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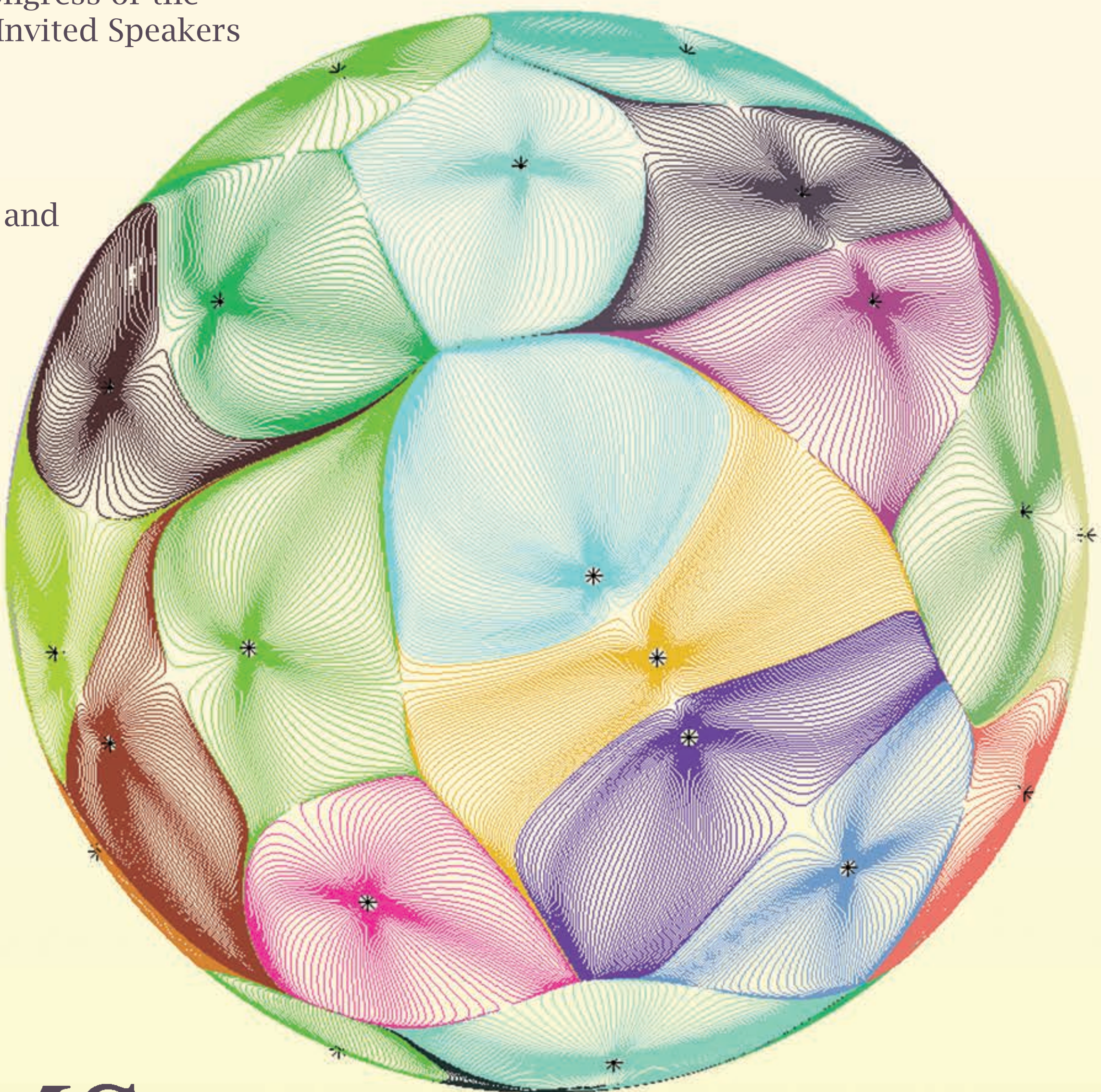

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Dividing the sphere into n equal areas about n given points (see page 446).

AMERICAN MATHEMATICAL SOCIETY

CALL FOR NOMINATIONS

NEW

ULF GRENANDER PRIZE IN STOCHASTIC THEORY AND MODELING

This prize was established in 2016 by colleagues of Ulf Grenander (1923–2016).

Professor Grenander was an influential scholar in stochastic processes, abstract inference, and pattern theory. He published landmark works throughout his career, notably his 1950 dissertation, “Stochastic Processes and Statistical Interference” at Stockholm University, *Abstract Inference*, and seminal works in pattern theory, *General Pattern Theory* and *Pattern Theory: From Representation to Inference*. A long-time faculty member of Brown University’s Division of Applied Mathematics, Grenander received many honors. He was a fellow of the American Academy of Arts and Sciences, the National Academy of Sciences and was a member of the Royal Swedish Academy of Sciences.

The Grenander Prize recognizes exceptional theoretical and applied contributions in stochastic theory and modeling. It is awarded for seminal work, theoretical or applied, in the areas of probabilistic modeling, statistical inference, or related computational algorithms, especially for the analysis of complex or high-dimensional systems.

The prize amount is $5,000 and the prize is awarded every three years. The first award will be made in 2018.

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Nomination Period: March 1–June 30, 2017

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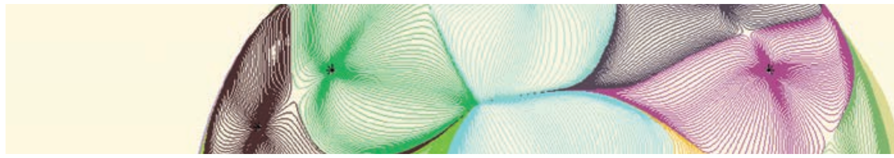

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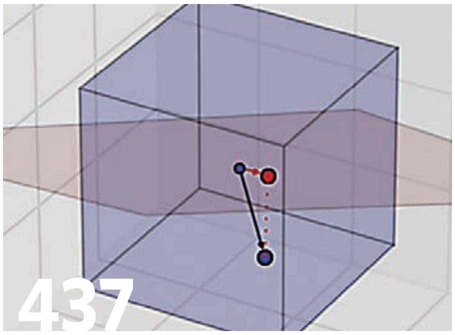

*We celebrate the May Eastern Sectional—with Marques on minimal surfaces, Maynard on primes, and Ramanan on random projections—and the upcoming July Mathematical Congress of the Americas—with Granville's alternative approach to analytic number theory and Peres's cover story on a fair partition of the sphere and overhanging blocks. Allyn Jackson recalls two highlights of the January Joint Mathematics Meetings: inspiring talks by Alice Silverberg and Francis Su. We have reports on CeMEAI, the Brazilian center for industrial mathematics, and the Mathematics Genealogy Project. Further inside you'll find announcements of three AMS awards for 2017—Impact Award, Exemplary Program Award, and Mathematics Programs that Make a Difference—as well as the 2017 JPBM Communications Award. And of course we have the usual book reviews and Graduate Student Section, including "WHAT IS...a Virtual Knot?" —**Frank Morgan, Editor-in-Chief***

FROM THE SECRETARY

ALSO IN THIS ISSUE

Notices
of the American Mathematical Society

ALSO IN THIS ISSUE, CT'D.

IN EVERY ISSUE

ADDENDUM TO: "A Golden Age in Minimal Surfaces" (April 2017 *Notices* Feature) by Joaquín Perez

Minimal surfaces is a vast and extremely active subject that has seen recently many important developments in different lines of research. My article does not cover entire lines of research where major progress has been made, including the proof of important conjectures.

