia** and **E. Nart**, Genetics of polynomials over local fields; *Explicit algebraic geometry:* **E. Alekseenko** and **A. Zaytsev**, Explicit

equations of optimal curves of genus 3 over certain finite fields with three parameters; **A. Eid** and **I. Duursma**, Smooth embeddings for the Suzuki and Ree curves; *Arithmetic geometry:* **A. Zykin**, Uniform distribution of zeroes of *L*-functions of modular forms; **A. Schmidt**, A survey on class field theory for varieties.

Contemporary Mathematics, Volume 637

March 2015, 306 pages, Softcover, ISBN: 978-1-4704-1461-0, LC 2014037646, 2010 *Mathematics Subject Classification:* 11G10, 11G20, 11G25, 11H71, 11Y16, 14G05, 14G15, 14Q05, 14Q15, 94B27, **AMS members US$84**, List US$105, Order code CONM/637
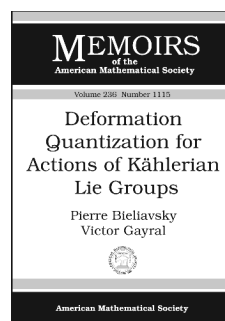
Deformation Quantization for Actions of Kählerian Lie Groups

Pierre Bieliavsky, *Université Catholique de Louvain, Louvain le Neuve, Belgium*, and **Victor Gayral**, *Laboratoire de Mathématiques, Reims, France*

Contents: Introduction; Notations and conventions; Oscillatory integrals; Tempered pairs for Kählerian Lie groups; Non-formal star-products; Deformation of Fréchet algebras; Quantization of polarized symplectic symmetric spaces; Quantization of Kählerian Lie groups; Deformation of C^*-algebras; Bibliography.

Memoirs of the American Mathematical Society, Volume 236, Number 1115

June 2015, 154 pages, Softcover, ISBN: 978-1-4704-1491-7, LC 2015007760, 2010 *Mathematics Subject Classification:* 22E30, 46L87, 81R60, 58B34, 81R30, 53C35, 32M15, 53D55, **Individual member US$51.60**, List US$86, Institutional member US$68.80, Order code MEMO/236/1115
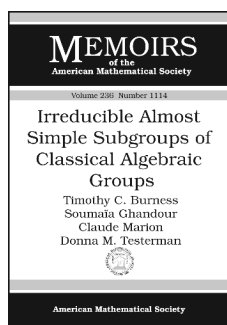
Irreducible Almost Simple Subgroups of Classical Algebraic Groups

Timothy C. Burness, *University of Bristol, United Kingdom*, **Soumaïa Ghandour**, *Lebanese University, Nabatieh, Lebanon*, **Claude Marion**, *University of Fribourg, Switzerland*, and **Donna M. Testerman**, *École Polytechnique Fédérale de Lausanne, Switzerland*

Contents: Introduction; Preliminaries; The case $H^0 = A_m$; The case $H^0 = D_m$, $m \geq 5$; The case $H^0 = E_6$; The case $H^0 = D_4$; Proof of Theorem 5; Notation; Bibliography.

Memoirs of the American Mathematical Society, Volume 236, Number 1114

June 2015, 110 pages, Softcover, ISBN: 978-1-4704-1046-9, LC 2015007756, 2010 *Mathematics Subject Classification:* 20G05; 20E28, 20E32, **Individual member US$48**, List US$80, Institutional member US$64, Order code MEMO/236/1114
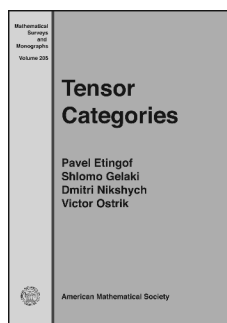
Tensor Categories

Pavel Etingof, *Massachusetts Institute of Technology, Cambridge, MA*, **Shlomo Gelaki**, *Technion-Israel Institute of Technology, Haifa, Israel*, **Dmitri Nikshych**, *University of New Hampshire, Durham, NH*, and **Victor Ostrik**, *University of Oregon, Eugene, OR*

Is there a vector space whose dimension is the golden ratio? Of course not—the golden ratio is not an integer! But this can happen for generalizations of vector spaces—objects of a tensor category. The theory of tensor categories is a relatively new field of mathematics that generalizes the theory of group representations. It has deep connections with many other fields, including representation theory, Hopf algebras, operator algebras, low-dimensional topology (in particular, knot theory), homotopy theory, quantum mechanics and field theory, quantum computation, theory of motives, etc. This book gives a systematic introduction to this theory and a review of its applications. While giving a detailed overview of general tensor categories, it focuses especially on the theory of finite tensor categories and fusion categories (in particular, braided and modular ones), and discusses the main results about them with proofs. In particular, it shows how the main properties of finite-dimensional Hopf algebras may be derived from the theory of tensor categories.

Many important results are presented as a sequence of exercises, which makes the book valuable for students and suitable for graduate courses. Many applications, connections to other areas, additional results, and references are discussed at the end of each chapter.

Contents: Abelian categories; Monoidal categories; $\mathbb{Z}_+$-rings; Tensor categories; Representation categories of Hopf algebras; Finite tensor categories; Module categories; Braided categories; Fusion categories; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 205

July 2015, approximately 350 pages, Hardcover, ISBN: 978-1-4704-2024-6, LC 2015006773, 2010 *Mathematics Subject Classification:* 17B37, 18D10, 19D23, 20G42, **AMS members US$88**, List US$110, Order code SURV/205
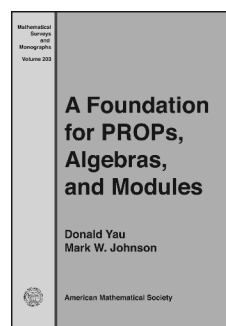
A Foundation for PROPs, Algebras, and Modules

Donald Yau, *The Ohio State University at Newark, OH*, and **Mark W. Johnson**, *Pennsylvania State University Altoona, PA*

PROPs and their variants are extremely general and powerful machines that encode operations with multiple inputs and multiple outputs. In this respect PROPs can be viewed as generalizations of operads that would allow only a single output. Variants of PROPs are important in several mathematical fields, including string topology, topological conformal field theory, homotopical algebra, deformation theory, Poisson geometry, and graph cohomology. The purpose of this monograph is to develop, in full technical detail, a unifying object called a generalized PROP. Then with an appropriate choice of pasting scheme, one recovers (colored versions of) dioperads, half-PROPs, (wheeled) operads, (wheeled) properads, and (wheeled) PROPs.

Here the fundamental operation of graph substitution is studied in complete detail for the first time, including all exceptional edges and loops as examples of a new definition of wheeled graphs. A notion of generators and relations is proposed which allows one to build all of the graphs in a given pasting scheme from a small set of basic graphs using graph substitution. This provides information at the level of generalized PROPs, but also at the levels of algebras and of modules over them. Working in the general context of a symmetric monoidal category, the theory applies for both topological spaces and chain complexes in characteristic zero.

This book is useful for all mathematicians and mathematical physicists who want to learn this new powerful technique.

*This item will also be of interest to those working in geometry and topology.*

Contents: *Wheeled graphs and pasting schemes:* Wheeled graphs; Special sets of graphs; Basic operations on wheeled graphs; Graph groupoids; Graph substitution; Properties of graph substitution; Generators for graphs; Pasting schemes; Well-matched pasting schemes; *Generalized PROPs, algebras, and modules:* Generalized PROPs; Biased characterizations of generalized PROPs; Functors of generalized PROPs; Algebras over generalized PROPs; Alternative descriptions of generalized PROPs; Modules over generalized PROPs; May modules over algebras over operads; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 203

July 2015, 311 pages, Hardcover, ISBN: 978-1-4704-2197-7, LC 2014049153, 2010 *Mathematics Subject Classification:* 18D99; 55U40, 13D10, 81T30, **AMS members US$88**, List US$110, Order code SURV/203

Analysis
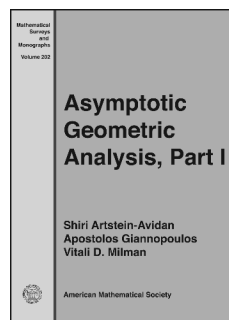
Asymptotic Geometric Analysis, Part I

Shiri Artstein-Avidan, *Tel Aviv University, Israel*, **Apostolos Giannopoulos**, *University of Athens, Greece*, and **Vitali D. Milman**, *Tel Aviv University, Israel*

The authors present the theory of asymptotic geometric analysis, a field which lies on the border between geometry and functional analysis. In this field, isometric problems that are typical for geometry in low dimensions are substituted by an "isomorphic" point of view, and an asymptotic approach (as dimension tends to infinity) is introduced. Geometry and analysis meet here in a non-trivial way. Basic examples of geometric inequalities in isomorphic form which are encountered in the book are the "isomorphic isoperimetric inequalities" which led to the discovery of the "concentration phenomenon", one of the most powerful tools of the theory, responsible for many counterintuitive results.

A central theme in this book is the interaction of randomness and pattern. At first glance, life in high dimension seems to mean the existence of multiple "possibilities", so one may expect an increase in the diversity and complexity as dimension increases. However, the concentration of measure and effects caused by convexity show that this diversity is compensated and order and patterns are created for arbitrary convex bodies in the mixture caused by high dimensionality.

The book is intended for graduate students and researchers who want to learn about this exciting subject. Among the topics covered in the book are convexity, concentration phenomena, covering numbers, Dvoretzky-type theorems, volume distribution in convex bodies, and more.

This item will also be of interest to those working in geometry and topology.

Contents: Convex bodies: Classical geometric inequalities; Classical positions of convex bodies; Isomorphic isoperimetric inequalities and concentration of measure; Metric entropy and covering numbers estimates; Almost Euclidean subspaces of finite dimensional normed spaces; The ℓ-position and the Rademacher projection; Proportional theory; M-position and the reverse Brunn-Minkowski inequality; Gaussian approach; Volume distribution in convex bodies; Elementary convexity; Advanced convexity; Bibliography; Subject index; Author index.

Mathematical Surveys and Monographs, Volume 202

June 2015, 451 pages, Hardcover, ISBN: 978-1-4704-2193-9, LC 2014049152, 2010 *Mathematics Subject Classification:* 52Axx, 46Bxx, 60Dxx, 28Axx, 46B20, 46B09, 52A20, 52A21, 52A23, 68-02, **AMS members US$88**, List US$110, Order code SURV/202
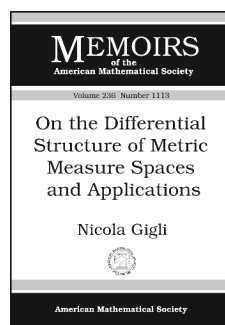
## On the Differential Structure of Metric Measure Spaces and Applications

Nicola Gigli, *University of Bordeaux 1, France*

Contents: Introduction; Preliminaries; Differentials and gradients; Laplacian; Comparison estimates; Appendix A. On the duality between cotangent and tangent spaces; Appendix B. Remarks about the definition of the Sobolev classes; References.

Memoirs of the American Mathematical Society, Volume 236, Number 1113

June 2015, 91 pages, Softcover, ISBN: 978-1-4704-1420-7, LC 2015007762, **Individual member US$45.60**, List US$76, Institutional member US$60.80, Order code MEMO/236/1113
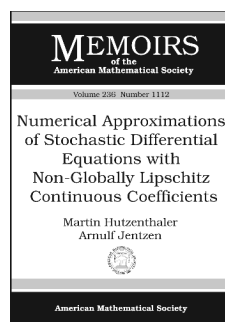
Numerical Approximations of Stochastic Differential Equations with Non-Globally Lipschitz Continuous Coefficients

Martin Hutzenthaler, *University of Duisburg-Essen, North Rhine-Westphalia, Germany*, and **Arnulf Jentzen**, *ETH Zurich, Switzerland*

This item will also be of interest to those working in differential equations.

Contents: Introduction; Integrability properties of approximation processes for SDEs; Convergence properties of approximation processes for SDEs; Examples of SDEs; Bibliography.

Memoirs of the American Mathematical Society, Volume 236, Number 1112

June 2015, 99 pages, Softcover, ISBN: 978-1-4704-0984-5, LC 2015007761, 2010 *Mathematics Subject Classification:* 60H35; 65C05, 65C30, **Individual member US$45.60**, List US$76, Institutional member US$60.80, Order code MEMO/236/1112
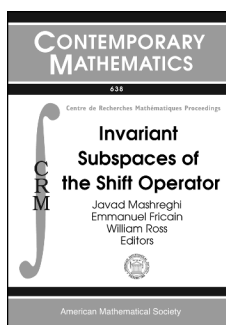
Invariant Subspaces of the Shift Operator

Javad Mashreghi, *Laval University, Quebec, Canada*, **Emmanuel Fricain**, *Université Lille 1, Villeneuve d'Ascq, France*, and **William Ross**, *University of Richmond, VA*, Editors

This volume contains the proceedings of the CRM Workshop on Invariant Subspaces of the Shift Operator, held August 26–30, 2013, at the Centre de Recherches Mathématiques, Université de Montréal, Montréal, Quebec, Canada.

The main theme of this volume is the invariant subspaces of the shift operator (or its adjoint) on certain function spaces, in particular, the Hardy space, Dirichlet space, and de Branges–Rovnyak spaces.

These spaces, and the action of the shift operator on them, have turned out to be a precious tool in various questions in analysis such as function theory (Bieberbach conjecture, rigid functions, Schwarz–Pick inequalities), operator theory (invariant subspace problem, composition operator), and systems and control theory.

Of particular interest is the Dirichlet space, which is one of the classical Hilbert spaces of holomorphic functions on the unit disk. From many points of view, the Dirichlet space is an interesting and challenging example of a function space. Though much is known about it, several important open problems remain, most notably the characterization of its zero sets and of its shift-invariant subspaces.

This book is co-published with the Centre de Recherches Mathématiques.

Contents: H. Queffélec, Approximation numbers of composition operators on a Hilbert space of Dirichlet series; **D. Timotin**, A short introduction to de Branges-Rovnyak spaces; **C. Chu**, Asymptotic Bohr radius for the polynomials in one complex variable; **A. Bourhim** and **J. Mashreghi**, A survey on preservers of spectra and local spectra; **C. C. Cowen** and **R. G. Wahl**, Commutants of finite Blaschke product multiplication operators; **P. M. Gauthier**, Complex approximation and extension-interpolation on arbitrary sets in one dimension; **E. Fricain**, **J. Mashreghi**, and **D. Seco**, Cyclicity in non-extreme de Branges-Rovnyak spaces; **E. Fricain** and **J. Mashreghi**, Integral representations of the derivatives in $\mathcal{H}(b)$ spaces; **A. Boivin** and **C. Zhu**, Interpolation and moment in weighted Hardy spaces; **S. R. Garcia** and **W. T. Ross**, Model spaces: A survey; **D. Timotin**, Note on a Julia operator related to model spaces; **C. Bénéteau** and **D. Khavinson**, Selected problems in classical function theory; **K. Bickel**, **E. T. Sawyer**, and **B. D. Wick**, The linear bound for Haar multiplier paraproducts; **R. G. Douglas** and **A. Xu**, Transitivity and bundle shifts; **V. V. Andreev** and **J. A. Cima**, Weak H^1, the real and complex case.

Contemporary Mathematics, Volume 638

April 2015, 317 pages, Softcover, ISBN: 978-1-4704-1045-2, LC 2014038149, 2010 *Mathematics Subject Classification:* 47-XX, 30-XX, 31-XX, 32-XX, **AMS members US\$84**, List US\$105, Order code CONM/638

Applications
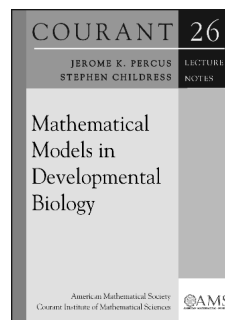
Mathematical Models in Developmental Biology

Jerome K. Percus and **Stephen Childress**, *New York University, Courant Institute of Mathematical Sciences, NY*

The path from relatively unstructured egg to full organism is one of the most fascinating trajectories in the biological sciences. Its complexity calls for a very high level of organization, with an array of subprocesses in constant communication with each other. These notes introduce an interleaved set of mathematical models representative of research in the last few decades, as well as the techniques that have been developed for their solution. Such models offer an effective way of incorporating reliable data in a concise form, provide an approach complementary to the techniques of molecular biology, and help to inform and direct future research.

Titles in this series are co-published with the Courant Institute of Mathematical Sciences at New York University.

Contents: Introduction; Catastrophe theory; Pattern formation; Differential adhesion and morphogenesis; The origins of movement; Chemotaxis; Cell proliferation; Somite formation in vertebrates; Compartments; Segmentation of insect embryos; Supplementary notes; Bibliography; Index.

Courant Lecture Notes, Volume 26

July 2015, 249 pages, Softcover, ISBN: 978-1-4704-1080-3, LC 2015004198, 2010 *Mathematics Subject Classification:* 92C10, 92C15, 92C17, 92C45, **AMS members US\$35.20**, List US\$44, Order code CLN/26

Differential Equations
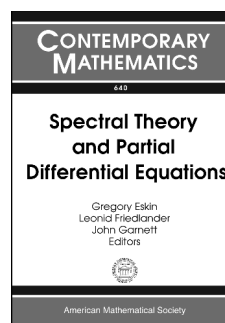
Spectral Theory and Partial Differential Equations

Gregory Eskin, *University of California, Los Angeles, CA*, **Leonid Friedlander**, *University of Arizona, Tucson, AZ*, and **John Garnett**, *University of California, Los Angeles, CA*, Editors

This volume contains the proceedings of the Conference on Spectral Theory and Partial Differential Equations, held from June 17–21, 2013, at the University of California, Los Angeles, California, in honor of James Ralston's 70th Birthday.

Papers in this volume cover important topics in spectral theory and partial differential equations such as inverse problems, both

analytical and algebraic; minimal partitions and Pleijel's Theorem; spectral theory for a model in Quantum Field Theory; and beams on Zoll manifolds.

Contents: M. I. Belishev, Algebras in reconstruction of manifolds; **J.-C. Guillot**, Spectral theory of a mathematical model in quantum field theory for any spin; **B. Helffer** and **T. Hoffmann-Ostenhof**, A review on large k minimal spectral k-partitions and Pleijel's theorem; **V. Isakov**, Increasing stability for near field from the scattering amplitude; **H. Isozaki**, **Y. Kurylev**, and **M. Lassas**, Inverse scattering on multi-dimensional asymptotically hyperbolic orbifolds; **H. Liu** and **M. Pryporov**, Error estimates of the Bloch band-based Gaussian beam superposition for the Schrödinger equation; **D. Robert** and **L. Thomann**, On random weighted Sobolev inequalities on $\mathbb{R}^4$ and applications; **O. Y. Imanuvilov** and **M. Yamamoto**, Calderón problem for Maxwell's equations in the waveguide; **S. Zelditch**, Gaussian beams on Zoll manifolds and maximally degenerate Laplacians.

Contemporary Mathematics, Volume 640

June 2015, 197 pages, Softcover, ISBN: 978-1-4704-0989-0, LC 2014040087, 2010 *Mathematics Subject Classification:* 35-06, **AMS members US$84**, List US$105, Order code CONM/640

Discrete Mathematics and Combinatorics
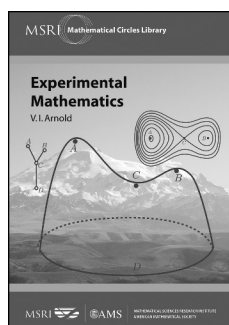
Experimental Mathematics

V. I. Arnold
Translated by Dmitry Fuchs and Mark Saul.

One of the traditional ways mathematical ideas and even new areas of mathematics are created is from experiments. One of the best-known examples is that of the Fermat hypothesis, which was conjectured by Fermat in his attempts to find integer solutions for the famous Fermat equation. This hypothesis led to the creation of a whole field of knowledge, but it was proved only after several hundred years.

This book, based on the author's lectures, presents several new directions of mathematical research. All of these directions are based on numerical experiments conducted by the author, which led to new hypotheses that currently remain open, i.e., are neither proved nor disproved. The hypotheses range from geometry and topology (statistics of plane curves and smooth functions) to combinatorics (combinatorial complexity and random permutations) to algebra and number theory (continuous fractions and Galois groups). For each subject, the author describes the problem and presents numerical results that led him to a particular conjecture. In the majority of cases there is an indication of how the readers can approach the formulated conjectures (at least by conducting more numerical experiments).

Written in Arnold's unique style, the book is intended for a wide range of mathematicians, from high school students interested in exploring unusual areas of mathematics on their own, to college and graduate students, to researchers interested in gaining a new, somewhat nontraditional perspective on doing mathematics.

In the interest of fostering a greater awareness and appreciation of mathematics and its connections to other disciplines and everyday life, MSRI and the AMS are publishing books in the Mathematical Circles Library series as a service to young people, their parents and teachers, and the mathematics profession.

*This item will also be of interest to those working in applications.*

Titles in this series are co-published with the Mathematical Sciences Research Institute (MSRI).

Contents: Introduction; The statistics of topology and algebra; Combinatorial complexity and randomness; Random permutations of Young diagrams of their cycles; The geometry of Frobenius numbers for additive semigroups; Bibliography.

MSRI Mathematical Circles Library, Volume 16

August 2015, approximately 165 pages, Softcover, ISBN: 978-0-8218-9416-3, LC 2015009318, 2010 *Mathematics Subject Classification:* 00A05; 34C07, 68Q17, 20B30, 11P99, **Individual member US$21.75**, **All Individuals US$21.75**, List US$29, Institutional member US$23.20, Order code MCL/16

General Interest
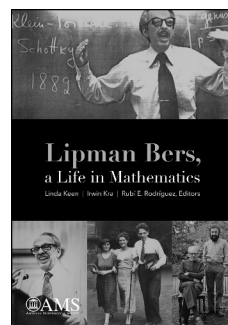
Lipman Bers, a Life in Mathematics

Linda Keen, *Lehman College, CUNY, New York, NY*, **Irwin Kra**, *Stony Brook University, NY*, and **Rubí E. Rodríguez**, *Pontificia Universidad Católica de Chile, Santiago, Chile*, Editors

The book is part biography and part collection of mathematical essays that gives the reader a perspective on the evolution of an interesting mathematical life. It is all about Lipman Bers, a giant in the mathematical world who lived in turbulent and exciting times. It captures the essence of his mathematics, a development and transition from applied mathematics to complex analysis—quasiconformal mappings and moduli of Riemann surfaces—and the essence of his personality, a progression from a young revolutionary refugee to an elder statesman in the world of mathematics and a fighter for global human rights and the end of political torture.

The book contains autobiographical material and short reprints of his work. The main content is in the exposition of his research contributions, sometimes with novel points of view, by students, grand-students, and colleagues. The research described was fundamental to the growth of a central part of 20th century mathematics that, now in the 21st century, is in a healthy state with much current interest and activity. The addition of personal recollections, professional tributes, and photographs yields a picture of a man, his personal and professional family, and his time.

Contents: L. Bers, **R. Shapiro**, and **V. Bers**, Pages from a memoir; **L. Nirenberg**, Lipman Bers and partial differential equations; **W. Abikoff** and **R. J. Sibner**, Bers—From graduate student to quasiconformal mapper; **S. A. Wolpert**, Measurable Riemann mappings; **A. Marden**, The Ahlfors-Bers creation of the modern theory of Kleinian groups—A small acorn grows to a mighty oak; **I. Kra** and **B. Maskit**, The Bers embedding and (some of) its ramifications;

F. P. Gardiner and L. Keen, Lipman Bers, a retrospective; G. Riera and R. E. Rodríguez, The Weil-Petersson geometry of a family of Riemann surfaces; H. Masur, Legacy of work of Bers on the mapping class group; A. Basmajian and P. Susskind, Bers' pants decomposition theorem; I. Kra, Dennis Sullivan and Jeremy Kahn reminiscences; Y. Minsky, Bers embeddings, skinning maps and hyperbolic geometry; N. A'Campo, L. Ji, and A. Papadopoulos, On the early history of moduli and Teichmüller spaces; L. Bers, Correction to "Spaces of Riemann surfaces as bounded domains"; L. Bers, The migration of European mathematicians to America; I. Kra and H. Bass, Lipman Bers May 22, 1914–October 29, 1993; C. S. Morawetz, C. Corillon, I. Kra, T. Weinstein, and J. Gilman, Remembering Lipman Bers; L. Keen, T. K. Milnor, L. Sibner, I. Kra, J. Gilman, and J. Dodziuk, Lipman Bers, a mathematical mentor; L. Keen, I. Kra, and R. E. Rodríguez, Doctoral students of Lipman Bers; L. Keen, I. Kra, and R. E. Rodríguez, Publications of Lipman Bers.

September 2015, approximately 323 pages, Softcover, ISBN: 978-1-4704-2056-7, LC 2015007926, 2010 *Mathematics Subject Classification:* 01-02, 01A55, 01A60, 30-02, 30-03, 30F10, 30F40, 30F60, **AMS members US$35.20**, List US$44, Order code MBK/93
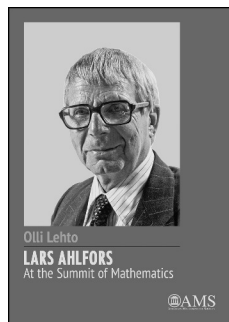
Lars Ahlfors—At the Summit of Mathematics

Olli Lehto, *University of Helsinki, Finland*
Translated by William Hellberg

This book tells the story of the Finnish-American mathematician Lars Ahlfors (1907–1996). He was educated at the University of Helsinki as a student of Ernst Lindelöf and Rolf Nevanlinna and later became a professor there. He left Finland permanently in 1944 and was professor and emeritus at Harvard University for more than fifty years.

Already at the age of twenty-one Ahlfors became a well-known mathematician having solved Denjoy's conjecture, and in 1936 he established his world renown when he was awarded the Fields Medal, the "Nobel Prize in mathematics". In this book the description of his mathematics avoids technical details and concentrates on his contributions to the general development of complex analysis.

Besides mathematics there is also a lot to tell about Ahlfors. World War II marked his life, and he was a colorful personality, with many interesting stories about him.

Olli Lehto, the author of the book, first met Lars Ahlfors and his family as a young doctor at Harvard in 1950. Numerous meetings after that in various parts of the world led to a close friendship between them.

Contents: Family background; Exceptional talent emerges; Mathematical renown secured; To America and back again; War years in Finland; In Sweden and Switzerland; Professorship at Harvard University; The legacy of Riemann and Teichmüller; New research and return to the old; Distinctions; Additions to the portrait; Epilogue in Finland; Sources; Index.

July 2015, 125 pages, Softcover, ISBN: 978-1-4704-1846-5, LC 2015006617, 2010 *Mathematics Subject Classification:* 01-XX, **AMS members US$31.20**, List US$39, Order code MBK/92

Geometry and Topology
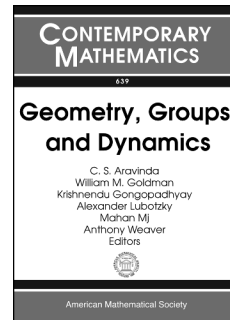
Geometry, Groups and Dynamics

C. S. Aravinda, *TIFR, Bangalore, India*, **William M. Goldman**, *University of Maryland, College Park, MD*, **Krishnendu Gongopadhyay**, *Indian Institute of Science Education and Research Mohali, Punjab, India*, **Alexander Lubotzky**, *Hebrew University of Jerusalem, Israel*, **Mahan Mj**, *RKM Vivekanada University, Howrah, India*, and **Anthony Weaver**, *Bronx Community College, CUNY, New York, NY*, Editors

This volume contains the proceedings of the ICTS Program: Groups, Geometry and Dynamics, held December 3–16, 2012, at CEMS, Almora, India. The activity was an academic tribute to Ravi S. Kulkarni on his turning seventy.

Articles included in this volume, both introductory and advanced surveys, represent the broad area of geometry that encompasses a large portion of group theory (finite or otherwise) and dynamics in its proximity. These areas have been influenced by Kulkarni's ideas and are closely related to his work and contribution.

This item will also be of interest to those working in algebra and algebraic geometry.

Contents: W. Barrera, A. Cano, J. P. Navarrete, and J. Seade, Complex Kleinian groups; V. Charette and T. A. Drumm, Complete Lorentzian 3-manifolds; M. Chas, The Goldman bracket and the intersection of curves on surfaces; S. G. Dani, An introduction to flows on homogeneous spaces; P. B. Shalen, Quantitative geometry of hyperbolic manifolds; A. Weaver, Discrete groups and Riemann surfaces; V. T. Aithal, A note on Chern's theorem on invariant measures; J. S. Athreya, Random affine lattices; V. G. Bardakov and M. V. Neshchadim, Upper central series for the group of unitriangular automorphisms of a free associative algebra; I. Biswas, Hermitian structure and bundles on G/Γ; K. Biswas and R. Perez-Marco, Log-Riemann surfaces, caratheodory convergence and Euler's formula; K. Biswas and R. Perez-Marco, Uniformization of simply connected finite type log-Riemann surfaces; A. L. Edmonds, The Euler characteristic of a Haken 4-manifold; V. Erlandsson and S. Zakeri, A discreteness criterion for groups containing parabolic isometries; R. Gouraige, On the z-classes in a centrally finite division ring; F. Guéritaud, On Lorentz spacetimes of constant curvature; S. Gupta, On the asymptotic behavior of complex earthquakes and Teichmüller disks; G. A. Jones, Characteristically simple Beauville groups, I: Cartesian powers of alternating groups; A. Pal and A. K. Singh, Relatively hyperbolic spaces; J. R. Parker and P. Will, Complex hyperbolic free groups with many parabolic elements; T. Nayak, On Fatou components and omitted values; S. Yuan, Some dynamical properties of certain meromorphic functions.

Contemporary Mathematics, Volume 639
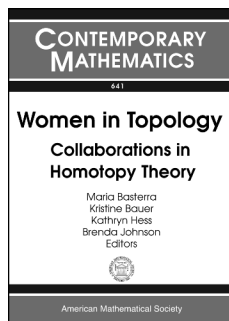
Women in Topology

Collaborations in Homotopy Theory

Maria Basterra, *University of New Hampshire, Durham, NH*, **Kristine Bauer**, *University of Calgary, Alberta, Canada*, **Kathryn Hess**, *Ecole Polytechnique Fédérale de Lausanne, Switzerland*, and **Brenda Johnson**, *Union College, Schenectady, NY*, Editors

This volume contains the proceedings of the WIT: Women in Topology workshop, held from August 18–23, 2013, at the Banff International Research Station, Banff, Alberta, Canada. The Women in Topology workshop was devoted primarily to active collaboration by teams of five to seven participants, each including senior and junior researchers, as well as graduate students.

This volume contains papers based on the results obtained by team projects in homotopy theory, including A-infinity structures, equivariant homotopy theory, functor calculus, model categories, orbispaces, and topological Hochschild homology.

Contents: C. I. Aponte Román, M. Livernet, M. Robertson, S. Whitehouse, and S. Ziegenhagen, Representations of derived A-infinity algebras; M. Basterra, K. Bauer, A. Beaudry, R. Eldred, B. Johnson, M. Merling, and S. Yeakel, Unbased calculus for functors to chain complexes; M. Bayeh, K. Hess, V. Karpova, M. Kędziorek, E. Riehl, and B. Shipley, Left-induced model structures and diagram categories; J. E. Bergner, R. Joachimi, K. Lesh, V. Stojanoska, and K. Wickelgren, Fixed points of p-toral groups acting on partition complexes; I. Bobkova, A. Lindenstrauss, K. Poirier, B. Richter, and I. Zakharevich, On the higher topological Hochschild homology of $\mathbb{F}_p$ and commutative $\mathbb{F}_p$-group algebras; A. M. Bohmann, K. Mazur, A. M. Osorno, V. Ozornova, K. Ponto, and C. Yarnall, A model structure on $GCat$; V. Coufal, D. Pronk, C. Rovi, L. Scull, and C. Thatcher, Orbispaces and their mapping spaces via groupoids: A categorical approach.

Contemporary Mathematics, Volume 641
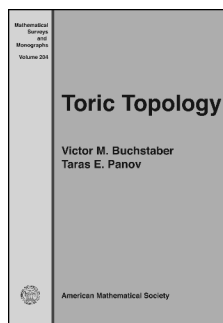
Toric Topology

Victor M. Buchstaber, *Steklov Mathematical Institute, Moscow, Russia*, and **Taras E. Panov**, *Moscow State University, Russia*

This book is about toric topology, a new area of mathematics that emerged at the end of the 1990s on the border of equivariant topology, algebraic and symplectic geometry, combinatorics, and commutative algebra. It has quickly grown into a very active area with many links to other areas of mathematics, and continues to attract experts from different fields.

The key players in toric topology are moment-angle manifolds, a class of manifolds with torus actions defined in combinatorial terms. Construction of moment-angle manifolds relates to combinatorial geometry and algebraic geometry of toric varieties via the notion of a quasitoric manifold. Discovery of remarkable geometric structures on moment-angle manifolds led to important connections with classical and modern areas of symplectic, Lagrangian, and non-Kaehler complex geometry. A related categorical construction of moment-angle complexes and polyhedral products provides for a universal framework for many fundamental constructions of homotopical topology. The study of polyhedral products is now evolving into a separate subject of homotopy theory. A new perspective on torus actions has also contributed to the development of classical areas of algebraic topology, such as complex cobordism.

This book includes many open problems and is addressed to experts interested in new ideas linking all the subjects involved, as well as to graduate students and young researchers ready to enter this beautiful new area.