To avoid misleading interpretations, I chose not to discuss some major recent developments in the field and to focus instead on advances in the classical theory of minimal surfaces in Euclidean three-space. —*Joaquín Perez*

Comments about our articles are always welcome on the *Notices* webpage at www.ams.org/notices. —*Frank Morgan, Editor-in-Chief*

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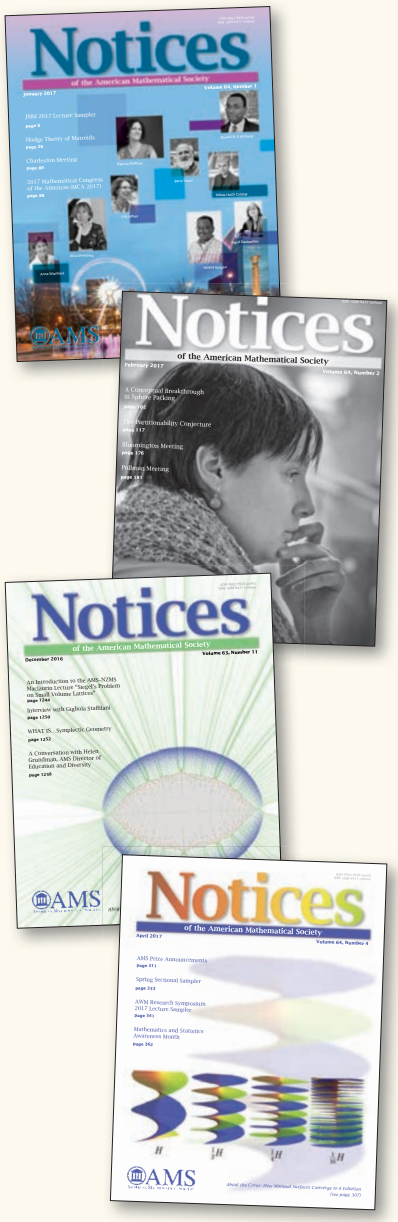
Call for Applications & Nominations

Chief Editor of the *Notices*



Applications and nominations are invited for the position of Chief Editor of the *Notices of the American Mathematical Society*, to commence with the January 2019 issue. The Society seeks an individual with strong mathematical research experience, broad mathematical interests, and a commitment to communicating mathematics to a diverse audience at a wide range of levels. The applicant must demonstrate excellent written communication skills.

The Chief Editor has editorial responsibility for a major portion of the *Notices* within broad guidelines. The goal of the *Notices* is to serve all mathematicians by providing a lively and informative magazine containing exposition about mathematics and mathematicians, and information about the profession and the Society.

The Chief Editor is assisted by a board of Associate Editors, nominated by the Chief Editor, who help to fashion the contents of the *Notices* and solicit material for publication. Some writing, and all publication support, will be provided by AMS staff. The Chief Editor will operate from her or his home base. Compensation will be negotiated for this half-time position and local part-time secretarial support will be provided. In order to begin working on the January 2019 issue, some editorial work would begin in early 2018.

Nominations and applications (including curriculum vitae) should be sent to the Chair of the Search Committee, Executive Director Catherine A. Roberts, at `exdir@ams.org`. Confidential inquiries may also be sent directly to Catherine A. Roberts or to any other member of the Search Committee (David Jerison, Mary Pugh, Kenneth Ribet, or Carla Savage).

To receive full consideration, nominations and applications should be sent on or before **September 15, 2017**.

Notices
of the American Mathematical Society

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SPRING EASTERN SECTIONAL SAMPLER

In this sampler, the speakers below have kindly provided introductions to their Invited Addresses for the upcoming AMS Spring Eastern Sectional Meeting **May 6–7, 2017** (Saturday–Sunday) Hunter College, City University of New York, New York, NY.

Fernando Codá Marques

James Maynard

Kavita Ramanan

Weyl's Law for Minimal Hypersurfaces by Fernando Codá Marques (Princeton University)
page 438

The Erdős Memorial Lecture: *Large Gaps between Primes* by James Maynard (Magdalen College, Oxford, and Clay Mathematics Institute)
page 438

Random Projections of High-Dimensional Measures by Kavita Ramanan (Brown University)
page 440

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Fernando Codá Marques

Weyl's Law for Minimal Hypersurfaces

The famous Weyl's law is a beautiful formula describing the asymptotic behavior of the eigenvalues of the Laplace operator. It was discovered in 1911 by Hermann Weyl for Dirichlet eigenvalues of a bounded domain in Euclidean space, but it holds true also in the more general case of eigenvalues of the Laplace–Beltrami operator of a compact Riemannian manifold. One possible formulation states that if $\lambda_1 \leq \lambda_2 \leq \cdots \leq \lambda_p \leq \cdots$ is the sequence of eigenvalues of a compact Riemannian manifold M of dimension $n+1$, then

$$\lim_{p\to\infty} \lambda_p p^{-\frac{2}{n+1}} = c(n)\mathrm{vol}\,(M)^{-\frac{2}{n+1}},$$

for some universal dimensional constant $c(n) > 0$. But what does this have to do with minimal surfaces?

Minimal hypersurfaces $\Sigma^n \subset M^{n+1}$ are critical points of the area functional, while eigenfunctions (solutions of an equation $\Delta_g \varphi + \lambda\varphi = 0$) are critical points of the Rayleigh functional $E(f) = (\int_M |\nabla f|^2 dM)/\int_M f^2 dM$. Even though the two settings seem dramatically different, they share deep topological principles whose basic implication is the existence of a Weyl law in which the eigenvalues are replaced by the areas of minimal hypersurfaces. The validity of this Weyl law was proven recently in joint work of the speaker with Liokumovich and Neves and answers a conjecture of Gromov.

The Rayleigh functional satisfies the symmetry $E(f) = E(-f)$, so it descends to the projectivization of the Sobolev space $W^{1,2}(M)$. Similarly, the space of unoriented closed hypersurfaces with the appropriate topology is weakly homotopically equivalent to $\mathbb{RP}^\infty$. One can mimic the min-max characterization of the p-th eigenvalue and define ω_p to be the infimum over all families of hypersurfaces modeled on $\mathbb{RP}^p$ of the supremum of the area functional. The sequence $\omega_1 \leq \omega_2 \leq \cdots \leq \omega_p \leq \cdots$ is called the volume spectrum of the Riemannian manifold M and amazingly obeys a Weyl law:

$$\lim_{p\to\infty} \omega_p(M) p^{-\frac{1}{n+1}} = a(n)\mathrm{vol}\,(M)^{\frac{n}{n+1}}.$$

Yau conjectured that a compact Riemannian three-manifold should contain infinitely many closed minimal surfaces. This should be true in higher dimensions as well and the volume spectrum should play an important role. In fact the $\mathbb{RP}^\infty$ structure was used in joint work of the speaker with Neves to prove the conjecture in any dimension $(n+1) \geq 3$ for manifolds of positive Ricci curvature. This work uses the min-max theory of Almgren and Pitts, which gives that each ω_p is achieved as the area of a minimal hypersurface, possibly with integer multiplicities. We are currently improving the theory further by proving index estimates inspired by finite-dimensional Morse theory. This is not an easy thing to do, because the space of cycles lacks a Hilbert space structure and so there is no Palais–Smale condition to check. Ultimately this will lead to a program that reduces the general case of Yau's conjecture to understanding the multiplicity phenomenon.

Photo Credit

Photo of Fernando Codá Marques is courtesy of Fernando Codá Marques.

Fernando Codá Marques is professor of mathematics at Princeton University. His e-mail address is coda@math.princeton.edu.

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ABOUT THE AUTHOR

Fernando Codá Marques is a differential geometer. He is a member of the Brazilian Academy of Sciences and a recipient of the Oswald Veblen Prize in Geometry.

Fernando Codá Marques

James Maynard

Large Gaps between Primes

Abstract. We discuss our recent joint proof of a conjecture of Erdős on the size of gaps between primes.

How large can gaps between primes be? This is a very basic question in the study of the distribution of primes, which could have been studied by the ancient Greeks (see Figure 1) but also has some direct relevance to the modern world. Various computer programs generate prime numbers of a given approximate size X by starting at X and then sequentially testing X, $X+1$, $X+2$, etc., in turn until one finds a prime. It is quick to test an individual number to see if it is prime, but it would take a long time to find a prime if you have to test a very large number of integers. How many numbers would you need to test before you found a prime? This is exactly the problem of how large gaps between primes are!