Contents: Geometry and combinatorics of polytopes; Combinatorial structures; Combinatorial algebra of face rings; Moment-angle complexes; Toric varieties and manifolds; Geometric structures on moment-angle manifolds; Half-dimensional torus actions; Homotopy theory of polyhedral products; Torus actions and complex cobordism; Commutative and homological algebra; Algebraic topology; Categorical constructions; Bordism and cobordism; Formal group laws and Hirzebruch genera; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 204
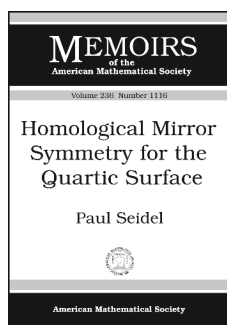
Homological Mirror Symmetry for the Quartic Surface

**Paul Seidel**, *Massachusetts Institute of Technology, Cambridge, MA*

Contents: Introduction; A_∞-categories; Deformation theory; Group actions; Coherent sheaves; Symplectic terminology; Monodromy and negativity; Fukaya categories; Computations in Fukaya categories; The algebras Q_4 and Q_{64}; Counting polygons; References.

Memoirs of the American Mathematical Society, Volume 236, Number 1116

June 2015, 129 pages, Softcover, ISBN: 978-1-4704-1097-1, LC 2015007757, 2010 *Mathematics Subject Classification:* 53D37; 14D05, 18E30, **Individual member US$48.60**, List US$81, Institutional member US$64.80, Order code MEMO/236/1116

Logic and Foundations
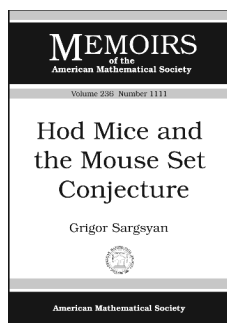
Hod Mice and the Mouse Set Conjecture

**Grigor Sargsyan**, *Rutgers University, Piscataway, NJ*

Contents: Introduction; Hod mice; Comparison theory of Hod mice; Hod mice revisited; Analysis of HOD; Hod pair constructions; A proof of the mouse set conjecture; Appendix A. Descriptive set theory primer; Index; Bibliography.

Memoirs of the American Mathematical Society, Volume 236, Number 1111

June 2015, 171 pages, Softcover, ISBN: 978-1-4704-1692-8, LC 2015007758, 2010 *Mathematics Subject Classification:* 03E15, 03E45, 03E60, **Individual member US$53.40**, List US$89, Institutional member US$71.20, Order code MEMO/236/1111

New AMS-Distributed Publications

Analysis
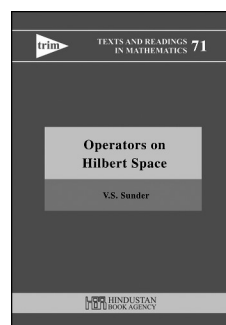
Operators on Hilbert Space

V. S. Sunder, *Institute of Mathematical Sciences, Chennai, India*

This book's principal goals are: (i) to present the spectral theorem as a statement on the existence of a unique continuous and measurable functional calculus, (ii) to present a proof without digressing into a course on the Gelfand theory of commutative Banach algebras, (iii) to introduce the reader to the basic facts concerning the various von Neumann-Schatten ideals, the compact operators, the trace-class operators and all bounded operators, and finally, (iv) to serve as a primer on the theory of bounded linear operators on separable Hilbert space.

A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: Hilbert space; The spectral theorem; Beyond normal operators; Appendix; Bibliography; Index.

Hindustan Book Agency

May 2015, 110 pages, Softcover, ISBN: 978-93-80250-74-8, 2010 *Mathematics Subject Classification:* 47-01, **AMS members US$32**, List US$40, Order code HIN/69

General Interest
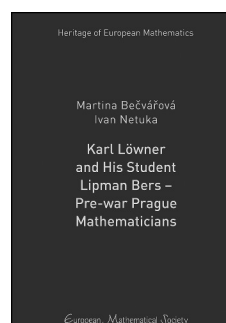
Karl Löwner and His Student Lipman Bers—Pre-war Prague Mathematicians

Martina Bečvářová and **Ivan Netuka**, *Charles University, Prague, Czech Republic*

This monograph is devoted to two distinguished mathematicians, Karl Löwner (1893–1968) and Lipman Bers (1914–1993), whose lives are dramatically interlinked with key historical events of the 20th century. Karl Löwner, Professor of Mathematics at the German University in

Prague (Czechoslovakia), was dismissed from his position because he was a Jew, and emigrated to the USA in 1939 (where he changed his name to Charles Loewner). Earlier, he had published several outstanding papers in complex analysis and a masterpiece on matrix functions. In particular, his groundbreaking parametric method in geometric function theory from 1923, which led to Löwner's celebrated differential equation, brought him worldwide fame and turned out to be a cornerstone in de Branges' proof of the Bieberbach conjecture.

Unexpectedly, Löwner's differential equation has gained recent prominence with the introduction of a conformally invariant stochastic process called stochastic Loewner evolution (SLE) by O. Schramm in 2000. SLE features in two Fields Medal citations from 2006 and 2010. Lipman Bers was the final Prague Ph.D. student of Löwner. His dissertation on potential theory (1938), completed shortly before his emigration and long thought to be irretrievably lost, was found in 2006. It is made accessible here for the first time, with an extensive commentary, to the mathematical community.

This monograph presents an in-depth account of the lives of both mathematicians, with special emphasis on the pre-war period. Löwner's teaching activities and professional achievements are presented in the context of the prevailing complex political situation and against the background of the wider development of mathematics in Europe. Each of his publications is accompanied by an extensive commentary, tracing the origin and motivation of the problem studied, and describing the state-of-art at the time of the corresponding mathematical field. Special attention is paid to the impact of the results obtained and to the later development of the underlying ideas, thus connecting Löwner's achievements to current research activity. The text is based on an extensive archival search, and most of the archival findings appear here for the first time.

This item will also be of interest to those working in number theory.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: Brief overview of Karl Löwner's life; Karl Löwner: Distinguished teacher and scholar; Publications of Karl Löwner before 1939; Bibliography of Karl Löwner; List of reviews by Karl Löwner; Lecture courses and seminars attended by Karl Löwner; Lecture courses and seminars delivered by Karl Löwner; Karl Löwner and dissertations at the German University in Prague; Karl Löwner lectures to the mathematical community; Brief overview of Lipman Bers' life; Lipman Bers: The final doctoral student of Löwner in Prague; L. Bers' dissertation on potential theory; Harmonisches Maß im Raume; Karl Löwner and Lipman Bers according to Marian Tracy's memory; Karl Löwner and Lipman Bers: Ruth Bers Shapiro recalls their friendship; Name index; Subject index.

Heritage of European Mathematics, Volume 10

April 2015, 310 pages, Hardcover, ISBN: 978-3-03719-144-6, 2010 *Mathematics Subject Classification:* 01A60, 01A70, 11R37, 11R39, 11S37, 11Fxx, 11Mxx, **AMS members US$65.60**, List US$82, Order code EMSHEM/10
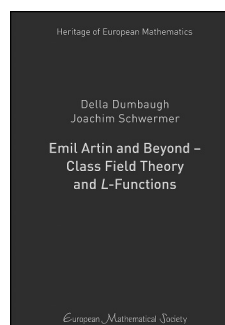
Emil Artin and Beyond—Class Field Theory and *L*-Functions

Della Dumbaugh, and **Joachim Schwermer**, *University of Vienna, Austria*

This book explores the development of number theory, and class field theory in particular, as it passed through the hands of Emil Artin, Claude Chevalley, and Robert Langlands in the middle of the twentieth century.

The volume consists of individual essays by the authors and two contributors, James Cogdell and Robert Langlands, and contains relevant archival material. Among these, the letter from Claude Chevalley to Helmut Hasse in 1935 is included, in which he introduces the notion of ideles and explores their significance, along with the previously unpublished thesis by Margaret Matchett and the seminal letter of Robert Langlands to André Weil of 1967 in which he lays out his ideas regarding a non-abelian class field theory. Taken together, these chapters offer a view of both the life of Artin in the 1930s and 1940s and the development of class field theory at that time. They also provide insight into the transmission of mathematical ideas, the careful steps required to preserve a life in mathematics at a difficult moment in history, and the interplay between mathematics and politics (in more ways than one).

Some of the technical points in this volume require a sophisticated understanding of algebra and number theory. The broader topics, however, will appeal to a wider audience that extends beyond mathematicians and historians of mathematics to include historically minded individuals, particularly those with an interest in the time period.

This item will also be of interest to those working in number theory.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: *I. Class field theory: From Artin's course in Hamburg to Chevalley's "Éléments idéaux:* Claude Chevalley's thesis on class field theory and his notion of "Éléments idéaux; Introduction; Letter from Claude Chevalley to Helmut Hasse, June 20, 1935; Letter from Helmut Hasse to Claude Chevalley, June 28, 1935; *II. Creating a life: Emil Artin in America:* Emigration, immigration and pre-remigration; Introduction; Letter from Solomon Lefschetz to Father John O'Hara, January 12, 1937; *III. The collaboration of Emil Artin and George Whaples:* The work of Artin and Whaples—A conceptual breakthrough in algebraic number theory; Introduction; George Whaples' application to the Institute for Advanced Study, School of Mathematics, Princeton, NJ, February 10, 1941; *IV. Margaret Matchett: Artin's student at Indiana and her thesis:* Margaret Matchett and her thesis "On the zeta function for ideles"; Introduction; Margaret Mathcett's doctoral dissertation "On the zeta function for ideles"; *V. L-functions by James W. Cogdell: L*-functions and non-abelian class field theory, from Artin to Langlands; *VI. Automorphic L-functions by Robert P. Langlands:* Letter from Robert Langlands to André Weil, January 1967; Funktorialität in der Theorie der automorphen Formen: Ihre Entdeckung und ihre Ziele; Einführung; Bibliography; Index.

Heritage of European Mathematics, Volume 9

March 2015, 245 pages, Hardcover, ISBN: 978-3-03719-146-0, 2010 *Mathematics Subject Classification:* 01A60, 01A70, 11R37, 11R39, 11S37, 11Fxx, 11Mxx, **AMS members US$60.80**, List US$76, Order code EMSHEM/9
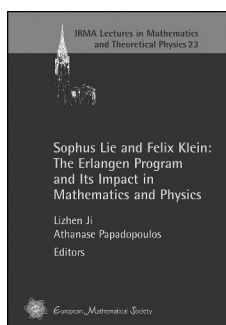
Sophus Lie and Felix Klein: The Erlangen Program and Its Impact in Mathematics and Physics

Lizhen Ji, *University of Michigan, Ann Arbor*, and **Athanase Papadopoulos**, *Université de Strasbourg, France*, Editors

The Erlangen program expresses a fundamental point of view on the use of groups and transformation groups in mathematics and physics. This volume is the first modern comprehensive book on that program and its impact in contemporary mathematics and physics. Klein spelled out the program, and Lie, who contributed to its formulation, is the first mathematician who made it effective in his work. The theories that these two authors developed are also linked to their personal history and to their relations with each other and with other mathematicians, including Hermann Weyl, Élie Cartan, Henri Poincaré, and many others. All these facets of the Erlangen program appear in this volume. The book is written by well-known experts in geometry, physics and the history of mathematics and physics.

A publication of the European Mathematical Society. Distributed within the Americas by the American Mathematical Society.

Contents: L. Ji, Sophus Lie, A giant in mathematics; **L. Ji**, Felix Klein: His life and mathematics; **J. J. Gray**, Klein and the Erlangen Programme; **H. Goenner**, Klein's "Erlanger Programme": Do traces of it exist in physical theories?; **N. A'Campo** and **A. Papadopoulos**, On Klein's so-called non-Euclidean geometry; **A, Vinogradov**, What are symmetries of PDEs and what are PDEs themselves?; **C. Frances**, Transformation groups in non-Riemannian geometry; **N. A'Campo** and **A. Papadopoulos**, Transitional geometry; **A. Papadopoulos** and **S. Yamada**, On the projective geometry of constant curvature spaces; **Y. B. Suris**, The Erlangen program and discrete differential geometry; **C. Meusburger**, Three-dimensional gravity—An application of Felix Klein's ideas in physics; **J.-B. Zuber**, Invariances in physics and group theory; List of contributors; Index.

IRMA Lectures in Mathematics and Theoretical Physics, Volume 23

April 2015, 348 pages, Hardcover, ISBN: 978-3-03719-148-4, 2010 *Mathematics Subject Classification:* 01-00, 01-02, 01A05, 01A55, 01A70, 22-00, 22-02, 22-03, 51N15, 51P05, 53A20, 53A35, 53B50, 54H15, 58E40, **AMS members US$40.80**, List US$51, Order code EMSILMTP/23

Mathematical Physics
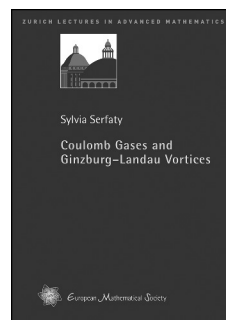
Coulomb Gases and Ginzburg–Landau Vortices

Sylvia Serfaty, *Courant Institute of Mathematical Sciences, New York, NY*

The topic of this book is systems of points in Coulomb interaction, in particular, the classical Coulomb gas, and vortices in the Ginzburg–Landau model of superconductivity. The classical Coulomb and Log gases are classical statistical mechanics models, which have seen important developments in the mathematical literature due to their connection with random matrices and approximation theory. At low temperature these systems are expected to "crystallize" to so-called Fekete sets, which exhibit microscopically a lattice structure. The Ginzburg–Landau model, on the other hand, describes superconductors. In superconducting materials subjected to an external magnetic field, densely packed point vortices emerge, forming perfect triangular lattice patterns, so-called Abrikosov lattices.

This book describes these two systems and explores the similarity between them. It presents the mathematical tools developed to analyze the interaction between the Coulomb particles or the vortices, at the microscopic scale, and describes a "renormalized energy" governing the point patterns. This is believed to measure the disorder of a point configuration and to be minimized by the Abrikosov lattice in dimension 2.

This book gives a self-contained presentation of results on the mean field limit of the Coulomb gas system, with or without temperature, and of the derivation of the renormalized energy. It also provides a streamlined presentation of the similar analysis that can be performed for the Ginzburg–Landau model, including a review of the vortex-specific tools and the derivation of the critical fields, the mean-field limit, and the renormalized energy.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: Introduction; The leading order behavior of the Coulomb gas; Splitting the Hamiltonian; Definition(s) and properties of renormalized energy; Deriving $\mathcal{W}$ as the large n limit: lower bound via a general abstract method; Deriving $\mathcal{W}$ as the large n limit: screening, upper bound, and consequences; The Ginzburg–Landau functional: Presentation and heuristics; Main mathematical tools for Ginzburg–Landau; The leading order behavior for Ginzburg–Landau; The splitting and next order behavior for Ginzburg–Landau; Bibliography; Index.

Zurich Lectures in Advanced Mathematics, Volume 21

March 2015, 165 pages, Softcover, ISBN: 978-3-03719-152-1, 2010 *Mathematics Subject Classification:* 82B05, 82B21, 82B26, 15B52, 82D55, 35A15, 35J20, 35J60, **AMS members US$30.40**, List US$38, Order code EMSZLEC/21

Number Theory
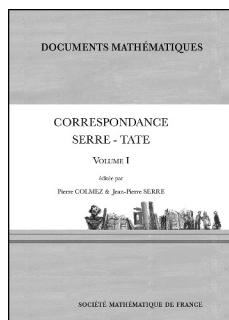
Correspondance Serre-Tate: Volume I (1956–1973)

Pierre Colmez, *Institut de Mathématique de Jussieu, Paris V, France*, and **Jean-Pierre Serre**, *Collège de France, Paris, France*, Editors

This volume and its companion volume (see SMFDM/14) reproduce, with notes and comments, the correspondence between Jean-Pierre Serre and John Tate from 1956 to 2000. They also contain a selection of their email correspondence after 2000.

The texts are reproduced in their original language: in English or in French. Most of them are from 1956–1976. They treat questions such as the write-up of Bourbaki's Elements, Galois cohomology, rigid geometry, Tate's conjectures on algebraic cycles, formal and p-divisible groups, complex multiplication, and modular forms: congruence properties, weight 1 forms, and Galois representations.

These volumes should be useful to people interested in number theory or the history of mathematics.

This item will also be of interest to those working in algebra and algebraic geometry.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: Correspondence Between Jean-Pierre Serre and John Tate, 1956–1973.

Documents Mathématiques, Number 13

May 2015, 448 pages, Softcover, ISBN: 978-2-85629-802-2, 2010 *Mathematics Subject Classification:* 11, 14, **AMS members US$96**, List US$120, Order code SMFDM/13
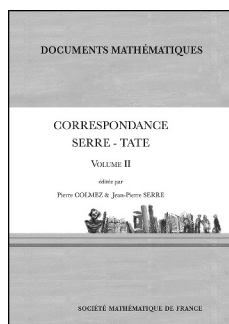
Correspondance Serre-Tate: Volume II (1973–2000)

Pierre Colmez, *Institut de Mathématique de Jussieu, Paris V, France*, and **Jean-Pierre Serre**, *Collège de France, Paris, France*, Editors

This volume and its companion volume (see SMFDM/13) reproduce, with notes and comments, the correspondence between Jean-Pierre Serre and John Tate from 1956 to 2000. They also contain a selection of their email correspondence after 2000.