James Maynard is a Clay Research Fellow at Magdalen College, Oxford. His e-mail address is james.alexander.maynard@gmail.com.

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Figure 1. Calculations performing the sieve of Eratosthenes. This is a simple way of finding prime numbers dating back to the ancient Greeks. Generalizations of such sieves play a major role in modern work on large gaps between primes.

The prime number theorem shows that the *average* gap between prime numbers of size X is approximately $\log X$. Thus *typically* one would need to test about $\log X$ numbers for primality, which is not too many.

Our current knowledge of this problem is very limited.

Conjecture (Cramér)**.** *Amongst primes less than X, all gaps are smaller than $C(\log X)^2$ (for some absolute constant $C > 0$).*

If Cramér's conjecture is true, then we would *never* have to test more than about $(\log X)^2$ integers. This would enable one to quickly find a prime of any given size. In fact, this would give a simple *deterministic* way of generating prime numbers of any given size very quickly, something that we don't know how to do.

Our current knowledge of this problem is very limited. The best upper bound is the following.

Theorem (Baker, Harman, Pintz)**.** *Amongst primes less than X, all gaps are smaller than $CX^{0.525}$ (for some absolute constant $C > 0$).*

Unfortunately this doesn't rule out the possibility of there being some pairs of consecutive primes very far apart. Testing $X^{0.525}$ consecutive integers when X has a hundred digits would take much longer than a lifetime.

In the other direction, there is a very easy high school method of showing that there are arbitrarily large gaps between prime numbers. For j between 2 and n, the integer $n! + j$ is a multiple of j and so cannot be prime. This gives $n - 1$ consecutive composite numbers which are all of size approximately $n!$. Put another way, this constructs gaps between primes smaller than X of size at least $c \log X / \log\log X$ (for some constant $c > 0$). This is worse than the average gap from the prime number theorem, but this argument has proven easier to generalize. A series of papers in the 1930s adapted this high school method to show that there are gaps which can be arbitrarily large compared with the average gap.

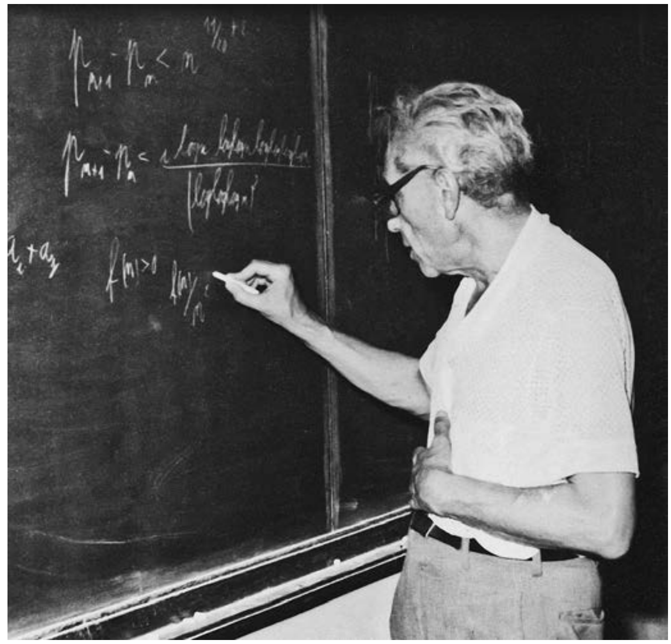
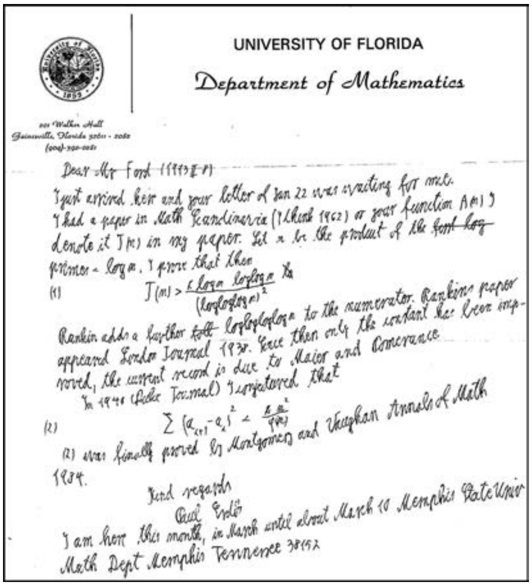


Figure 2. Paul Erdős explaining the large gaps between primes problem in a lecture in Madras, 1984.

Theorem (Erdős, Rankin, Westzynthius)**.** *There exist consecutive primes less than X which differ by more than $c \log X \cdot \log\log X \cdot \log\log\log\log X / (\log\log\log X)^2$ (for some absolute constant $c > 0$).*

This (rather ugly) expression is only slightly larger than the average gap of size $\log X$ and well off Cramér's prediction of $(\log X)^2$, but the underlying method is the only way we currently have of showing that there are arbitrarily large gaps compared with the average size. Unfortunately, progress was slow at improving this bound; subsequent improvements over the next seventy-five years were only in the value of the constant c. Paul Erdős, who liked to offer cash prizes for math problems, offered his largest-ever cash prize for the problem of showing that the constant c above could be made arbitrarily large as $X \to \infty$ and popularized the problem by mentioning it in several lectures and letters (see Figures 2 and 3). This was because any noticeable improvement in the bound would need to use new arithmetic information about prime numbers.

In 2014 this challenge was solved independently by the author and by Ford, Green, Konyagin, and Tao using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Department of Mathematics

Dear Mr Ford

I just arrived here and your letter of Jan 22 was waiting for me.
I had a paper in Math Scandinavia (I think 1962) on your function A(n) I
denote it J(n) in my paper. Let n be the product of the ~~first log~~
primes ≤ log n. I prove that then

(1) $J(n) > \frac{c \log n \log\log n}{(\log\log\log n)^2}$

Rankin adds a further ~~fol~~ loglogloglog n to the numerator. Rankins paper
appeared London Journal 1938. Since then only the constant has been improved, the current record is due to Maier and Pomerance
In 1940 (Duke Journal) I conjectured that

(2) $\sum (a_{i+1} - a_i)^2 < \frac{c\, n^2}{\varphi(n)}$

(2) was finally proved by Montgomery and Vaughan Annals of Math
1974.

Kind regards
Paul Erdős

I am here this month, in March until about March 10 Memphis State Univ
Math Dept Memphis Tennessee 38152

Figure 3. A letter from Paul Erdős to Kevin Ford when Ford was a graduate student on the large gaps problem. It includes the remark "Rankin adds a further log log log log n to the numerator." Ford later was one of the authors to solve Erdős's problem several years later.

rather different methods. Combining these approaches, the final result was

Theorem (Ford, Green, Konyagin, Maynard, Tao). *There exist consecutive primes less than X which differ by more than $c \log X \cdot \log\log X \cdot \log\log\log\log X / \log\log\log X$ (for some absolute constant $c > 0$).*

The improvement here (by a factor of $\log\log\log X$) is quantitatively quite modest, and we are still well off Cramér's conjecture. The key interest is that these approaches used stronger knowledge of the distribution of prime numbers to get these improvements of old questions. In my talk I will give an overview of this problem and recent developments, which involve a pleasing mixture of probability, combinatorics, analysis, and number theory.

Photo Credits

Figure 1 is courtesy of James Maynard.
Figure 2 is courtesy of Krishnaswami Alladi.
Figure 3 is courtesy of Kevin Ford.
Photo of James Maynard is courtesy of Eleanor Grant.}

ABOUT THE AUTHOR

James Maynard is a Clay Research Fellow at Magdalen College, Oxford. His research is in analytic number theory, particularly the distribution of prime numbers.