The texts are reproduced in their original language: in English or in French. Most of them are from 1956–1976. They treat questions

such as the write-up of Bourbaki's Elements, Galois cohomology, rigid geometry, Tate's conjectures on algebraic cycles, formal and p-divisible groups, complex multiplication, and modular forms: congruence properties, weight 1 forms, and Galois representations.

These volumes should be useful to people interested in number theory or the history of mathematics.

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A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: Correspondence Between Jean-Pierre Serre and John Tate, 1973–2000.

Documents Mathématiques, Number 14

May 2015, 521 pages, Softcover, ISBN: 978-2-85629-803-9, 2010 *Mathematics Subject Classification:* 11, 14, **AMS members US$96**, List US$120, Order code SMFDM/14
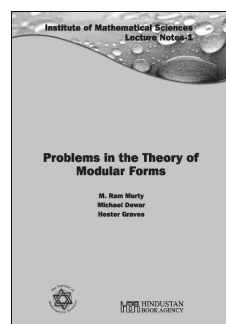
Problems in the Theory of Modular Forms

M. Ram Murty, **Michael Dewar**, and **Hester Graves**, *Queen's University, Kingston, Ontario, Canada*

This book introduces the reader to the fascinating world of modular forms through a problem-solving approach. As such, it can be used by undergraduate and graduate students for self-instruction. The topics covered include q-series, the modular group, the upper half-plane, modular forms of level one and higher level, the Ramanujan τ-function, the Petersson inner product, Hecke operators, Dirichlet series attached to modular forms, and further special topics. It can be viewed as a gentle introduction for a deeper study of the subject. Thus, it is ideal for non-experts seeking an entry into the field.

This item will also be of interest to those working in algebra and algebraic geometry.

A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Contents: *Part I. Problems:* Jacobi's q-series; The modular group; The upper half-plane; Modular forms of level one; The Ramanujan π-function; Modular forms of higher level; The Petersson inner product; Hecke operators of higher level; Dirichlet series and modular forms; The Petersson inner product; Hecke operators of higher level; Dirichlet series and modular forms; Special topics; *Part II:* Solutions to problems in Part I; Special topics; A short guide for further reading; References; Index.

Hindustan Book Agency

March 2015, 310 pages, Softcover, ISBN: 978-93-80250-72-4, 2010 *Mathematics Subject Classification:* 11F11, 11F03, 11F06; 11F12, 11F20, 11F25, 11F30, 11F33, 11F66, 11F67, **AMS members US$46.40**, List US$58, Order code HIN/68

Classified Advertisements

Positions available, items for sale, services available, and more

MICHIGAN

MICHIGAN STATE UNIVERSITY
Departments of Mathematics and Statistics and Probability
Director of Actuarial Sciences Program

The Departments of Mathematics and of Statistics and Probability at Michigan State University invite applications for the position of Director of the Actuarial Science Program. The position is open-rank, non-tenure stream, and fixed-term. The director will have chief responsibility for the management of the Program, including oversight of the BS degree in Actuarial Sciences, outreach, and university development. In addition, the director will have responsibilities including course instruction and student advising. The successful candidate will demonstrate outstanding leadership and administrative skills, excellent writing skills, and ability to work well in a team environment. Qualifications: Doctorate preferred in Actuarial Science or equivalent; Associate or Fellow status with the Society of Actuaries, the Casualty Actuarial Society, or similarly recognized actuarial professional association. Salary commensurate with experience.

The application should include a CV or resume, a vision statement for the future of the Actuarial Program, a statement of teaching philosophy, and at least three letters of recommendation.

Review of applications will begin April 1, 2015, and continue until the position is filled.

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MSU is committed to achieving excellence through cultural diversity. The university actively encourages applications and/or nominations of women, persons of color, veterans and persons with disabilities, and is committed to the hiring of dual-career couples. To apply go to www.jobs.msu.edu, and search for posting number 1129.

000016

SOUTH CAROLINA

UNIVERSITY OF SOUTH CAROLINA
Vasil Popov Prize, 2016
Call for Nominations

The Vasil Popov Prize is awarded every three years for outstanding research in fields related to the work of Vasil A. Popov, who is best known for his contributions to Approximation Theory. Candidates must have received their PhD within the previous six years. Nominations, to include a brief description of the relevant work and a vita of the nominee, should be sent to Pencho Petrushev, Chair, Popov Prize Selection Committee, Interdisciplinary Mathematics Institute, University of South Carolina, Columbia, SC 29208; email: popov.prize@gmail.com. The deadline for nominations is November 15, 2015. The Prize will be awarded in May of 2016 at the Fifteenth International Conference in Approximation Theory, in San Antonio, Texas. For further information, visit imi.cas.sc.edu/popov-prize-call-nominations/

000015

Meetings & Conferences of the AMS

Chicago, Illinois

Loyola University Chicago

October 3–4, 2015

Saturday – Sunday

Meeting #1112

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: June 2015
Program first available on AMS website: August 20, 2015
Issue of *Abstracts*: Volume 36, Issue 4

Deadlines

For organizers: Expired
For abstracts: August 11, 2015

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Julia Chuzhoy, Toyota Technological Institute at Chicago, *Title to be announced.*

Andrew Neitzke, The University of Texas at Austin, *Title to be announced.*

Sebastien Roch, University of Wisconsin-Madison, *Title to be announced.*

Peter Sarnak, Princeton University, *Title to be announced* (Erdős Memorial Lecture).

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at `www.ams.org/cgi-bin/abstracts/abstract.pl`.

Algebraic Methods Common to Association Schemes, Hopf Algebras, Tensor Categories, Finite Geometry, and Related Areas (Code: SS 1A), **Harvey Blau**, Northern Illinois University, **Sung Y. Song**, Iowa State University, and **Bangteng Xu**, Eastern Kentucky University.

Algebraic Statistics and its Interactions with Combinatorics, Computation, and Network Science (Code: SS 13A), **Sonja Petrovic**, Illinois Institute of Technology, and **Despina Stasi**, University of Cyprus and Illinois Institute of Technology.

Algebraic and Combinatorial Invariants of Knots (Code: SS 17A), **Micah Chrisman**, Monmouth University, **Heather Dye**, McKendree University, **Aaron Kaestner**, North Park University, **Louis Kauffman**, University of Illinois at Chicago, and **Emily Peters**, Loyola University Chicago.

Analysis of Partial Differential Equations and Fluid Dynamics (Code: SS 31A), **Mimi Dai**, University of Illinois at Chicago, **Vera Mikyoung Hur**, University of Illinois at Urbana-Champaign, and **Yao Yao**, University of Wisconsin-Madison.

Automorphic Forms and Representations (Code: SS 21A), **Moshe Adrian**, University of Toronto, and **Shuichiro Takeda** and **Aaron Wood**, University of Missouri-Columbia.

Automorphisms of Riemann Surfaces and Related Topics (Code: SS 11A), **S. Allen Broughton**, Rose-Hulman Institute

of Technology, **Peter Turbek**, Purdue University Calumet, **Anthony Weaver**, Bronx Community College, the City University of New York, and **Aaron Wootton**, University of Portland.

Coding Theory and Its Applications (Code: SS 24A), **W. Cary Huffman**, Loyola University Chicago.

Cohomology of Algebras and Deformation Theory (Code: SS 16A), **Anthony Giaquinto**, Loyola University Chicago, **Mihai D. Staic**, Bowling Green State University, and **Alin Stancu**, Columbus State University.

Combinatorial and Computational Algebra (Code: SS 4A), **David Cook II**, Eastern Illinois University, and **Sonja Mapes**, University of Notre Dame.

Combinatorial and Geometric Representation Theory (Code: SS 9A), **Ben Salisbury**, Central Michigan University, and **Peter Tingley**, Loyola University Chicago.

Commutative Algebra (Code: SS 27A), **Youngsu Kim** and **Paolo Mantero**, University of California, Riverside, and **Jonathan Montano**, Purdue University.

Computability Theory and Applications (Code: SS 19A), **Denis Hirschfeldt**, University of Chicago, and **Steffen Lempp**, University of Wisconsin-Madison.

Enumerative Algebraic and Geometric Combinatorics (Code: SS 5A), **Kyle Petersen**, DePaul University, and **Steven Klee**, Seattle University.

Enumerative Combinatorics and Graph Theoretic Applications (Code: SS 12A), **Adam Goyt**, Minnesota State University, and **Lara Pudwell**, Valparaiso University.

Ergodic and Symbolic Actions of Amenable Groups (Code: SS 39A), **Ayşe Şahin** and **Ilie Ugarcovici**, DePaul University.

Frontiers in Computational Mathematics (Code: SS 25A), **Sou-Cheng (Terrya) Choi**, NORC at the University of Chicago, and Illinois Institute of Technology.

Generalized Derivatives (Code: SS 36A), **J. Marshall Ash**, DePaul University, and **Paul Musial**, Chicago State University.

Geometric Partial Differential Equations (Code: SS 26A), **Morgan Sherman**, California Polytechnic State University, and **Valentino Tosatti** and **Ben Weinkove**, Northwestern University.

Geometric Perspectives in Knot Theory (Code: SS 14A), **David Krcatovich** and **Allison Moore**, Rice University.

Graduate Student Perspectives on Undergraduate Research (Code: SS 32A), **Mindy Capaldi** and **Zsuzsanna Szaniszlo**, Valparaiso University.

Groups, Rings, Group Rings, and Hopf Algebras (celebrating the 75th birthday of Donald S. Passman) (Code: SS 2A), **Jeffrey Bergen**, **Stefan Catoiu**, and **William Chin**, DePaul University.

History of Mathematics (Code: SS 10A), **Steven Jordan**, Loyola University Chicago.

Hopf Algebraic Combinatorics (Code: SS 6A), **Marcelo Aguiar**, Cornell University, and **Aaron Lauve**, Loyola University Chicago.

K-loops, Neardomains, Loops, and Nonassociative Division Algebras (Code: SS 38A), **Alper Bulut**, American University of the Middle East, **C. E. Ealy Jr.**, Western Michigan University, **Hubert Kiechle**, University of Hamburg, **Benjamin Phillips**, University of Michigan Dearborn, and **J. D. Phillips**, Northern Michigan University.

The Langlands Program and Related Topics (Code: SS 34A), **Andrei Jorza**, University of Notre Dame, and **Martin Luu**, University of Illinois at Urbana-Champaign.

The Mathematics of Evolution (Code: SS 3A), **Ruth Davidson**, University of Illinois Urbana-Champaign, and **Ruriko Yoshida**, University of Kentucky.

Mathematical Analysis and Computation of Nematic Liquid Crystals (Code: SS 20A), **Patricia Bauman**, **Daniel Phillips**, and **Changyou Wang**, Purdue University.

Metric Spaces: Geometry, Group Theory, and Dynamics (Code: SS 18A), **Tullia Dymarz**, University of Wisconsin-Madison, and **Anton Lukyanenko**, University of Michigan.

Model Theory (Code: SS 15A), **Uri Andrews**, University of Wisconsin-Madison, **Isaac Goldbring**, University of Illinois at Chicago, and **Maryanthe Malliaris**, University of Chicago.

Nonlinear PDEs and Calculus of Variations (Code: SS 22A), **Emmanuel Barron**, **Marian Bocea**, and **Robert Jensen**, Loyola University Chicago.

Nonlocal Diffusions (Code: SS 30A), **Jinqiao Duan**, **Xiaofan Li**, and **Xiaoxia Xie**, Illinois Institute of Technology.

Probability Theory (Code: SS 29A), **Antonio Auffinger**, Northwestern University, **Jian Ding**, University of Chicago, and **Sebastien Roch**, University of Wisconsin-Madison.

Recent Advances in Non-Commutative Analysis (Code: SS 37A), **Hari Bercovici**, Indiana University, and **John Williams**, Universität des Saarlandes.

Recent Developments in Graph and Matroid Theory (Code: SS 23A), **Sergei Bezrukov**, University of Wisconsin-Superior, **Dalibor Froncek**, University of Minnesota Duluth, and **Xiaofeng Gu** and **Steven Rosenberg**, University of Wisconsin-Superior.

Recent Developments in the Theory and Applications of Reaction Network Models (Code: SS 28A), **Carsten Conradi**, Max Planck Institute, and **Casian Pantea**, West Virginia University.

Singularities in Algebra, Geometry and Topology (Code: SS 33A), **Manuel Gonzalez Villa** and **Laurentiu Maxim**, University of Wisconsin-Madison.

Stochastic Analysis With Applications to Quantitative Finance (Code: SS 35A), **Igor Cialenco** and **Ruoting Gong**, Illinois Institute of Technology.

Topics in Graph Theory, Hypergraphs and Set Systems (Code: SS 8A), **John Engbers**, Marquette University, and **David Galvin**, University of Notre Dame.

Variational Analysis, Optimization, and Control (Dedicated to Terry Rockafellar on the occasion of his 80th birthday) (Code: SS 7A), **Rafal Goebel**, Loyola University Chicago.

Poster Session

A poster session is planned for this meeting. Space is limited, and priority will be given to graduate students and early career researchers who are not otherwise presenting at the conference. However, anyone is welcome to submit. **The submission deadline is August 11, 2015**, and decisions will be sent out by the university by Sept 1. Please submit poster proposals at `https://docs.google.com/forms/d/1qIrJpvKkahgopTZ0pKwq6vDnQIT7kMZCjULH8Ld_jAs/viewform?c=0&w=1`. Questions should be directed to Dr. Peter Tingley (`ptingley@luc.edu`).

Accommodations

Participants should make their own arrangements directly with the hotel of their choice. Special discounted rates were negotiated with the hotels listed below. **Rates quoted do not include a room tax of 16.4%**. Participants should mention "AMS Meeting on the Loyola campus" to receive the discounted rates. The AMS is not responsible for rate changes or for the quality of the accommodations. **Hotels have varying cancellation and early checkout penalties; be sure to ask for details.**

Best Western University Plaza, 1501 Sherman Ave., Evanston, IL 60201; 1-847-491-6400 (phone) or 1-847-328-3090 (fax); US$149.95/single or double; features coffee/tea in the lobby, fitness facilities, and seasonal outdoor pool, free WiFi in all rooms, and complimentary breakfast; parking is US$14/day; about four miles from campus. **Deadline for reservations is September 2, 2015**.

Hilton Garden Inn, Chicago North Shore/Evanston, 1818 Maple Ave., Evanston, IL 60201; 1-847-475-6400; US$189/one king bed or two double beds; rooms have microwave; 24-hour business center, complimentary Internet access throughout the hotel; fitness center with pool; on-site restaurant is open for breakfast and dinner with bar service; in-room dining is available. Guests may make reservations toll free at: 1-877-STAY HGI

Or direct with the hotel at: 847-475-6400: Ask for "Inhouse reservations" Monday-Friday.

Or online at: `www.evanston.hgi.com` – Enter the Group Meeting or Conference code "AMS" when prompted. Parking is US$13/day; about five miles from campus. **Deadline for reservations is September 2, 2015**.

Hotel Indigo, 1244 Dearborn Parkway, Chicago, IL 60610; 1-312-787-4980 or 1-312-266-0978 (fax); US$170/single or double; standard Internet is free for all guests and can be upgraded in your room for a fee; valet parking is US$47/day; located in the Gold Coast neighborhood with many restaurants nearby; about seven miles from campus. **Deadline for reservations is August 5, 2015.**

Hilton Orrington/Evanston, 1710 Orrington Ave., Evanston, IL 60201, 1-847-866-8700 or 1-866 539-8117 (toll free) or email `ordoe-reservations@hilton.com`; US$169/single or double; US$179/triple; US$189/quad; rooms have a coffee maker, 24-hour room service; free WiFi in public areas; restaurant with bar on premises; business center; valet parking; about 4.5 miles from campus. **Deadline for reservations is September 2, 2015.**

While the AMS has no agreement with the following properties, some participants may find them convenient:

Super 8, 7300 North Sheridan Rd., Chicago, IL 60626, 1-866-539-8117 (information) 1-800-454-3213 or 1-866-539-8117 (reservations); rates vary (US$100-147 at the time this announcement was published); rooms include coffee maker, microwave, refrigerator, free WiFi in public areas (included in some sleeping rooms); about 1.5 miles from campus.

DoubleTree by Hilton, 9599 Skokie Blvd., Skokie, IL 60077; 1-847-679-7000 or 1-847-679-0810 (fax); rates vary and were US$152/single or double at the time this announcement was published; restaurant on premises (including room service); business center services including free printing; fitness center; indoor and outdoor pools; Internet available; parking is complimentary; about 8 miles from campus.

Hotel Cass, 640 N. Wabash, Chicago, IL 60611, 1-312-447-2960; Room rates were approximately US$200 at the time of this printing; high speed Internet is available throughout the building; tea and coffee are complimentary in the lobby; complimentary hot breakfast; fitness center; complimentary use of the business center; about 7.5 miles from campus.