James Maynard

Kavita Ramanan

Random Projections of High-Dimensional Measures

The study of high-dimensional phenomena is an active research area that lies at the intersection of probability theory, statistics, and asymptotic geometric analysis. Classical theorems in probability theory concern the behavior of high-dimensional product measures. Specifically, suppose $X_1, X_2, \ldots$ are independent and identically distributed random variables; that is, for every n, the random vector $X^{(n)} = (X_1, \ldots, X_n)$ is distributed according to the n-fold product measure $\mu^{\otimes n}$ for some Borel probability measure μ on the real line. Then a central object of study is the empirical mean $S_n = \frac{1}{n}\sum_{i=1}^n X_i$ of $X_1, \ldots, X_n$. If μ satisfies $\int_{\mathbb{R}} x^2 \mu(dx) < \infty$, assuming without loss of generality that the sample mean $\int_{\mathbb{R}} x\mu(dx)$ is zero, the celebrated central limit theorem (CLT) established at the turn of the twentieth century says that the scaled empirical mean, $\sqrt{n}S_n$, is close to a centered Gaussian distribution for large n. While the CLT describes fluctuations of S_n around the sample mean, Cramér's theorem (1938) describes the asymptotic tail behavior, or large deviations from the mean, of S_n. In particular, under an additional finite exponential moment assumption on μ, Cramér's large deviation principle (LDP) shows that the probability of S_n exceeding a value x is roughly $\exp(-nI(x))$, where the so-called rate function I that captures the exponential decay rate is nonuniversal in the sense that it depends on the distribution μ.

These questions are clearly of intrinsic interest to probabilists, [but] they are also relevant to data analysis.

Taking a geometric perspective, one can equivalently view $\sqrt{n}S_n$ as the scalar projection of the n-dimensional random vector $X^{(n)}$ along the vector $(1, 1, \ldots, 1)/\sqrt{n}$ on the unit sphere $\mathbb{S}^{n-1}$ in $\mathbb{R}^n$. Thus, the classical CLT and Cramér's LDP can be viewed as statements on the behavior of (scalar) projections of high-dimensional random vectors with a product distribution. This leads naturally to the question of whether analogous results

Kavita Ramanan is professor of applied math at Brown University. Her e-mail address is Kavita_Ramanan@brown.edu.

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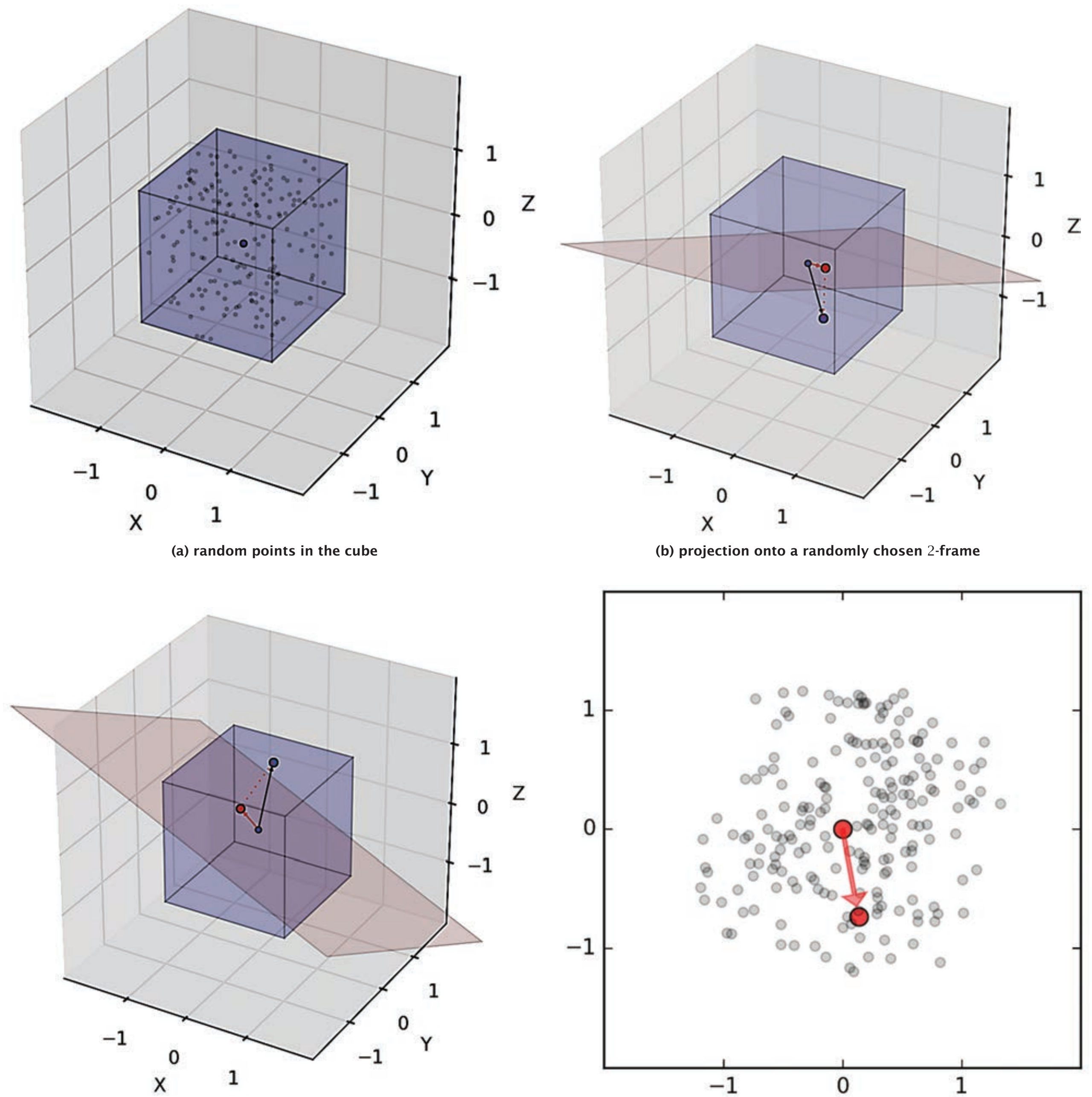

(a) random points in the cube

(b) projection onto a randomly chosen 2-frame

(c) projection onto another randomly chosen 2-frame

(d) distribution of projections onto a fixed 2-frame

Figure 1. Projections of the uniform distribution on the cube onto random 2-dimensional subspaces.

hold for (i) more general high-dimensional random vectors with a nonproduct distribution (beyond those satisfying classical weak independence conditions) and (ii) scalar projections along a random vector on the unit sphere $\mathbb{S}^{n-1}$, as well as multidimensional projections onto a random k-dimensional orthonormal basis on the Stiefel manifold. For example, Figure 1(d) depicts the distribution of coordinates of the projection of random points chosen from Lebesgue measure on the 3-dimensional cube onto a random 2-dimensional orthonormal basis.

While these questions are clearly of intrinsic interest to probabilists, they are also relevant to data analysis, where low-dimensional projections are used to study high-dimensional data and asymptotic convex geometry, where the high-dimensional distribution of interest is typically the uniform distribution on a convex set in a high-dimensional Euclidean space.

At the level of the CLT, such a line of inquiry has a long history, going back to Borel, who showed in 1906 that projections of the uniform measure on a high-dimensional sphere are approximately Gaussian. Building on subsequent work of Sudakov (1978) and Diaconis and Freedman (1984), over the last decade various generalizations have been obtained by Brehm and Voigt (2000), Attila, Ball, and Perissanski (2003), Klartag (2007), and Meckes (2012), to name a few. Essentially, these studies show that when the distribution of a high-dimensional random vector satisfies a certain geometric condition, its projections onto most k-dimensional orthonormal bases are approximately Gaussian as long as k is not too large compared to the dimension of the vector. While this is a striking universality result, it implies that fluctuations of typical low-dimensional projections do not capture much information about high-dimensional distributions.

This motivated me to look instead at the (nonuniversal) large deviation behavior of these random projections and seek corresponding geometric generalizations of Cramér's theorem, about which not much was known. In the invited address I will discuss my recent work (stemming from various collaborations with N. Gantert and graduate student S. Kim), which sheds light on the tail behavior of random projections of high-dimensional distributions. Along the way, I will describe large deviations on the Stiefel manifold and explain why the classical Cramér LDP is in a sense atypical!

Photo Credits

Figure 1 is courtesy of Steven S. Kim.
Photo of Kavita Ramanan is courtesy of Kavita Ramanan.

Kavita Ramanan

THE AUTHOR

Kavita Ramanan has received the IMS Medallion and the Applied Probability Society Erlang Prize and was elected Fellow of the IMS. She is founder of a math outreach group called the Math CoOp.

Photo by Hadimor; courtesy of iStock by Getty Images.

Mathematical Congress of the Americas 2017 (July 24–28, Montréal, Canada) Invited Speakers Lecture Sampler:

Andrew Granville
"The Benefits of an Alternative Approach to Analytic Number Theory" p. 444

Yuval Peres
"Two Surprising Appearances of Potential Theory" p. 446

DOI: http://dx.doi.org/10.1090/noti1527

Andrew Granville

The Benefits of an Alternative Approach to Analytic Number Theory

Abstract. In our talk we will survey the alternative (or "pretentious") approach to analytic number theory, which has the potential to be more flexible and broad reaching than traditional zeta-function methods, highlighting some spectacular recent developments. In this "sampler" we give some indication of the change in perspective that motivates this shift in technique.

Riemann's Memoir

In a nine-page memoir written in 1859, Riemann outlined an extraordinary plan to attack the elementary question of counting prime numbers using deep ideas from the theory of complex functions. His approach begins with what we now call the *Riemann zeta-function*:

$$\zeta(s) := \sum_{n\geq 1} \frac{1}{n^s}.$$

To make sense of an infinite sum, it needs to converge and preferably be absolutely convergent, implying that we can rearrange the order of the terms without changing the value. The sum defining $\zeta(s)$ is absolutely convergent when $\mathrm{Re}(s) > 1$.

Applying the *Fundamental Theorem of Arithmetic* to each term in the sum for $\zeta(s)$, we can write

$$\zeta(s) = \prod_{p \text{ prime}} \left(1 - \frac{1}{p^s}\right)^{-1}. \tag{1}$$

This connection between $\zeta(s)$ and prime numbers was exploited by Riemann: since the sum defining $\zeta(s)$ is absolutely convergent when $\mathrm{Re}(s) > 1$, it is safe to perform calculus operations on $\zeta(s)$ in this domain. By taking the logarithmic derivative we have

$$-\frac{\zeta'(s)}{\zeta(s)} = -\frac{d}{ds}\log\zeta(s)$$
$$= \sum_{p \text{ prime}} \frac{d}{ds}\log\left(1-\frac{1}{p^s}\right) = \sum_{\substack{p \text{ prime}\\ m\geq 1}} \frac{\log p}{p^{ms}}.$$

Notice that the $1/n^s$ term here is nonzero if and only if n is a prime power (that is, $n = p^m$), and so Riemann found a way to identify prime powers (the vast majority of which are primes) via the coefficients of an infinite series.

Andrew Granville is the Canada Research Chair in Number Theory, Université de Montréal and chair of pure mathematics, University College London. His e-mail address is `and.granville@gmail.com`.

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To count the primes up to x, one can make use of Perron's formula in the form

$$\frac{1}{2i\pi}\int_{\mathrm{Re}(s)=\sigma} \frac{(N/n)^s}{s}\, ds = \begin{cases} 0 & \text{if } 1 \leq n < N,\\ 1/2 & \text{if } n = N,\\ 1 & \text{if } n > N,\end{cases}$$

where $\sigma > 0$, which can be proved via Cauchy's theorem. Ignoring convergence issues one can then show that for any sequence of complex numbers $(a_n)_{n\geq 1}$ one has

(2)
$$\sum_{n<N} a_n + \frac{1}{2}a_N$$
$$= \frac{1}{2i\pi}\int_{\mathrm{Re}(s)=\sigma} A(s)\cdot\frac{x^s}{s}\, ds, \text{ where } A(s) := \sum_{n\geq 1}\frac{a_n}{n^s}.$$

In the particular case that $A(s) = -\zeta'(s)/\zeta(s)$, this yields, when x is not itself a prime power,

$$\sum_{\substack{p^m\leq x\\ p \text{ prime}\\ m\geq 1}} \log p = \frac{1}{2i\pi}\int_{\mathrm{Re}(s)=\sigma} -\frac{\zeta'(s)}{\zeta(s)}\cdot\frac{x^s}{s}\, ds$$

for $\sigma > 1$ (to ensure absolute convergence throughout the argument).

This formula morphs a perfectly understandable question like estimating the number of primes up to x, involving a sum that is easily interpreted, to a rather complicated integral, over an infinitely long line in the complex plane, of a function that is delicate to work with in that it is only well defined when $\mathrm{Re}(s) > 1$. It is by no means obvious how to proceed from here, but Riemann was up to the task.

How Do We Evaluate This Integral?

The idea is to pull the integral to the left and to use Cauchy's formula so that its value is given by a sum of residues. This is not an easy task. First, $\zeta(s)$ is not defined on or to the left of the line $\mathrm{Re}(s) = 1$, so we have to extrapolate $\zeta(s)$ in a meaningful way to the whole complex plane, which is achieved by *analytic continuation*. Then we need to ensure that the integral on the newly chosen contours is actually vanishingly small. And then we need to determine the poles of the integrand, the difficult bit being the function $\zeta'(s)/\zeta(s)$. Indeed, its poles are evidently given by the poles and zeros of $\zeta(s)$, and this leads to the mysterious *Riemann Hypothesis*.

Classical analytic number theory (including important aspects of the theory of elliptic curves and of the Langlands program) takes this type of approach for granted. Indeed, to proceed one has to assume that the relevant series $A(s)$ must be meromorphically continuable to the whole complex plane (and one expects that each such $A(s)$ satisfies a whole host of other remarkable properties). Here the coefficients, the a_n, arise naturally in arithmetic problems. However, there is a big problem with this: it is not easy to prove in general that $A(s)$ is meromorphically continuable (the great works of Wiles on Fermat's Last Theorem and of Taylor on the Sato–Tate conjecture end up proving, in some of the deepest advances of modern mathematics, just such results), and one can cook up interesting arithmetic examples in which this is not even true. This places significant limitations on which questions one can directly attack with classical analytic techniques.

An Alternative Approach

In typical arithmetic problems the coefficients a_n are not too large, and so we may assume that the series for $A(s)$ is absolutely convergent for s with $\text{Re}(s) > 1$.

The core problem is to develop methods to

$$\text{Estimate } \sum_{n \le N} a_n \text{ via the formula (2)}$$

without assuming that $A(s)$ can be analytically continued.

Indeed, we do not even want to assume that $A(s)$ can be analytically continued onto the line $\text{Re}(s) = 1$. Evidently this must require a careful study of $A(s)$ on the line $\text{Re}(s) = \sigma$ (or a slight variation, since one can manipulate contours freely in the domain of absolute convergence). First we need to understand when $|A(s)|$ is large, which can be shown to happen rarely. But if $A(s)$ is large at $s = s_0$, then by continuity it is large nearby, so we need to understand how it varies in a short interval near s_0. This is the start of the *alternative* (or *pretentious*) approach to analytic number theory. These sorts of questions have their roots in classical analytic developments, but have recently been taking on a life of their own.

These sorts of questions have their roots in classical analytic developments, but have recently been taking on a life of their own.