Dining Information

There are a number of dining halls and cafes spread throughout campus. In addition to all you can eat options in the dining halls, there is food-court style dining at the Damen Food Court, a sustainable menu at Engrained, and coffee and snacks at Center Stage. For more information and a complete list of on campus dining options, visit Loyola Dining Services at `luc.campusdish.com/`.

There are many restaurants and fast food options within walking distance of campus:

Leona's, 6935 North Sheridan Rd., Chicago, IL 60626, 773-764-5757; `www.leonas.com`. Leona's offers affordable Italian dining along with takeout and delivery options. Open Monday–Thursday 11:00 a.m.–11:00 p.m.; Friday and Saturday, 11:00 a.m.–midnight, Sunday noon–11:00 p.m.

Giordano's, 6836 N. Sheridan Rd, Chicago, IL 60626, 773-262-1313; `www.giordanos.com`. Giordano's is known for their famous Chicago deep dish pizza. Open daily from 10:30 a.m. to midnight.

Royal Coffee, 6764 N. Sheridan Rd., Chicago, IL 60626, 773-761-8100; `www.royalcoffeechicago.com`. Royal Coffee is a coffee shop up Sheridan Rd. that also offers a selection of Ethiopian food. Open Sunday–Thursday, 6:00 a.m.–9:00 p.m., and Friday and Saturday, 6:00 a.m.–10:00 p.m.

bopNgrill, 6604 N. Sheridan Rd., Chicago, IL 60626, 773-654-3224; `www.bngrill.com`. BopNgrill offers a selection of Korean food and fantastic burgers. It was even featured on Diners, Drive-ins and Dives. Open Monday–Friday, 11:00 a.m.–10:00 p.m., and Saturday and Sunday, noon–10:00 p.m.

Felice's, 6441 N. Sheridan Rd., Chicago, IL 60626, 773-508-7990; `www.felicesromanstyle.com`. The only student-run pizzeria in the country. Open Monday–Thursday, 11:00 a.m.–10:00 p.m.; Friday and Saturday, 11:00 a.m.–2:30 a.m.; and Sunday, 11:00 a.m.–8:00 p.m.

Pete's Pizza, 1100 West Granville Avenue, Chicago, IL 60660, 773-262-4040; `www.petespizza.com`. In addition to pizza and sandwiches, Pete's offers gelato, desserts, and a coffee bar. Open to dine in Monday–Thursday, 9:00 a.m.–9:00 p.m.; Friday and Saturday, 10:00 a.m.–10:00 p.m.; and Sunday, noon to 9:00 pm. Additional hours for carry-out and delivery.

Dak, 1104 West Granville Avenue, Chicago, IL 60660, 773-754-0255; `www.dakwings.com`. Dak offers Korean chicken wings, rice bowls, and more at an affordable price. Open daily 11:30 a.m.–9:00 p.m.

Nori, 1235 W. Devon Ave., Chicago, IL 60660, 773-262-5216; `www.norichicago.com`. Nori is a tasty sushi and noodles restaurant. Open Sunday–Thursday, 11:00 am–10:00 pm; Friday and Saturday 11:00 a.m.–10:30 p.m.

Uncommon Ground, 1401 W. Devon Avenue, Chicago, IL 60660, 773-465-9801; `www.uncommonground`.com. Uncommon Ground offers new American food with organic ingredients and live music daily. Their menu changes weekly and with the seasons. Open Monday–Thursday, 11:00 a.m.–10:00 p.m., Friday, 11:00 a.m.–midnight, Saturday, 9:00 a.m.–midnight, and Sunday, 9:00 a.m.–10:00 p.m.

Bar 63, 6341 North Broadway, Chicago, IL 60660, 773-942-6269. A sports bar with classic pub food. Open Monday–Thursday, 4:00 p.m.–2:00 a.m., Friday and Sunday, 11:00 a.m.–2:00 a.m., and Saturday, 11:00 a.m.–3:00 a.m.

Registration and Meeting Information

Advance Registration

Advance registration for this meeting will open on **August 3**. Advance registration fees will be US$57 for AMS members, US$80 for nonmembers, and US$5 for students, unemployed mathematicians, and emeritus members.

On-site Information and Registration

The Registration Desk and the AMS Book Exhibit will be located in the Cuneo Hall, 6430 N. Kenmore Ave. Invited Addresses will be held in the Quinlan Life Sciences Building, 1050 W. Sheridan Rd. Sessions will be held in the Institute for Environmental Stability, 6349 N. Kenmore Ave. The Registration Desk will be open on Friday, March 27, 12:00 p.m.–4:30 p.m. and Saturday, March 28, 7:30 a.m.–4:00 p.m. Fees on-site will be US$57 for AMS Members, US$80 for nonmembers; and US$5 for students, unemployed mathematicians, and emeritus members. Fees are payable on-site via cash, check, or credit card.

Special Needs

It is the goal of the AMS to ensure that its conferences are accessible to all, regardless of disability. The AMS will strive, unless it is not practicable, to choose venues that are fully accessible to the physically handicapped. If special needs accommodations are necessary in order for you to participate in an AMS Sectional Meeting, please communicate your needs in advance to the AMS Meetings Department by:

- Registering early for the meeting
- Checking the appropriate box on the registration form, and
- Sending an email request to the AMS Meetings Department at `mmsb@ams.org` or `meet@ams.org`.

Other Activities

Book Sales: Stop by the on-site AMS bookstore and review the newest titles from the AMS, enjoy up to 25% off all AMS publications, or take home an AMS t-shirt!

Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Local Information and Maps

This meeting will take place on the Lake Shore Campus of Loyola University Chicago. A campus map can be viewed at `www.luc.edu/commencement/guests/travel/lsc-map/`. Information about the Loyola University Department of Mathematics and Statistics can be found on their website at `www.luc.edu/math/`. Please watch the website at `www.ams.org/meetings/sectional/sectional.html` for additional information on this meeting. Please visit the University website at `www.luc.edu/` for additional information about the campus.

Parking

Please check the meeting website at `www.ams.org/meetings/sectional/sectional.html` for updates.

Travel

The meeting will be held at Loyola University Chicago, Lake Shore Campus, 1032 W. Sheridan Rd., Chicago, IL.

By Air: The closest airport to the university is O'Hare International Airport, 10000 Bessie Coleman Dr., Chicago, IL 60666; `www.flychicago.com`. The distance from O'Hare International Airport to the campus at the Loyola University Chicago is approximately 11 miles.

Taxis: Taxi service is available from the airport for approximately US$40 to $50 to the listed hotels and the university. Taxis are readily available at the airport. For your protection, do not accept rides from drivers outside the cab stand or in the departure area of the terminal roadways. All taxis should have a working meter to calculate the fare based on time and mileage.

To determine your taxi fare:

Base Fare	$3.25
Each additional mile	$1.80
Every 36 seconds of time elapsed	$0.20
First additional passenger*	$1
Each additional passenger after first passenger*	$0.50
Airport Departure/Arrival Tax	$2

*Passengers aged 13 through 64 years old are charged an additional passenger fee.

* Tolls are an extra charge to the passenger.

* The fare does not include a tip.

* There is no extra charge for baggage, baggage handling, or payment by credit/debit card.

* If your driver voluntarily chooses to assist you, tipping is appropriate.

Trips to suburbs and not from the airport: The rate of fare is straight meter to the city limits PLUS one-half the straight metered fare from the city limit to the suburban destination.

Car Rental: Rental cars are available through a number of agencies at the airport. Please visit the airport website for information on rental car companies in Chicago.

Driving Directions: Please visit your favorite travel website to determine the best routes (e.g. `Google maps`; `mapquest.com`, etc.).

Public Transportation: See `www.transitchicago.com` for bus and CTA schedules to chart courses to your meeting and hotel destinations. The Lake Shore Campus (LSC) is conveniently located off the CTA Red Line, the Loyola "L" station at 1032 W. Sheridan Rd. The CTA bus 147 also drops off directly in front of the LSC.

Weather

In early October the weather in Chicago is generally in the mid 60s F. during the day, dropping to 50 degrees F. in the evening. Visitors should check weather forecasts in advance of their arrival and be prepared for changing weather conditions.

Information for International Participants

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the U.S. found at `sites.nationalacademies.org/pga/biso/visas/` and `travel.state.gov/visa/visa_1750.html`. If you need a preliminary conference invitation in order to secure a visa, please send your request to `aba@ams.org`.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of "binding" or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:

- family ties in home country or country of legal permanent residence

- property ownership

- bank accounts

- employment contract or statement from employer stating that the position will continue when the employee returns;

* Visa applications are more likely to be successful if done in a visitor's home country than in a third country;

* Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;

* Include a letter of invitation from the meeting organizer or the U.S. host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;

* If travel plans will depend on early approval of the visa application, specify this at the time of the application;

* Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the websites above for the most up-to-date information.

Social Networking

Participants are encouraged to tweet about the meeting using the hashtag #AMSmtg.

Memphis, Tennessee

University of Memphis

October 17–18, 2015

Saturday – Sunday

Meeting #1113

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: August 2015
Program first available on AMS website: September 3, 2015
Issue of *Abstracts*: Volume 36, Issue 3

Deadlines

For organizers: Expired
For abstracts: August 25, 2015

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Mark van Hoeij, Florida State University, *Title to be announced.*

Vaughan Jones, Vanderbilt University, *Title to be announced.*

Mette Olufsen, North Carolina State University, *Title to be announced.*

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

Advances in Operator Theory and Applications, in memory of James Jamison (Code: SS 5A), **Fernanda Botelho**, University of Memphis, and **T.S.S.R.K. Rao**, Indian Statistical Institute Bangalore.

Analysis of Differential and Integral Equations (Code: SS 18A), **D.P. Dwiggins** and **T. Hagen**, University of Memphis.

Banach Spaces and Applications (Code: SS 4A), **Anna Kaminska**, **Peikee Lin**, and **Bentuo Zheng**, University of Memphis.

Cahn-Hilliard and Related Equations and Applications. (Code: SS 11A), **Giséle Ruiz Goldstein**, University of Memphis, and **Alain Miranville**, Université de Poitiers.

Computational Analysis (Code: SS 1A), **George Anastassiou**, University of Memphis.

Control and Inverse Problems for Partial Differential Equations (Code: SS 6A), **Matthias Eller**, Georgetown University, **Shitao Liu**, Clemson University, and **Roberto Triggiani**, University of Memphis.

Difference Equations and Applications. (Code: SS 12A), **Michael A. Radin**, Rochester Institute of Technology, and **Youssef Raffoul**, University of Dayton.

Ergodic Theory (Code: SS 8A), **James T. Campbell** and **Mate Wierdl**, University of Memphis.

Evolution Equations and Partial Differential Equations (Code: SS 19A), **Jerome A. Goldstein**, University of Memphis, **Rainer Nagel**, Universitaet Tuebingen, and **Guillermo Reyes**, University of Southern California.

Extremal Graph Theory (in memory of Ralph Faudree) (Code: SS 3A), **Paul Balister**, University of Memphis, **Béla Bollobás**, University of Cambridge UK, and University of Memphis, and **Vladimir Nikiforov**, University of Memphis.

Fractal Geometry and Dynamical Systems (Code: SS 2A), **Mrinal Kanti Roychowdhury**, University of Texas-Pan American.

Probabilistic Combinatorics (Code: SS 17A), **Paul Balister**, University of Memphis, and **Béla Bollobás**, University of Cambridge UK, and University of Memphis.

Recent Advances in Commutative Algebra. (Code: SS 13A), **Sandra Spiroff**, University of Mississippi, and **Lance Miller**, University of Arkansas.

Recent Developments in the Statistical Analysis of Large Clustered Data (Code: SS 10A), **E. Olusegun George**, University of Memphis.

Spectra of Graphs and Hypergraphs. (Code: SS 9A), **Vladimir Nikiforov**, University of Memphis.

Stabilization, Control, and Analysis of Evolutionary Partial Differential Equations (Code: SS 7A), **George Avalos**, University of Nebraska Lincoln, **Scott Hansen**, Iowa State University, and **Justin Webster**, North Carolina State University & College of Charleston.

The Analysis, Geometry, and Topology of Groupoids (Code: SS 15A), **Emily Proctor**, Middlebury College, and **Christopher Seaton**, Rhodes College.

Topological Combinatorics (Code: SS 14A), **Eric Gottlieb**, Rhodes College, and **Russ Woodroofe**, Mississippi State University.

von Neumann Algebras (Code: SS 16A), **Vaughan Jones**, Vanderbilt University, and **David Penneys**, University of California Los Angeles.

Fullerton, California

California State University, Fullerton

October 24–25, 2015

Saturday – Sunday

Meeting #1114

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2015
Program first available on AMS website: September 10, 2015
Issue of *Abstracts*: Volume 36, Issue 4

Deadlines

For organizers: Expired
For abstracts: September 1, 2015
The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Mina Aganagic, University of California, Berkeley, *Title to be announced.*

John Lott, University of California, Berkeley, *Title to be announced.*

Eyal Lubetzky, Microsoft Research, Redmond, *Title to be announced.*

Zhiwei Yun, Stanford University, *Title to be announced.*

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

Algebraic and Combinatorial Structures in Knot Theory (Code: SS 9A), **Allison Henrich**, Seattle University, **Aaron M. Kaestner**, North Park University, **Sam Nelson**, Claremont McKenna College, and **Matt Rathbun**, California State University, Fullerton.

Analysis on Metric Spaces (in honor of Fred Gehring on the occasion of his 90th birthday) (Code: SS 23A), **Zair Ibragimov**, California State University, Fullerton.

Applied Mathematics in Industry: In Memory of Professor John G. Pierce (1942-2015) (Code: SS 8A), **Charles H. Lee** and **Angel R. Pineda**, California State University, Fullerton.

Fixed Point Theory and Applications (Code: SS 10A), **Clement B. Ampadu**, **Talat Nazir**, Malardalen University, and **Xavier A. Udo-Utun**, University of Uyo.

Geometric Analysis (Code: SS 1A), **John Lott**, University of California, Berkeley, and **Aaron Naber**, Northwestern University.

History and Philosophy of Mathematics (Code: SS 15A), **Jim Tattersall**, Providence College, and **Shawn McMurran**, California State University, San Bernardino.

Homological Methods in Commutative Algebra (Code: SS 22A), **Amanda Croll**, Concordia University, Irvine, and **Jack Jeffries**, University of Michigan.

Humanistic Mathematics (Code: SS 20A), **Mark Huber**, Claremont McKenna College, and **Gizem Karaali**, Pomona College.

Mathematical Techniques in Quantum Theories and Quantum Finance, with applications (Code: SS 11A), **Alfonso F. Agnew**, California State University at Fullerton, and **David Carfi**, University of Messina, Italy.

Mathematical/Statistical Modeling and Its Applications to Science and Engineering (Code: SS 19A), **Kanadpriya Basu**, University of Texas at El Paso.

Mathematicians and Outreach Programs (Code: SS 2A), **Olga Radko**, University of California Los Angeles, and **Bodgan D. Suceava**, California State University, Fullerton.

Recent Advances in Computational and Mathematical Biology (Code: SS 16A), **Fengzhu Sun**, University of Southern California, and **Jianjun Paul Tian** and **Mary Ballyk**, New Mexico State University.

Recent Advances in Finite Groups and their Representations (Code: SS 5A), **Adam Glesser**, California State University, Fullerton, and **Mandi Schaeffer Fry**, Metropolitan State University of Denver.

Recent Advances in Number Theory (Code: SS 18A), **Christopher Lyons**, California State University, Fullerton, and **Karl Rubin** and **Alice Silverberg**, University of California, Irvine.

Recent Developments in Nonlinear Partial Differential Equations (Code: SS 12A), **Changyou Wang**, Purdue University, and **Yifeng Yu**, University of California at Irvine.

Recent Results in Operator Theory and Operator Algebras (Code: SS 14A), **Asuman G. Aksoy**, Claremont McKenna College, **Don Hadwin**, University of New Hampshire, and **Hassan Yousefi**, California State University, Fullerton.

Research in Mathematics by Early Career Graduate Students (Code: SS 7A), **Tamas Forgacs**, **Carmen Caprau**, and **Oscar Vega**, California State University, Fresno.

Spatial Graphs (Code: SS 13A), **Erica Flapan**, Pomona College, **Thomas Mattman**, California State University, Chico, **Blake Mellor**, Loyola Marymount University, **Ramin Naimi**, Occidental College, and **Ryo Nikkuni**, Tokyo Women's Christian University.

Spatio-Temporal Modeling of Neuronal Data (Code: SS 6A), **Reza Ramezan** and **Sam Behseta**, California State University, Fullerton.

Spectral Asymptotics of Large Matrices (Code: SS 3A), **Alain Bourget** and **Tyler McMillen**, California State University, Fullerton.

Spectral Theory of Ergodic Schrödinger Operators and related models (Code: SS 21A), **S. Jitomirskaya**, University of California, Irvine, and **Christoph Marx**, Oberlin College.

Stochastic Modeling and Statistical Inference (Code: SS 17A), **Qidi Peng**, Claremont Graduate University.