Let's study this question with an example. Fix $\delta > 0$ very small. When is $|\zeta(1 + \delta + it)|$ large? We will examine the value using the Euler product (1). Since this is convergent the tail should not be too relevant; indeed, if $\delta = \frac{1}{\log x}$, then one can truncate the Euler product to the primes $\le x$ and deduce that

$$\zeta(s) \approx \prod_{\substack{p \text{ prime} \\ p \le x}} \left(1 - \frac{1}{p^{1+it}}\right)^{-1}.$$

The pth term in this Euler product looks like $(1 - \frac{X(p)}{p})^{-1}$, where $X(p) = p^{-it}$ is some complex number of absolute value 1. This might be, in absolute value, anything between $(1 + \frac{1}{p})^{-1}$ and $(1 - \frac{1}{p})^{-1}$, and so the product is minimized when all of the p^{-it} are close to -1. Therefore $|\zeta(1+\delta+it)|$ is "large" if and only if most of the p^{it}, with $p \le x$, are roughly -1. Formulating this usefully takes some work but allows precise control over the size of $|\zeta(1 + \delta + it)|$, and similar techniques work with $|A(1 + \delta + it)|$ provided the a_n are multiplicative (that is, $a_{mn} = a_m a_n$).

This simple idea suddenly allows us to work with all sorts of L-functions that were not easily accessible to classical techniques and has been a central focus of research for the author and Soundararajan, as well as many collaborators, colleagues, postdocs, and students. We first identified such an approach in improving the long dormant upper bounds for character sums. Recognizing the potential for such methods, our next goal became to show that many of the main results of classical analytic number theory could be reproven without recourse to analytic continuation, a project that is highlighted in recent joint work with Harper and Soundararajan. Moreover, estimates of equal strength to the classical results could be proven, most notably in 2013 by Koukoulopoulos, reproving the best bounds known on the error term in the prime number theorem without recourse to zeta-function zeros. We went on, more recently, to understanding with de la Bréteche precisely when exponential sums can be large, which has relevance to, amongst other things, the circle method. In 2010 Soundararajan showed how such methods could be used to provide "weak subconvexity estimates" for a wide variety of L-functions leading to the completion (with Holowinsky) of the proof of the holomorphic quantum unique ergodicity conjecture (a case in which Lindenstrauss's methods do not work). Much of this will feature in the forthcoming monograph by the speaker and Soundararajan.

These ideas are now beginning to permeate a broad spectrum of questions in analytic number theory. Related recent spectacular advances include Terry Tao's resolution of Erdős's discrepancy conjecture and Matomäki and Radziwill's sensational recent work on multiplicative functions in very short intervals.

In this talk we will survey these and other of the more recent developments, including intriguing developing links with the groundbreaking work of Green, Tao, and Ziegler on prime patterns.

Photo Credit

Photo of Andrew Granville is courtesy of Anthony Kennedy.

ABOUT THE AUTHOR

Andrew Granville does his best work relaxing aux vignaux in the south of France. His mathematical graphic novel, *Mathematical Sciences Investigation: The Anatomy of Integers and Permutations*, co-authored with Jennifer Granville and drawn by artist Robert Lewis, will appear soon from Princeton University Press.

Andrew Granville

Yuval Peres

Two Surprising Appearances of Potential Theory: A Fair Partition of the Sphere and Overhanging Blocks

Given n points on the surface of a sphere, how can we partition the sphere fairly among them in an equivariant way? (See Figure 1.) "Fairly" means that each region has the same area. "Equivariant" means that if we rotate the sphere, the solution rotates along with the points. It turns out that if the given points apply a two-dimensional gravity force to the rest of the sphere, then the basins of attraction for the resulting gradient flow yield such a partition—with exactly equal areas, no matter how the points are distributed. Moreover, this partition minimizes, up to a bounded factor, the average distance between points in the same cell. This is joint work with Nina Holden, Manjunath Krishnapur, and Alex Zhai, based on earlier work of others [1].

Figure 1. An efficient fair allocation on the sphere is given by basins of gravitational attraction.

A second topic where potential theory surprisingly appears starts from the classical overhang problem: Given n blocks supported on a table, how far can they be arranged to extend beyond the edge of the table without falling off? Mike Paterson and Uri Zwick [2] showed that an overhang of order $n^{1/3}$ is attainable, as in Figure 2; we proved [3] that this is best possible. A crucial element in the proof involves an optimal control problem for diffusion on a discrete line segment. In recent work with Laura Florescu and Miklos Racz, we extended the solution of this control problem to higher dimensions, using Green functions and properties of the divisible sandpile established in earlier work with Lionel Levine.

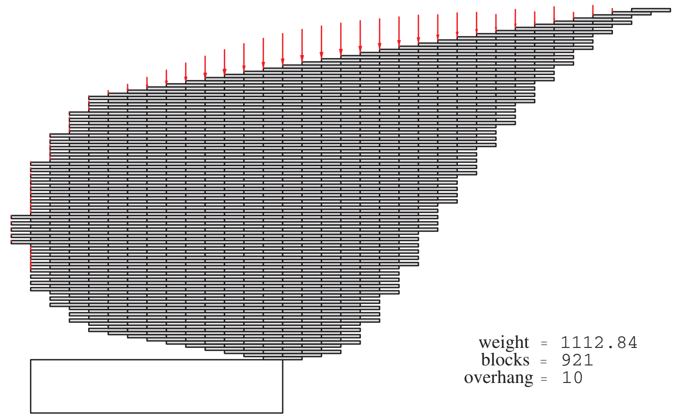

Figure 2. The maximum possible overhang for n blocks is of order $n^{1/3}$.

Yuval Peres is principal researcher at Microsoft Research. His e-mail address is peres@microsoft.com.

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Photo Credit

Figure 1 is courtesy of Jian Ding and Ron Peled.
Figure 2 is courtesy of Uri Zwick.
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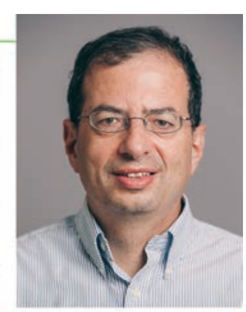

Yuval Peres

Yuval Peres's most recent books are *Probability on Trees and Networks* with Russell Lyons (Cambridge U. P., 2016), *Fractals in Probability and Analysis* with Christopher J. Bishop (Cambridge U. P., 2017) and *Game Theory, Alive* with Anna R. Karlin (Amer. Math. Soc., 2017). In 2016 Peres was elected as a foreign associate to the National Academy of Science. His webpage is yuvalperes.com.

AMERICAN MATHEMATICAL SOCIETY

AMS EXEMPLARY PROGRAM AWARD
CALL FOR NOMINATIONS

The AMS Award for Exemplary Program or Achievement in a Mathematics Department is presented annually to a department that has distinguished itself by undertaking an unusual or particularly effective program of value to the mathematics community, internally or in relation to the rest of the society. Examples might include a department that runs a notable minority outreach program, a department that has instituted an unusually effective industrial mathematics internship program, a department that has promoted mathematics so successfully that a large fraction of its university's undergraduate population majors in mathematics, or a department that has made some form of innovation in its research support to faculty and/or graduate students, or which has created a special and innovative environment for some aspect of mathematics research.

The award amount is $5,000. All departments in North America that offer at least a bachelor's degree in the mathematical sciences are eligible.

The Award Selection Committee requests nominations for this award, which will be announced in Spring 2018. Letters of nomination may be submitted by one or more individuals. Nomination of the writer's own institution is permitted. The letter should describe the specific program(s) for which the department is being nominated as well as the achievements that make the program(s) an outstanding success, and may include any ancillary documents which support the success of the program(s). The letter should not exceed two pages, with supporting documentation not to exceed an additional three pages.

Nominations with supporting information should be submitted to www.ams.org/profession/prizes-awards/nominations. Those who prefer to submit by regular mail may send nominations to the AMS Secretary, Professor Carla D. Savage, North Carolina State University, Department of Computer Science, Campus Box 8206, Raleigh, NC 27695-8206. The nominations will be forwarded by the Secretary to the Prize Selection Committee.

Deadline for nominations is September 15, 2017.

OPINION

Can Mathematics Light the Way?

Allyn Jackson

Note: The opinions expressed here are not necessarily those of Notices. *Responses on the* Notices *webpage are invited.*

At the most recent Joint Mathematics Meetings, held in January in Atlanta, I attended two extraordinary lectures. The first was by Alice Silverberg, who spoke on Diffie-Hellman key cryptography. After a lucid exposition of the basics, she worked up to new results she and her collaborators have obtained, which provide mathematical insights into why the Diffie-Hellman method is effective—and why it sometimes isn't. Into the talk she wove an *Alice in Wonderland* theme, illustrated with the lovely, gently humorous drawings of John Tenniel that accompanied the original edition of that classic.[1]

The mathematics was beautiful, the presentation accessible, entertaining, and polished. What more could you ask for? Well, Alice Silverberg did ask for more—more of herself, more of her audience, more of her community. In the last twenty minutes of the talk, she reflected on what she learned in collaborating with cryptographers, whose needs and approaches are very different from those of mathematicians. The lessons she distilled from this experience were simple and profound. Listen to others. Give them your whole attention. Listen without half your mind planning what you will say. Do not assume you can read the other person's mind. Instead, ask what's on his or her mind. If someone makes you angry, don't respond in anger. Get curious, not furious, she said, using a phrase borrowed from a 2016 book written by Martin Hellman—the same Hellman of Diffie-Hellman—together with his wife, Dorothie Hellman.

"Every being cries out silently to be read differently."

It would be easy for such a lecture to slide into pompousness, but Silverberg's sense of humor prevented that, as did her humility. She did not present these lessons as ones she has mastered herself. Rather, she encouraged her fellow mathematicians to welcome the experience of allowing deep mathematical interactions—which are essentially encounters with truth and beauty—to influence other parts of their lives, especially their attitudes toward others.

After her talk, I thought, "Of course it was a woman who had the daring to talk about how mathematics can lead us toward more humane living. Women mathematicians are changing things. Let's hear a cheer for the distaff side of the community!"

My rather chauvinistic reaction—and here I am referring not to male chauvinism but to the female brand—was blown out of the water by another lecture I attended, that of retiring MAA president Francis Su.[2]

Profound and wide-ranging, Su's lecture is difficult to summarize, but let me try: Mathematics can transform the human heart, turning it toward compassion. Let this transformation resound in your interactions with students. A quotation of Simone Weil formed a leitmotif in the talk: "Every being cries out silently to be read differently." Su called on the audience to read their students' struggles differently—to read them with empathy and to respond with encouragement.

He began the lecture by quoting from a poignant letter he had received from Christopher, a prison inmate who had been studying mathematics. Su's voice cracked slightly as he read from the letter, which told the story of a life gone wrong at an early age through drugs and crime, but one that was in the process of redemption through

Allyn Jackson is senior writer and deputy editor of the Notices. *Her e-mail address is* axj@ams.org.

[1] *Silverberg wrote a brief outline of the lecture for the "JMM 2017 Lecture Sampler" that appeared in the January 2017 issue of the* Notices.

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[2] *The full text of Su's lecture, "Mathematics for Human Flourishing," is available on his blog,* https://mathyawp.wordpress.com *and will appear in an upcoming issue of the* American Mathematical Monthly.

Silverberg encouraged fellow mathematicians to welcome deep mathematical interactions.

Su recounted stories of students whose mathematical work was hampered by prejudice.

study of mathematics. "When you think of who does mathematics, do you think of Christopher?" Su asked. "Every being cries out silently to be read differently."

Mathematics has the power to redeem by bringing the mind into contact with truth and beauty. But this contact frequently leads to struggles not with the mathematics itself, but with the social and institutional structures in which mathematics is embedded. Too often mathematics students lack a sense of belonging, of being worthy, of being understood. Su described how Simone Weil herself struggled with mathematics, standing as she did in the shadow of her prodigiously talented brother, André Weil.

Su also recounted stories of students whose mathematical work was hampered by prejudice. In one example, a female student with a gender-neutral first name had top grades on homework in her mathematics class—until the grader found out that this impressive student was not male. After that, her homework scores dropped, with points taken away on the basis of vague comments like "give more detail." In another example, a student who had done great work in a summer mathematics program was told by a faculty member at her home institution that she should change from mathematics to an "easier" profession. Eventually she switched to engineering.

Su also spoke of his own experiences growing up in a town in south Texas, where his was just about the only Asian family. He desperately longed to be white. (This resonated with me: As a white kid in a predominantly black middle school, I wanted to be black so badly that I asked my parents to buy me an afro wig.) In graduate school at Harvard, he felt out of place because he lacked an Ivy League background. One professor even told him he didn't belong in graduate school. Su was on the verge of quitting when another professor reached out to him and became his advisor. Su also witnessed the toll taken on Harvard undergraduates burdened by hierarchical structures, such as the two levels of honors calculus sitting above the regular calculus class. Even though they'd made it into honors calculus in one of the top universities in the world, the students in the "lower" honors calculus felt inadequate.

Many of us have such tales to tell. I had been a straight-A student in high school, so as a freshman I was confident I would do well in Calculus 1A. The course had a couple hundred students, but I was pretty fearless and raised my hand often to ask questions in the huge lecture hall. One day after class, the professor said to me: "Keep asking questions. It's good to hear from the B students." That stopped my questions. As predicted, I got a B in Calculus 1A—my only non-A grade as a math major. And as in many tales of this sort, not everything in mine is black and white. This professor was actually an outstanding and wonderful teacher who cared deeply about students. He would have listened had I found the courage to tell him about the effect of his comment.

"Every being cries out silently to be read differently." As Su repeated this quotation several times in the lecture, Simone Weil's insight itself seemed to cry out to be taken to heart. Painting a collective portrait of students and their struggles, Su called upon his colleagues to seek out one student who faces challenges and to become a long-term advocate for that student. "Be the one who says 'I see you, and I think you have a future in math.' Be the one who searches out opportunities for them. Be the one who pulls them towards virtue. Be the one who calls them up when they've skipped class and asks 'Is everything okay? What are you going through?'"

This was no ordinary math lecture. When the audience, rapt throughout, got to their feet for a standing ovation at the end, many had tears in their eyes—as did Su.

Silverberg's and Su's talks took place just days before the presidential inauguration that capped one of the most divisive races in the history of the US, and against an international backdrop of suspicion and outright fear about the future. While neither lecture addressed political issues, societal discord weighed heavily on both. By showing how mathematics can open hearts to greater empathy, greater understanding, greater humanity, Silverberg and Su posed a challenge: Can mathematics light a way toward a better world?

Photo Credits

Photos by Kate Awtrey, JMM 2017 photographer.

CeMEAI: The Brazilian Center and Its Mathematics Research for Industry

E. G. Birgin, J. A. Cuminato, J. M. Martínez, and T. Pereira

Abstract. We describe the Brazilian applied mathematics research center CeMEAI and some of the work being done there.

Introduction

CeMEAI, Center for Research in Mathematical Sciences Applied to Industry, hosted at the Institute of Mathematics and Computer Sciences of the University of São Paulo in São Carlos, is one of seventeen cross-disciplinary research, innovation, and dissemination centers funded by FAPESP, the São Paulo state research funding agency. CeMEAI started its activities in 2011 and has received substantial financial support from FAPESP since 2013. The present funding will last until June 2018, and it can be renewed for another two periods of three years each, pending the outcome of international assessment. CeMEAI involves five research institutions in São Paulo state with twenty-five principal investigators, around forty associated researchers, fifteen postdocs, twenty-five PhD students, and some master's students. In total more than one hundred researchers contribute directly to technological innovation projects in the main concentration areas of the center: applied optimization and operational research, computational fluid mechanics, risk analysis, and computational intelligence and software engineering. The main purpose of CeMEAI is to provide a broad and well-resourced mechanism for connecting scientists, engineers, mathematicians, and computer experts in order to address scientific and technological challenges in a collaborative, engaging environment, developing transformative new mathematical techniques and exploring their applications. CeMEAI is also highly engaged in the training of the next generation of researchers, educators, and industry and government personnel. In 2013 CeMEAI started an MSc in industrial mathematics that has taken students from the banking and hospital industries for retraining in risk technology analysis and data systems.