Strategies of Training Pre-Service Teachers (Code: SS 4A), **Margaret Kidd**, **Cherie Ichinose**, **David Pagni**, and **Bogdan D. Suceava**, California State University, Fullerton.

New Brunswick, New Jersey

Rutgers University

November 14–15, 2015

Saturday – Sunday

Meeting #1115

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: September 2015
Program first available on AMS website: October 1, 2015
Issue of *Abstracts*: Volume 36, Issue 4

Deadlines

For organizers: Expired
For abstracts: September 22, 2015
The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Lee Mosher, Rutgers University, *Title to be announced*.
Jill Pipher, Brown University, *Title to be announced*.
David Vogan, Massachusetts Institute of Technology, *Title to be announced*.
Wei Zhang, Columbia University, *Title to be announced*.

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the

abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

Advances in Valuation Theory (Code: SS 6A), **Samar El Hitti**, New York City College of Technology, City University of New York, **Franz-Viktor Kuhlmann**, University of Saskatchewan, and **Hans Schoutens**, New York City College of Technology, City University of New York.

Algebraic Geometry and Combinatorics (Code: SS 9A), **Elizabeth Drellich**, University of North Texas, **Erik Insko**, Florida Gulf Coast University, **Aba Mbirika**, University of Wisconsin-Eau Claire, and **Heather Russell**, Washington College.

Applications of CAT(0) Cube Complexes (Code: SS 1A), **Sean Cleary**, City College of New York and the City University of New York Graduate Center, and **Megan Owen**, Lehman College of the City University of New York.

Aspects of Minimal Surfaces in Riemannian Manifolds (Code: SS 4A), **Zheng Huang** and **Marcello Lucia**, City University of New York, Staten Island and Graduate Center.

Aspects of Resolutions and Syzygies in Commutative Algebra (Code: SS 12A), **Courtney Gibbons**, Hamilton College, and **Denise Rangel Tracy**, Syracuse University.

Commutative Algebra (Code: SS 2A), **Laura Ghezzi**, New York City College of Technology, City University of New York, and **Jooyoun Hong**, Southern Connecticut State University.

Difference Equations and Applications (Code: SS 5A), **Manos Drymonis**, Providence College, **Evelina Lapierre**, Johnson and Wales University, and **Michael Radin**, Rochester Institute of Technology.

Geometric Topology: A Celebration of Jim West's 70th Birthday (Code: SS 3A), **Alexandre Dranishnikov**, University of Florida, **Steve Ferry**, Rutgers University, and **Boris Goldfarb**, State University of New York at Albany.

Geometry and Combinatorics of Polytopes (Code: SS 19A), **Egon Schulte**, Northeastern University, and **Asia Ivić Weiss**, York University.

Geometry of Groups, Surfaces and 3-Manifolds (Code: SS 14A), **Abhijit Champanerkar**, College of Staten Island and The Graduate Center, City University of New York, **Feng Luo**, Rutgers University, and **Joseph Maher**, College of Staten Island and The Graduate Center, City University of New York.

Invariants of Knots, Links and 3-Manifolds (Code: SS 16A), **Ilya Kofman**, College of Staten Island and The Graduate Center, City University of New York, and **Adam Lowrance**, Vassar College.

Modern Schubert Calculus (Code: SS 17A), **Anders Buch** and **Chris Woodward**, Rutgers University.

Multiple Combinatorial Numbers and Associated Identities (Code: SS 8A), **Hasan Coskun**, Texas A&M University-Commerce.

Multiscale Methods in Cell and Developmental Biology (Code: SS 15A), **Anastasios Matzavinos**, Brown University, and **Chuan Xue**, Ohio State University.

Nonlinear Waves in Differential Equations (Code: SS 10A), **Linghai Zhang**, Lehigh University.

Number Theory, Spectral Theory, and Homogeneous Dynamics (Code: SS 13A), **Dubi Kelmer**, Boston College, and **Alex Kontorovich**, Rutgers University.

Representation Theory, Vertex Operator Algebras, and Related Topics (Code: SS 7A), **Corina Calinescu**, New York City College of Technology, City University of New York, **Andrew Douglas**, New York City College of Technology and Graduate Center, City University of New York, and **Joshua Sussan**, Medgar Evers College, City University of New York.

Representations of Reductive Groups (Code: SS 11A), **Jeffrey Adams**, University of Maryland, **Stephen D. Miller**, Rutgers University, and **David Vogan**, Massachusetts Institute of Technology.

Topological Data Analysis: Computations, Statistics, and Applications (Code: SS 18A), **Miroslav Kramar** and **Rachel Levanger**, Rutgers University.

Seattle, Washington

Washington State Convention Center and the Sheraton Seattle Hotel

January 6–9, 2016
Wednesday – Saturday

Meeting #1116
Joint Mathematics Meetings, including the 122nd Annual Meeting of the AMS, 99th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2015
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2016
Issue of *Abstracts*: Volume 37, Issue 1

Deadlines

For organizers: Expired
For abstracts: September 22, 2015

Call for MAA Contributed Papers

The MAA Committee on Contributed Paper Sessions solicits contributed papers pertinent to the sessions listed below. Contributed Paper Session presentations are limited to fifteen minutes, except in the general session where they are limited to ten minutes. Each session room is equipped with a computer projector, an overhead projector, and a screen. Please note that the dates and times scheduled for these sessions remain tentative.

The deadline for submission of abstracts is Tuesday, September 22, 2015.

Contributed Paper Sessions with Themes

Addressing the Needs of Mathematics and Computer Science Majors in Discrete Mathematics Courses, organized by **Ksenija Simic-Muller**, Pacific Lutheran University; and **Tom J. Edgar**, Pacific Lutheran University; Saturday

afternoon. The needs of mathematics and computer science majors in discrete mathematics courses differ: while a proof-based approach is typically desired for mathematics majors, computer science majors need to understand the connection between the mathematics and concepts they encounter in computer science coursework. Yet all students can benefit from both approaches: computer science majors from more mathematical rigor, and mathematics majors from more programming applications. One possible approach to making discrete mathematics courses more meaningful to all students is through the use of technology, especially as computer software becomes more freely available (e.g., SAGE or Wolfram Alpha) and easier to use (e.g., newer versions of `Maple` and `Mathematica`). Other approaches include meaningful projects and activities.

For this session, we invite proposals that describe an activity, problem, assignment, or project that was successful in advancing the knowledge and engagement of students enrolled in a discrete mathematics course. Descriptions of entire courses are also welcome. While we are especially interested in proposals about courses that simultaneously serve computer science and mathematics majors by implementing computer software or programming, proposals describing other innovative approaches to teaching discrete mathematics in general will also be considered. Talks in this session should also describe outcomes, giving evidence of the success of the intervention.

Assessing Student Learning: Alternative Approaches, organized by **David Clark**, Grand Valley State University; **Jane Butterfield**, University of Victoria; **Robert Campbell**, College of St. Benedict/St. John's University; and **Cassie Williams**, James Madison University; Wednesday morning. Assessment is central to determining a student's level of mastery, yet traditional methods of assessment (such as exams, quizzes, and homework) may not accurately and robustly measure student understanding. With the recent increase in the popularity of non-lecture-based course structures, techniques that assess deeper learning are coming to the forefront. This session invites presenters to describe innovative methods of assessment with which they have experimented in the attempt to accurately reflect the diversity of ways students learn and understand course material. Presenters should focus on practical issues of implementation and discuss the level of success of the method in the college classroom. Presenters may also share methods to determine the validity of their assessments, advice for others looking to implement or create alternative assessment methods, or how these methods can help instructors evaluate the effectiveness of a non-traditional classroom.

Bringing the Community into the College Mathematics Classroom, organized by **Ksenija Simic-Muller**, Pacific Lutheran University; Thursday afternoon. Colleges and universities are often involved in the surrounding communities, typically through partnerships and outreach. But how often are communities present in college classrooms, in particular in mathematics classrooms? This session is concerned with collaborations between universities and the communities they serve that enhance student mathematical learning, while also building stronger ties with individuals and organizations based in these communities. Such collaborations can happen in any mathematics course, from liberal arts mathematics to the capstone; they can be implemented at any level, of an individual course or program-wide; and they can take many forms. For example, community members may share their expertise during a class visit; students may serve as consultants to a community-based organization; or course meetings can take place on-site in the community, to name a few. Proposals for this session should describe collaborations between mathematics courses or programs, and community members or organizations. These collaborations should be more than simple attempts to "fix" the communities, and should view communities as sources of knowledge rather than as deficient. All proposals must provide rich descriptions of the collaboration and the mathematics learning that took place, and should provide evidence of the impact that the collaboration had on participants, both students and community members (if applicable). Accounts of internships will also be considered.

The Broad Impact of Math Circles, organized by **Katherine Morrison,** University of Northern Colorado; and **Philip Yasskin**, Texas A&M University; Thursday afternoon. A mathematics circle is an enrichment activity for K–12 students or their teachers, which brings them into direct contact with mathematics professionals, fostering a passion and excitement for deep mathematics in the participants. Math circles provide a unique opportunity to reach a wide variety of audiences and have a lasting impact. This session is focused on how math circles have served this variety of populations and the effect of this service. Talks are invited that address how math circles have served nonstandard or often underrepresented audiences. Talks are also invited that describe the lasting impact of math circles on various audiences; for example, talks that describe how math circles impacted you as a young mathematician are welcome. Sponsored by the SIGMAA on Math Circles for Students and Teachers.

Common Core State Standards (CCSS) for Mathematics Practices and Content: The Role of Math Departments in Preparing Math Education Candidates for New Assessments, organized by **William Martin**, North Dakota State University; **Karen Morgan**, New Jersey City University; **Gulden Karakok**, University of Northern Colorado; and **James A. Mendoza Epperson**, University of Texas-Arlington; Thursday afternoon. The Common Core State Standards for Mathematics have been widely adopted and implemented nationally. Mathematics Departments share responsibility with Teacher Education Programs to prepare future teachers who are ready to teach school mathematics so that their students can meet

both the content and especially mathematical practices standards. Mathematics faculty also collaborate with the K–12 system to ensure a smooth transition from school to higher education, one of the primary purposes of the CCSS. This session seeks reports of mathematics faculty experiences with their department's implementation of the CCSS mathematics standards focusing on the requirements of new assessments. We invite contributed papers describing efforts, including evidence of their impact, that (a) investigate how well their math education candidates are prepared with the knowledge and skills necessary to assess that their students meet the CCSS for mathematics content and practices, (b) partner with K–12 educators to focus on the implications related to the assessments (such as PARCC and Smarter Balanced) being used, (c) discuss changes mathematics departments have made to their programs implementing the CCSS and assessments for the mathematical education of teachers, or (d) discuss departmental initiatives to ensure a smooth transition from school to higher education in light of the CCSS and their associated assessments. Sponsored by the MAA Committee on the Mathematical Education of Teachers (COMET) and the MAA Committee on Assessment.

Contemplative Pedagogy and Mathematics, organized by **Luke Wolcott**, Lawrence University; and **Justin Brody**, Goucher College; Friday afternoon. Contemplative pedagogy aims to incorporate contemplative/introspective practices into the classroom in order to deepen the educational experience. Students are challenged to engage more fully with the material and their experience of learning. Common techniques include in-class mindfulness activities, deep listening or dialoguing, journaling, and beholding. As more and more data comes in showing the efficacy and benefits of such practices in all aspects of life, the Contemplative Education Movement has been gaining momentum, strengthening connections with established good pedagogy, and expanding to departments outside the humanities and social sciences. This contributed paper session solicits presentations from college-level educators with hands-on experience of contemplative pedagogy or contemplative practices. We welcome reports on successful, or unsuccessful, attempts at contemplative pedagogy, whether anecdotal or systematic. We also invite educators with personal out-of-class contemplative practices, to reflect on how that practice has informed their teaching.

The Contributions of Minorities to Mathematics Throughout History, organized by **Amy Shell-Gellasch**, Montgomery College; and **Lloyd Douglas**, University of North Carolina; Friday morning. The history of mathematics is filled with inspiring stories of mathematicians. This session will focus on the stories of minority mathematicians (people of color, native peoples, women, and other peoples historically underrepresented in mathematics) of the distant and not so distant past and the impact they have had on mathematics and its teaching. Sponsored by the SIGMAA on the History of Mathematics.

Conversations with the Partner Disciplines: Collaborations to Improve the Mathematics Curriculum, organized by **Victor Piercey**, Ferris State University; **Suzanne I. Doree**, Augsburg College; **Jason Douma**, University of Sioux Falls; and **Susan Ganter**, East Carolina University; Saturday afternoon. The undergraduate mathematics curriculum is an essential component of the education of future scientists, health professionals, engineers, computer scientists, business professionals, and social scientists, and supports the quantitative education of all students. Understanding and adapting to the evolving needs of the partner disciplines is critical to maintaining a vital and relevant mathematics curriculum. The 2013 NRC report "The Mathematical Sciences in 2025" revealed that "the educational offerings of typical departments in the mathematical sciences have not kept pace with the changes in how the mathematical sciences are used," and a "community-wide effort is needed … to make undergraduate courses more compelling to students and better aligned with the needs of user departments." One national effort to improve such communication over the past decade has been the MAA's "Curriculum Foundations Project: Voices of the Partner Disciplines." This session presents successful collaborations with partner disciplines to revise mathematics courses or programs. Talks should identify the research basis for curricular change such as on-campus conversations, the Curriculum Foundations Project, or other professional reports or guidelines. Talks illustrating successful models for collaboration or interdisciplinary courses/programs developed from these partnerships are also welcome. Projects renewing mathematics courses in the first two years of the undergraduate curriculum are especially encouraged. Papers from the session may be considered for a special issue of PRIMUS. Sponsored by the Curriculum Renewal Across the First Two Years (CRAFTY) and Mathematics Across the Disciplines (MAD) subcommittees of CUPM and the journal PRIMUS: Problems, Resources, and Issues in Undergraduate Mathematics Studies.

The Development and Adoption of Open Educational Resources for Teaching and Learning, organized by **Benjamin Atchison**, Framingham State University; and **Jeremy Russell**, The College of New Jersey; Friday afternoon. This session will showcase the increasing popularity of open educational resources (OER) for courses in mathematics and the sciences. Examples of this may include, but are not limited to, the development, enhancement, or adoption of open source or open access course texts and related materials, the creation and/or implementation of course technological enhancements, such as instructional apps and video tutorials, and experiences with the inclusion of low- or no-cost homework platforms or mathematics software systems in a particular course. Presenters should attempt to address the effectiveness (formally or informally assessed) of the adoption of such resources in their courses. Presenters from all educational levels and STEM-related fields are encouraged to submit abstracts, with preference awarded to those topics focusing on the high school, community college, and undergraduate levels.

Experiences and Innovations in Teaching Probability Theory, organized by **Jonathon Peterson**, Purdue University; and **Nathaniel Eldredge**, University of Northern Colorado; Wednesday morning. We invite papers and scholarly presentations on improving the teaching of probability

theory, at the undergraduate or beginning graduate level, by innovative methods. Possible topics could include inquiry-based learning, projects, mathematical writing, real-world applications, connections to other areas of mathematics, integration of technology, or simulation. The focus of this session will be on the teaching of probability theory (the construction, analysis, and theoretical properties of probabilistic models) rather than statistics or data analysis. Reports on student outcomes, either anecdotal or empirical, are encouraged.

Graduate Students Teach Too: Ideas and Best Practices, organized by **Samuel L. Tunstall**, Appalachian State University; Saturday morning. Graduate teaching assistants (GTAs) comprise a nontrivial portion of the teaching workforce at many universities. Though their duties vary, most are responsible for teaching introductory general education courses in some capacity. In fact a 2010 AMS survey of four-year colleges and universities suggests that roughly 8% of introductory math courses (15% for statistics) are taught fully by graduate students. This responsibility may seem straightforward at first glance; however, there is a growing movement toward accountability for general education outcomes in such courses. Students in these classes deserve a positive, engaging experience; one that not only permits them to take future math courses (if desired), but also fosters gains in numeracy. In light of a GTA's workload and background, such an experience can be challenging to create. This session is designed to encourage dialogue among both graduate programs and graduate instructors. Talks might include reports on innovative preparation methods for new instructors, accountability measures for GTAs, means for infusing quantitative literacy into GTA-led courses, as well as novel ideas or reports from graduate students themselves.

Helping Students See Beyond Calculus, organized by **David Strong**, Pepperdine University; **James Tanton**, MAA; **Courtney Davis**, Pepperdine University; and **Angela Spalsbury**, Youngstown State University; Saturday afternoon. We need more and better educated mathematics and science students. Too many high school and beginning college students think of mathematics merely as calculus and the topics leading to it. Many talented and promising students lose interest in mathematics—some never take a single math class in college and some drop out of the math major soon after beginning—because they are never exposed to the beauty and usefulness of the many other areas of mathematics. Students—and society—would immensely benefit from the students being exposed to other areas of mathematics before leaving high school or during their first semesters in college. Papers submitted for this session should describe classroom presentations and materials which provide students with the exposure described above. Such classroom presentations and materials should be an introduction to a specific mathematical idea or application; accessible to high school or early college-level students; self-contained (including information on how to most effectively use the presentation or materials); comprised of power points, video or audio clips, online or printed handouts, materials or tools for experimentation and visualization, etc., and be interesting, entertaining, and possibly captivating. The organizers hope that speakers will make their classroom presentations available online (on their own websites) for use by other instructors. Sponsored by the SIGMAA Teaching Advanced High School Mathematics.

Incorporating the History of Mathematics into Developmental Math Courses, organized by **Van Herd**, University of Texas, Austin; and **Amy Shell-Gellasch**, Montgomery College; Saturday morning. Developmental math courses and courses prerequisite to the calculus sequence such as college algebra and precalculus are challenging for many students. By incorporating the history of mathematics into these courses, a deeper level of understanding and interest may be achieved. This session seeks papers which offer ideas for incorporating the history of mathematics (generally or specifically) into these courses. Sponsored by the SIGMAA on the History of Mathematics.

Innovative Approaches to One-Semester Calculus Courses, organized by **Joel Kilty** and **Alex M. McAllister**, Centre College; Thursday morning. Students who major in such fields as agriculture, architecture, biology, business, economics, liberal arts, and human sciences often take a one-semester, terminal calculus course with a focus on applications. One approach to these courses are focused, targeted versions of calculus such as applied calculus, business calculus, or calculus for the life sciences. Some schools cannot offer a wide range of calculus courses and must design a single course to meet the needs of these students. This session invites presenters to share innovative course designs for a one-semester calculus course for students interested in a variety of disciplines, particularly those that involve mathematical modeling. Presenters are expected to report their course design, how it meets the needs of students, and evidence for the effectiveness of their approach.

Innovative and Effective Ways to Teach Linear Algebra, organized by **David Strong**, Pepperdine University; **Gil Strang**, MIT; and **Megan Wawro**, Virginia Tech; Friday afternoon. Linear algebra is one of the most interesting and useful areas of mathematics, because of its beautiful and multifaceted theory, as well as the enormous importance it plays in understanding and solving many real world problems. Consequently, many valuable and creative ways to teach its rich theory and its many applications are continually being developed and refined. This session will serve as a forum in which to share and discuss new or improved teaching ideas and approaches. These innovative and effective ways to teach linear algebra include, but are not necessarily limited to: (1) hands-on, in-class demos; (2) effective use of technology, such as `Matlab`, `Maple`, `Mathematica`, `Java Applets`, or `Flash`; (3) interesting and enlightening connections between ideas that arise in linear algebra and ideas in other mathematical branches; (4) interesting and compelling examples and problems involving particular ideas being taught; (5) comparing and contrasting visual (geometric) and more abstract (algebraic) explanations of specific ideas; and (6) other novel and useful approaches or pedagogical tools.

Innovative Targeted Solutions in Teaching Introductory Statistics, organized by **Patti Frazer Lock**, St.

Lawrence University; **Randall Pruim**, Calvin College; and **Sue Schou**, Idaho State University; Thursday afternoon. Statistics is a very rapidly growing field and enrollments in Introductory Statistics are expanding. The 2015 MAA Curriculum Guide recommends that all math majors learn effective data analysis. This is also a time of great innovation and change in the way Introductory Statistics is taught. This session invites papers on successful methods used in Intro Stats. These methods can range from an innovative full course curriculum overhaul to a single effective in-class activity. All papers should provide participants with a clear take-away idea for use in Introductory Statistics. Sponsored by the SIGMAA on Statistics Education.

Integrating Research into the Undergraduate Classroom, organized by **Shannon R. Lockard**, Bridgewater State University; and **Timothy B. Flowers**, Indiana University of Pennsylvania; Saturday afternoon. Undergraduate research is a high-impact practice that inspires student learning, builds crucial skills, boosts retention and graduation rates, and particularly benefits underrepresented and at-risk students. While students often engage in undergraduate research outside of the classroom, incorporating research projects into the classroom can bring this impactful experience to even more students. This session will focus on incorporating research into the undergraduate classroom, from introductory to upper level mathematics courses. Presentations may describe a particular research project or activity, faculty experiences in mentoring undergraduate research in the classroom, or student experiences and feedback. All talks should emphasize why the project(s) being discussed is considered undergraduate research rather than a typical assignment. Participants are encouraged to share the impact on the students involved if possible.

Inquiry-Based Teaching and Learning, organized by **Brian Katz**, Augustana College; and **Victor Piercey**, Ferris State University; Friday morning. The goal of Inquiry-Based Learning (IBL) is to transform students from consumers to producers of mathematics. Inquiry-based methods aim to help students develop a deep understanding of mathematical concepts and the processes of doing mathematics by putting those students in direct contact with mathematical phenomena, questions, and communities. Within this context, IBL methods exhibit great variety. Activities can take place in single class meetings and span entire curricula for students of any age; students can be guided to re-invent mathematical concepts, to explore definitions and observe patterns, to justify core results, and to take the lead in asking new questions. There is a growing body of evidence that IBL methods are effective and important for teaching mathematics and for fostering positive attitudes toward the subject. This session invites scholarly presentations on the use of inquiry-based methods for teaching and learning. We especially invite presentations that include successful IBL activities or assignments that support observations about student outcomes with evidence, or that could help instructors who are new to IBL to try new methods.

Mathematical Modeling in the Undergraduate Curriculum, organized by **Jason Douma**, University of Sioux

Falls; and **Rachel Levy**, Harvey Mudd College; Saturday morning. Both the MAA's 2015 CUPM Curriculum Guide and SIAM's Modeling Across the Curriculum Report emphasize the value in teaching mathematical modeling as a dynamic problem-solving process. In addition to courses specifically dedicated to mathematical modeling and applied mathematics, many undergraduate mathematics programs have made an effort to infuse modeling into courses across their existing curriculum. This session welcomes papers concerning best practices, useful examples, or effective strategies in the design and teaching of undergraduate courses in which mathematical modeling comprises a significant activity or core learning objective. Collectively, the papers presented in this session will represent applications of mathematics to a broad range of fields. Sponsored by the MAA CUPM Mathematics Across the Disciplines Subcommittee and the SIAM Education Committee.

Mathematics and the Arts, organized by **Douglas Norton**, Villanova University; Wednesday morning and afternoon. Presentations exploring connections between Mathematics and the Arts are invited from any of various perspectives, including mathematical aspects of traditional art, mathematical topics represented by or incorporated into art, and artistic and aesthetic aspects of mathematical topics. All artistic areas are welcome: visual, poetical, dramatic, musical, literary, dance, fiber arts, and so forth. Practitioners from anywhere along the spectrum of math and the arts as well as educators with experience at this intersection are invited to report on their experiences, whether primarily artistic, mathematical, pedagogical, or blended. Sponsored by the SIGMAA on Mathematics and the Arts.

Mathematics Experiences and Projects in Business, Industry, and Government, organized by **Carla D. Martin**, Dept. of Defense; and **Allen Butler**, Wagner Associates; Friday afternoon. The MAA Business, Industry and Government Special Interest Group (BIG SIGMAA) provides resources and a forum for mathematicians working in Business, Industry and Government (BIG) to help advance the mathematics profession by making connections, building partnerships, and sharing ideas. BIG SIGMAA consists of mathematicians in BIG as well as faculty and students in academia who are working on BIG problems. Mathematicians, including those in academia, with BIG experience are invited to present papers or discuss projects involving the application of mathematics to BIG problems. The goal of this contributed paper session is to provide a venue for mathematicians with experience in business, industry, and government to share projects and mathematical ideas in this regard. Anyone interested in learning more about BIG practitioners, projects, and issues, will find this session of interest. Sponsored by the SIGMAA on Business, Industry, and Government.

Mathematics and Sports, organized by **Drew Pasteur**, College of Wooster; and **John David**, Virginia Military Institute; Saturday morning. The expanding availability of play-by-play statistics and video-based spatial data, for professional and some collegiate sports, is leading to innovative kinds of research, using techniques from

various areas of the mathematical sciences. By modeling the outcome distributions in certain situations, researchers can develop new metrics for player or team performance in various aspects of a sport, comparing actual results to expected values. Such work often has implications for strategic game management and personnel evaluation. Classic areas of study, such as tournament design, ranking methodology, forecasting future performance, insight into rare or record events, and physics-based analysis, also remain of interest. This session will include both presentations of original research and expository talks; topics related to the use of sports applications in curriculum are welcome. With a broad audience in mind, all talks are requested to be accessible to mathematics majors. Undergraduates and their mentors are particularly encouraged to submit abstracts for consideration.

New Ideas in Teaching Upper-Level Statistics Courses, organized by **Patti Frazer Lock**, St. Lawrence University; **Randall Pruim**, Calvin College; and **Sue Schou**, Idaho State University; Friday afternoon. Much attention has been paid recently to improving student learning in the introductory statistics course. This session is focused on the rest of the undergraduate statistics curriculum. We invite submissions that provide details about innovative learning activities, technologies, resources, or teaching methods that have been used effectively in "Stat 2", mathematical statistics, or other statistics courses beyond the Intro Stat course. Submissions may range from single effective activities used in these courses to major curricular revisions or completely new courses. We welcome submissions that include partnerships with other disciplines. Presentations should explicitly address the objectives and effectiveness of the described activities. Sponsored by the SIGMAA on Statistics Education

Origami in the Mathematics K–12 Classroom, organized by **Roger Alperin**, San Jose State University; and **Perla Myers**; University of San Diego; Saturday afternoon. Programs that take advantage of paper folding to teach mathematics are thriving in many parts of the world. Presenters in this session will describe their innovative strategies for exploring mathematics in the K–12 classroom and/or with future/in-service teachers using paper folding/origami as the means to reach the goals established by the Common Core. The focus of the session will be on rich mathematical explorations that are based on or enhanced by paper folding. Presentations are expected to be scholarly in nature.

Preparation, Placement and Support of Elementary Mathematics Specialists, organized by **Laurie J. Burton**, Western Oregon University; **Cheryl Beaver**, Western Oregon University; and **Klay Kruczek**, Southern Connecticut State University; Thursday morning. Over the last decade, there have been numerous calls for the use of mathematics specialists in elementary and middle schools. In 2013 the Association of Mathematics Teacher Educators (AMTE) created a set of Standards for Elementary Mathematics Specialists (amte.net/publications) to encourage states to address the urgent need to increase the mathematical knowledge and expertise of elementary school staff by establishing an elementary mathematics specialist (EMS)

license, certificate, or endorsement. Elementary mathematics specialists are teachers, teacher leaders, or coaches who are responsible for supporting effective mathematics instruction and student learning at the classroom, school, district, or state levels.

Recently some institutions have begun degree or certificate programs to educate these elementary mathematics specialists. Papers will report on the preparation, placement, and support of mathematics specialists in the elementary grades as well as on the development of degree or certificate programs to educate these mathematics specialists. Papers may describe programs to prepare pre-service or in-service teachers to become elementary mathematics specialists, or may describe efforts with school districts to create positions and support for these specialists. Reports on the successful installation and implementation of elementary mathematics specialists are also welcome. Papers should include evidence of success or the potential for application to other institutions or districts. Sponsored by the MAA Committee on the Mathematical Education of Teachers.

Professional Development for Mathematicians: A Session for MAA PREP Organizers and Participants, organized by **Jon Scott**, Montgomery College; **Barbara Edwards**, Oregon State University; **Nancy Hastings**, Dickinson College; and **Stan Yoshinobu**, Cal Poly, San Luis Obispo; Wednesday afternoon. MAA has supported professional development activities that have enhanced the mathematics profession through the Professional Enhancement Program (MAA PREP), funded by the National Science Foundation. A variety of professional development workshops have been conducted under the MAA PREP umbrella, and it would be beneficial for workshop organizations and participants to share their experiences and insights. This session will provide a venue for organizers to share their ideas with one another, and for participants to share their experiences. Sponsored by the MAA Committee on Professional Development.

Proofs and Mathematical Reasoning in the First Two Years of College, organized by **Joanne Peeples**, El Paso Community College; **Chris Oehrlein**, Oklahoma City Community College; and **Dean Gooch**, Santa Rosa Junior College; Wednesday morning. As more students begin their college education at a two-year college before transferring to a Bachelor's degree program, it is increasingly important to ensure that students choosing to major in mathematics are adequately prepared for the rigor of advanced mathematics courses. In particular, they will need to read, comprehend and write proofs. Most standard calculus sequences do not or cannot provide the needed preparation because they must serve a significantly diverse set of majors. Therefore many Bachelor degree programs in mathematics require an "Introduction to Proofs" style course that mathematics majors must take. This kind of course is not currently offered in most two-year college mathematics programs. We invite faculty from two and four-year institutions to share introduction to Proofs and Mathematical Reasoning courses for students who have had a year of calculus and intend to take upper division mathematics courses especially as taught to students in

two-year colleges; methods of integrating the teaching and practice of proof-writing for mathematics majors into standard first- and second-year mathematics courses; or collaborative efforts between two- and four-year institutions to create or facilitate transfer of Introduction to Proof and Mathematical Reasoning courses or course equivalents. Sponsored by the MAA Committee on Two Year Colleges.

Quantitative Literacy in the K–16 Curriculum, organized by **Aaron Montgomery**, Central Washington University; **Gary Franchy**, Southwestern Michigan College; **Gizem Karaali**, Pomona College; **Andrew Miller**, Belmont University; and **Victor Piercey**, Ferris State University; Wednesday afternoon. Because of its nature, Quantitative Literacy (QL) is referenced at almost all levels of the educational system. Traditional mathematical topics such as calculus have relatively well-defined prerequisites and outcomes and an established location in the traditional mathematical curriculum sequence. QL typically involves the use of a wide variety of pre-collegiate level mathematics to enable a deeper understanding within a nonmathematical context. As a result, changing requirements for K–12 mathematics can have a significant impact on what we do at the collegiate level. Papers in this session will focus on the interface between the K–12 curriculum and collegiate QL. Given the breadth of this area, it is expected that papers with a variety of different focuses will be accepted. Papers which provide insights on the following questions are explicitly invited: requirements for K–12 that impact collegiate level QL, QL requirements for two-year colleges, the distinction between K–12 QL standards and collegiate QL standards, and the impact of changing requirements at the K–12 and two-year schools on four-year school curricula. Sponsored by the SIGMAA on Quantitative Literacy.

Recreational Mathematics: Puzzles, Card Tricks, Games, Game Shows, and Gambling, organized by **Paul R. Coe**, **Sara B. Quinn**, and **Marion Weedermann**, Dominican University; Thursday morning. Puzzles, card tricks, games, game shows and gambling provide an excellent laboratory for testing mathematical strategy, probability, and enumeration. Pencil and paper puzzles, board games, game shows, card tricks and card games all provide opportunities for mathematical and statistical analysis. Submissions to this session are encouraged that look at new problems as well as novel approaches to old problems. Submissions by undergraduates or examples of the use of the material in the undergraduate classroom are encouraged.

Research in Undergraduate Mathematics Education, organized by **Karen A. Keene**, North Carolina State University; Thursday morning and afternoon. This session presents research reports on undergraduate mathematics education. The session will feature research in a number of mathematical areas including calculus, linear algebra, advanced calculus, abstract algebra, and mathematical proof. The goals of this session are to foster high-quality research in undergraduate mathematics education, to disseminate well-designed educational studies to the greater mathematics community, and to transform theoretical work into practical consequences in college mathematics. Examples of such types of research include rigorous and scientific studies about students' mathematical cognition and reasoning, teaching practice in inquiry-oriented mathematics classrooms, design of research-based curricular materials, and professional development of mathematics teachers, with intention to support and advance college students' mathematical thinking and activities. The presentation should report results of completed research that builds on the existing literature in mathematics education and employs contemporary educational theories of the teaching and learning of mathematics. The research should use well-established or innovative methodologies (e.g., design experiment, classroom teaching experiment, and clinical interview, with rigorous analytic methods) as they pertain to the study of undergraduate mathematics education. We also welcome preliminary reports on research projects in early stages of development or execution. Sponsored by the SIGMAA on Research in Undergraduate Mathematics Education.

Revitalizing Complex Analysis, organized by **Russell Howell**, Westmont College; **Paul Zorn**, St. Olaf College; and **Alan Noellni**, Oklahoma State University; Saturday morning. Complex Analysis, despite its beauty and power, seems to have lost some of the prominence it once enjoyed in undergraduate mathematics, science, and engineering. Thanks to funding from NSF a national dialog has begun with the intention of remedying this situation. Two sessions at the 2015 San Antonio JMM focused on suggestions for curricular reform from a variety of perspectives: modifying the traditional course to include more modern ideas including modules suitable for student investigation, and instituting a "transitions" course containing a meaty component of complex analysis. Papers at this session should likewise be scholarly, and focus on ways to enliven complex analysis as taught to undergraduates. The table is open to suggestions for technological innovation, pedagogical ideas, or other innovative approaches that seem promising.

The Scholarship of Teaching and Learning in Collegiate Mathematics, organized by **Jacqueline Dewar**, Loyola Marymount University; **Thomas Banchoff**, Brown University; **Curtis Bennett**, Loyola Marymount University; **Pam Crawford**, Jacksonville University; and **Edwin Herman**, University of Wisconsin-Stevens Point; Wednesday morning and afternoon. In the scholarship of teaching and learning, faculty bring disciplinary knowledge to bear on questions of teaching and learning and systematically gather evidence to support their conclusions. Work in this area includes investigations of the effectiveness of pedagogical methods, assignments, or technology, as well as probes of student understanding. The goals of this session are to (1) feature scholarly work focused on the teaching of postsecondary mathematics, (2) provide a venue for teaching mathematicians to make public their scholarly investigations into teaching/learning, and (3) highlight evidence-based arguments for the value of teaching innovations or in support of new insights into student learning. Appropriate for this session are preliminary or final reports of postsecondary classroom-based investigations of teaching methods, student learning difficulties, curricular assessment, or insights into student

(mis)understandings. Abstract submissions should have a clearly stated question that was or is under investigation and should give some indication of the type of evidence that has been gathered and will be presented. For example, papers might reference the following types of evidence: student work, participation or retention data, pre/post tests, interviews, surveys, think-alouds, etc.

The Teaching and Learning of Undergraduate Ordinary Differential Equations, organized by **Christopher S. Goodrich**, Creighton Preparatory School; and **Beverly H. West**, Cornell University; Friday morning. The teaching of undergraduate Ordinary Differential Equations (ODEs) provides a unique way to introduce students to the beauty and applicative power of calculus. ODEs are also rich with aesthetically pleasing theory, which often can be successfully communicated visually and explored numerically. This session will feature talks that describe innovative teaching in the ODEs course as well as the description of either projects or pedagogy that can be used to engage students in their study of ODEs. Successful contributions could include but are not limited to (1) innovative ways of teaching standard topics in the ODEs course, (2) strategies for teaching both differential equations and linear algebra simultaneously, (3) the inclusion of technology in the ODEs course, and (4) descriptions of applications or nonstandard topics and how such topics can lead to student engagement and interest.

Sponsored by the Community of Ordinary Differential Equations Educators (CODEE).

Topics and Techniques for Teaching Real Analysis, organized by **Erik Talvila**, University of the Fraser Valley; **Paul Musial**, Chicago State University; **Robert Vallin**, Lamar University; and **James Peterson**, Alma College; Wednesday afternoon. Real analysis is a core component of the mathematics program. It has traditionally been considered difficult for students but is also challenging to teach since the student body can be diverse and there are many choices in subject matter. Students may end up applying their knowledge of real analysis in differential equations, functional analysis, probability, even economics and physics. There are many exciting topics that can be covered and many possible strategies for success. Speakers at this session can present topics that could be added to real analysis courses and can discuss improved presentation techniques of traditional topics.

Trends in Undergraduate Mathematical Biology Education, organized by **Timothy Comar**, Benedictine University; and **Daniel Hrozencik,** Chicago State University; Friday morning. Several recent reports emphasize that aspects of biological research are becoming more quantitative and that life science students, including pre-med students, should be introduced to a greater array of mathematical, statistical, and computational techniques and to the integration of mathematics and biological content at the undergraduate level. Mathematics majors also benefit from coursework at the intersection of mathematics and biology because there are interesting, approachable research problems and mathematics students need to be trained to collaborate with scientists in other disciplines, particularly biology. Topics may include scholarly work addressing the issues related to the design of effective biomathematics course content, courses and curricula, the integration of biology into mathematics courses, student recruitment efforts, the gearing of content toward pre-med students, undergraduate research projects, effective use of technology in biomathematics courses, preparation for graduate work in biomathematics and computational biology or for medical careers, and assessment issues. Sponsored by the SIGMAA on Mathematical and Computational Biology.

Using Philosophy to Teach Mathematics Analysis, organized by **Carl Behrens**, Alexandria, VA; and **Dan Sloughter**, Furman University; Thursday morning. Courses in the philosophy of mathematics are rare, but philosophical questions frequently arise in the regular curriculum, often presenting difficulties to teachers who haven't prepared to respond to them. In recent years a growing number of teachers of mathematics are discovering that addressing philosophical issues deliberately in their courses not only eases the strain but also enhances students' ability to grasp difficult mathematical concepts. The upcoming MAA Notes volume, *Using the Philosophy of Mathematics in Teaching Collegiate Mathematics*, illustrates the ways a wide variety of teachers have found to introduce philosophical questions as an exciting part of presenting standard mathematical material. This session invites teachers at all levels to discuss ways they have found to include philosophy in the mathematics classroom. Papers on other topics in the philosophy of mathematics will be considered as time permits. Sponsored by the SIGMAA on the Philosophy of Mathematics.

General Contributed Paper Sessions, organized by **Bem Cayco**, San Jose State University; **Timothy Comar**, Benedictine University, and **T. James Reid**, University of Mississippi; Wednesday, Thursday, Friday, and Saturday, mornings and afternoons. These sessions accept contributions in all areas of mathematics, curriculum, and pedagogy. When you submit your abstract you will be asked to classify it according to the following scheme: *Algebra*; *Analysis*; *Applied Mathematics*; *Assessment*; *Geometry*; *Graph Theory*; *History or Philosophy of Mathematics*; *Interdisciplinary Topics in Mathematics*; *Linear Algebra*; *Logic and Foundations*; *Mathematics and Technology*; *Mentoring*; *Modeling and Applications*; *Number Theory*; *Outreach*; *Probability and Statistics*; *Teaching and Learning Introductory Mathematics*; *Teaching and Learning Calculus*; *Teaching and Learning Advanced Mathematics*; *Teaching and Learning Developmental Mathematics*; *Topology*; or *Other*.

Submission Procedures for MAA Contributed Paper Abstracts

Abstracts may be submitted electronically at `jointmathematicsmeetings.org/meetings/abstracts/abstract.pl?type=jmm`. Simply fill in the number of authors, click "New Abstract", and then follow the step-by-step instructions. **The deadline for abstracts submission is Tuesday, September 22, 2015.**

Each participant may give at most one talk in the MAA contributed paper sessions. If your paper cannot be

accommodated in the session to which it was submitted, it will automatically be considered for the general session.

The organizer(s) of your session will automatically receive a copy of the abstract, so it is not necessary for you to send it directly to the organizer. All accepted abstracts are published in a book that is available to registered participants at the meeting. Questions concerning the submission of abstracts should be addressed to abs-coord@ams.org.

Athens, Georgia

University of Georgia

March 5–6, 2016

Saturday – Sunday
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 5, 2015
For abstracts: January 19, 2016

Stony Brook, New York

State University of New York at Stony Brook

March 19–20, 2016

Saturday – Sunday

Meeting #1118
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 19, 2015
For abstracts: February 2, 2016

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

Invariants of Closed Curves on Surfaces (Code: SS 1A), **Ara Basmajian**, Hunter College and Graduate Center, City University of New York.

Salt Lake City, Utah

University of Utah

April 9–10, 2016

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 9, 2015
For abstracts: February 16, 2016

Fargo, North Dakota

North Dakota State University

April 16–17, 2016

Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 16, 2015
For abstracts: February 23, 2015

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at www.ams.org/cgi-bin/abstracts/abstract.pl.

Commutative Algebra and Its Interactions with Combinatorics and Algebraic Geometry (Code: SS 4A), **Susan Cooper**, North Dakota State University, and **Adam Van Tuyl**, McMaster University.
Convexity and Harmonic Analysis (Code: SS 2A), **Maria Alfonseca-Cubero**, North Dakota State University, and **Dmitry Ryabogin**, Kent State University.
Ergodic Theory and Dynamical Systems (Code: SS 1A), **Dogan Comez**, North Dakota State University, and **Mrinal Kanti Roychowdhury**, University of Texas-Pan American.

Integrable Dynamical Systems and Special Functions (Code: SS 5A), **Oksana Bihun**, Concordia College.

Mathematical Finance (Code: SS 3A), **Indranil SenGupta**, North Dakota State University.

Brunswick, Maine

Bowdoin College

September 24–25, 2016

Saturday – Sunday
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: July 23, 2016

Denver, Colorado

University of Denver

October 8–9, 2016

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 8, 2016
For abstracts: August 16, 2016

Minneapolis, Minnesota

University of St. Thomas

October 28–30, 2016

Friday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 22, 2016
For abstracts: August 30, 2016

Raleigh, North Carolina

North Carolina State University at Raleigh

November 12–13, 2016

Saturday – Sunday
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: September 2016
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 12, 2016
For abstracts: To be announced

Atlanta, Georgia

Hyatt Regency Atlanta and Marriott Atlanta Marquis

January 4–7, 2017

Wednesday – Saturday
Joint Mathematics Meetings, including the 123rd Annual Meeting of the AMS, 100th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: October 2016
Program first available on AMS website: To be announced
Issue of *Abstracts*: Volume 38, Issue 1

Deadlines

For organizers: April 1, 2016
For abstracts: To be announced

Charleston, South Carolina

College of Charleston

March 10–12, 2017

Friday – Sunday
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: November 10, 2016
For abstracts: To be announced

Bloomington, Indiana

Indiana University

April 1–2, 2017

Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

Pullman, Washington

Washington State University

April 22–23, 2017

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

Buffalo, New York

SUNY at Buffalo

September 16–17, 2017

Saturday – Sunday
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 14, 2017
For abstracts: To be announced

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 10–13, 2018

Wednesday – Saturday

Joint Mathematics Meetings, including the 124th Annual Meeting of the AMS, 101st Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2017
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2017
For abstracts: To be announced

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner-Harbor Hotel

January 16–19, 2019

Wednesday – Saturday
Joint Mathematics Meetings, including the 125th Annual Meeting of the AMS, 102nd Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: October 2018
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 2, 2018
For abstracts: To be announced

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Central Section: **Georgia Benkart**, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388; e-mail: `benkart@math.wisc.edu`; telephone: 608-263-4283.

Eastern Section: **Steven H. Weintraub**, Department of Mathematics, Lehigh University, Bethlehem, PA 18105-3174; e-mail: `steve.weintraub@lehigh.edu`; telephone: 610-758-3717.

Southeastern Section: **Brian D. Boe,** Department of Mathematics, University of Georgia, 220 D W Brooks Drive, Athens, GA 30602-7403, e-mail: `brian@math.uga.edu`; telephone: 706-542-2547.

Western Section: Michel L. Lapidus, Department of Mathematics, University of California, Surge Bldg., Riverside, CA 92521-0135; e-mail: `lapidus@math.ucr.edu`; telephone: 951-827-5910.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Information in this issue may be dated. Up-to-date meeting and conference information can be found at `www.ams.org/meetings/`.

Meetings:

Important Information regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 200 in the February 2015 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarly coded material (such as accent marks in text) must be typeset in LaTeX. Visit `www.ams.org/cgi-bin/abstracts/abstract.pl`. Questions about abstracts may be sent to `abs-info@ams.org`. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences in Cooperation with the AMS: (See `www.ams.org/meetings/` for the most up-to-date information on these conferences.)

July 13–31, 2015: 2015 Summer Research Institute on Algebraic Geometry, University of Utah, Salt Lake City, Utah

December 16–19, 2015: Amrita School of Engineering hosts the International Conference on Graph Theory and its Applications, Tamil Nadu, India (For further information see `https://www.amrita.edu/site/icgta15/`.)

Search for an Executive Director for the American Mathematical Society

Position

The Trustees of the American Mathematical Society seek candidates for the position of Executive Director of the Society to replace Dr. Donald McClure, who plans to retire in the summer of 2016. This position offers the appropriate candidate the opportunity to have a strong positive influence on all activities of the Society, as well as the responsibility of overseeing a large, complex, and diverse spectrum of people, publications, and budgets. The desired starting date is July 1, 2016.

Duties and terms of appointment

The American Mathematical Society, with headquarters in Providence, RI, is the oldest scientific organization of mathematicians in the U.S. The Society's activities are mainly directed toward the promotion and dissemination of mathematical research and scholarship, broadly defined; the improvement of mathematical education at all levels; increasing the appreciation and awareness by the general public of the role of mathematics in our society; and advancing the professional status of mathematicians. These aims are pursued mainly through an active program of publications, meetings, and conferences. The Society is a major publisher of mathematical books and journals, including MathSciNet, an organizer of numerous meetings and conferences each year, and a leading provider of electronic information in the mathematical sciences. The Society maintains a Washington office for purposes of advocacy and to improve interaction with federal agencies.

The Executive Director is the principal executive officer of the Society and is responsible for the execution and administration of the policies of the Society as approved by the Board of Trustees and by the Council. The Executive Director is a full-time employee of the Society appointed by the Trustees and is responsible for the operation of the Society's offices in Providence and Pawtucket, RI; Ann Arbor, MI; and Washington, DC. The Executive Director is an ex-officio member of the policy committees of the Society and is often called upon to represent the Society in its dealings with other scientific and scholarly bodies.

The Society employs a staff of about 200 in the four offices. The directors of the various divisions report directly to the Executive Director. A major part of the Society's budget is related to publications. Almost all operations (including the printing) of the publications program are done in-house. Information about the operations and finances of the Society can be found in its Annual Reports, available at www.ams.org/annual-reports.

The Executive Director serves at the pleasure of the Trustees. The terms of appointment, salary, and benefits will be consistent with the nature and responsibilities of the position and will be determined by mutual agreement between the Trustees and the prospective appointee.

Qualifications

Candidates for the office of Executive Director should have a Ph.D. (or equivalent) in mathematics, published research beyond the Ph.D., and significant administrative experience. The position calls for interaction with the staff, membership, and patrons of the Society as well as leaders of other scientific societies and publishing houses; thus leadership, communication skills, and diplomacy are prime requisites.

Applications

A search committee chaired by Robert Bryant (bryant@math.duke.edu) and Ruth Charney (charney@brandeis.edu) has been formed to seek and review applications. All communication with the committee will be held in confidence. Suggestions of suitable candidates are most welcome. Applicants can submit a CV and letter of interest to:

Executive Director Search Committee
c/o Carla D. Savage
Secretary, American Mathematical Society
Department of Computer Science
North Carolina State University
Raleigh, NC 27695-8206
ed-search@ams.org

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American Mathematical Society
Distribution Center

35 Monticello Place,
Pawtucket, RI 02861 USA

Select Biographies from the American Mathematical Society

Lars Ahlfors – At the Summit of Mathematics

Olli Lehto, *University of Helsinki, Finland*

Translated by William Hellberg

This book tells the story of the Finnish-American mathematician Lars Ahlfors (1907-1996) and concentrates on his contributions to the general development of complex analysis.

2015; 125 pages; Softcover; ISBN: 978-1-4704-1846-5; List US$39; AMS members US$31.20; Order code MBK/92

ARNOLD: Swimming Against the Tide

Boris A. Khesin, *University of Toronto, Ontario, Canada*, **and Serge L. Tabachnikov,** *ICERM, Brown University, Providence, RI, and Pennsylvania State University, State College, PA*, **Editors**

[This book recounts] the work and life of eminent mathematician Vladimir Arnold.

2014; 224 pages; Softcover; ISBN: 978-1-4704-1699-7; List US$29; AMS members US$23.20; Order code MBK/86
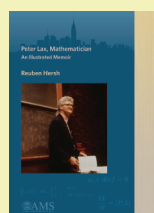
## Peter Lax, Mathematician

An Illustrated Memoir

Reuben Hersh, *University of New Mexico, Albuquerque, NM*

Reuben Hersh, a former student of Peter Lax, has produced a wonderful account of the life and career of this remarkable man. The book is well researched and full of interesting facts, yet light-hearted and lively. It is very well written. A nice feature is the abundance of photographs, not only of Peter Lax and his family, but also of colleagues and students. Although written for mathematicians, the book will have wider appeal. Highly recommended.

—Peter Duren, University of Michigan

A life of Peter Lax, one of the most famous and influential mathematicians of the modern era.

2015; 253 pages; Softcover; ISBN: 978-1-4704-1708-6; List US$35; AMS members US$28; Order code MBK/88
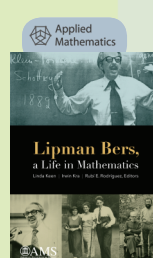
Lipman Bers, a Life in Mathematics

Linda Keen, *Lehman College, CUNY, New York, NY*, **Irwin Kra,** *Stony Brook University, NY*, **and Rubí E. Rodríguez,** *Pontificia Universidad Católica de Chile, Santiago, Chile*, **Editors**

The book is all about Lipman Bers, a giant in the mathematical world who lived in turbulent and exciting times. It captures the essence of his mathematics, a development and transition from applied mathematics to complex analysis–quasiconformal mappings and moduli of Riemann surfaces–and the essence of his personality, a progression from a young revolutionary refugee to an elder statesman in the world of mathematics and a fighter for global human rights and the end of political torture. The book contains autobiographical material and short reprints of his work.

2015; approximately 340 pages; Softcover; ISBN: 978-1-4704-2056-7; List US$44; AMS members US$35.20; Order code MBK/93