Some research projects begin with industry visits: once industry's problems are identified, representatives are put in contact with researchers who may be able to help address them. Other strategies like an Oxford-style study group with industry and modeling camps have been organized annually since 2015.[1] Since the center started its activities in 2011, many industrial projects have been contracted: multiscale methods for reservoir simulation, broiler house environment control in fluid dynamics, mammal cancer treatment protocol, and a computer system for helping high school sports coaches rank their students in statistics. Our researchers have also worked on projects that have made an impact on a larger community, such as the systems Packmol, PUMA, and TANGO, described in more detail in what follows. Other researchers have worked on complex systems such as power grids, lasers, and biological oscillators.

Industrial Applications

Building Initial Configurations for Molecular Dynamics Simulations—Packmol

Molecular dynamics simulations consist of arrangements of molecules distributed in space in such a way as to approximately represent the system's overall structure. For the simulations not to be disrupted by large Van

E. G. Birgin is professor of mathematics at the University of São Paulo, Brazil. His e-mail address is egbirgin@ime.usp.br.

J. A. Cuminato is professor of mathematics at the University of São Paulo, Brazil, and coordinator of CeMEAI. His e-mail address is jacumina@icmc.usp.br.

J. M. Martínez is professor of mathematics at the State University of Campinas, Brazil, and deputy coordinator of CeMEAI. His e-mail address is martinez@ime.unicamp.br.

T. Pereira is associate professor of mathematics at the University of São Paulo, Brazil. His e-mail address is tiago@icmc.usp.br.

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[1] *For further information on the study group reports and activities please visit the site* www.cemeai.icmc.usp.br/2WSMPI.

An engineer from industry and problem presenter (Y. C. S. Ribeiro from Tecumseh), three academic mathematicians (A. C. P. L. F. Carvalho from ICMC-USP, G. N. Silva from IBILCE-UNESP, and Z. Liang from FFCLRP-USP), a postdoctoral scholar (C. Affonso from ICMC-USP), and a PhD student (P. H. Pisani from ICMC-USP) participating in the activities of the Second Brazilian Study Group with Industry held at the Institute of Mathematics and Computer Sciences of the University of São Paulo July 11–15, 2016.

Students and mentors discussing alternatives for solving a problem (at the front table: Professors J. Ueyema and M. O. Santos and students A. C. V. Figur, E. D. Bernardes, and F. A. Aureliano; in the back: students H. F. Vieira and L. Y. M. Alves).

der Waals repulsive interactions, atoms from different molecules must keep safe pairwise distances. Obtaining such a molecular arrangement can be considered a packing problem: Each type of molecule must satisfy spatial constraints related to the geometry of the system, and the distance between atoms of different molecules must be greater than some specified tolerance. Packmol [3] is software able to pack millions of atoms, grouped in arbitrarily complex molecules, inside a variety of three-dimensional regions. The regions may be intersections of spheres, ellipses, cylinders, planes, or boxes. The user must provide only the structure and geometrical constraints for a molecule of each type. Building complex mixtures and interfaces and placing biomolecules in water or other solvents is straightforward. In addition, different atoms belonging to the same molecule may also be restricted to different spatial regions in such a way that more ordered molecular arrangements can be built, such as micelles or lipid double-layers. The packing time for state-of-the-art molecular dynamics systems varies from a few seconds to a few minutes on a personal computer. The input files are simple and currently compatible with PDB, Tinker, Molden, or Moldy coordinate files.

Let us call *nmol* the total number of molecules that we want to place in a region of the three-dimensional space. For each $i = 1, \dots, nmol$, let $natom(i)$ be the number of atoms of the ith molecule. Each molecule is represented by the Cartesian coordinates of its atoms. The point whose coordinates are the arithmetic averages of the coordinates of the atoms is called the barycenter. To facilitate visualization, assume that the origin is the barycenter of all the molecules. For all $i = 1, \dots, nmol$, $j = 1, \dots, natom(i)$, let $a^{ij} = (a_1^{ij}, a_2^{ij}, a_3^{ij})$ be the coordinates of the jth atom of the ith molecule.

Suppose that the ith molecule is sequentially rotated around the axes x_1, x_2, and x_3 at angles $\theta^i = (\theta_1^i, \theta_2^i, \theta_3^i)$. Moreover, suppose that, after these rotations, the whole molecule is displaced so that its barycenter becomes $c^i = (c_1^i, c_2^i, c_3^i)$. These movements transform the coordinates a^{ij} to $p^{ij} = (p_1^{ij}, p_2^{ij}, p_3^{ij})$. Observe that p^{ij} is always a function of (c^i, θ^i):

$$p^{ij} = c^i + R(\theta^i) a^{ij}, \tag{1}$$

where $R(\theta^i)$ is the rotation matrix given by

$$R(\theta^i) = \begin{pmatrix} c_1^i c_2^i c_3^i - s_1^i s_3^i & s_1^i c_2^i c_3^i + c_1^i s_3^i & -s_2^i c_3^i \\ -c_1^i c_2^i s_3^i - s_1^i c_3^i & -s_1^i c_2^i s_3^i + c_1^i c_3^i & -s_2^i s_3^i \\ c_1^i s_2^i & s_1^i s_2^i & c_2^i \end{pmatrix}, \tag{2}$$

in which $s_k^i \equiv \sin \theta_k^i$ and $c_k^i \equiv \cos \theta_k^i$, for $k = 1, 2, 3$.

Our objective is to find angles θ^i and displacements c^i, $i = 1, \dots, nmol$, in such a way that, for all $i = 1, \dots, nmol$, $j = 1, \dots, natom(i)$, the point whose coordinates are $(p_1^{ij}, p_2^{ij}, p_3^{ij})$ satisfies the constraints imposed on the atom j of the molecule i. In addition, we wish that for all $i \neq i'$, $j = 1, \dots, natom(i)$, $j' = 1, \dots, natom(i')$,

$$\| p^{ij} - p^{i'j'} \| \geq d_{\text{tol}}, \tag{3}$$

where $d_{\text{tol}} > 0$ is a user-specified tolerance. The symbol $\| \cdot \|$ stands for the usual Euclidean distance. In other words, the rotated and displaced molecules must remain in the desired region, and the distance between any pair of atoms of different molecules must not be less than d_{tol}.

A large variety of positioning constraints may be imposed individually on the atoms. Let r^{ij} be the number of constraints that apply to the jth atom of the ith molecule. These constraints can be represented as

$$g_\ell^{ij}(p^{ij}) \leq 0, \qquad \ell = 1, \dots, r^{ij}. \tag{4}$$

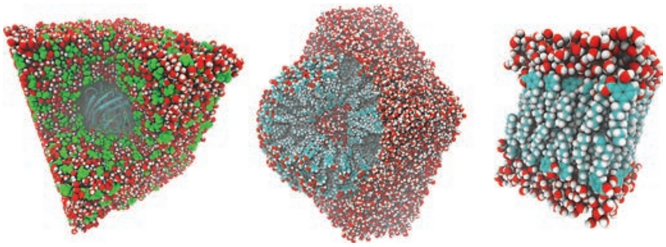

Figure 1. Molecular systems built with Packmol for molecular dynamics simulations: Left: a protein solvated with a mixture of water (red) and glucose (green); Center: a spherical lipid vesicle with water inside and outside; Right: a lipid bilayer with water above and below.

The objectives (3)–(4) lead us to define the following merit function f:

$$f(c,\theta) = \sum_{i=1}^{nmol}\sum_{j=1}^{natom(i)}\left(\sum_{i'=i+1}^{nmol}\sum_{j'=1}^{natom(i')}\max\{0, d_{tol}^2 - \|p^{ij} - p^{i'j'}\|^2\}^2\right) + \sum_{i=1}^{nmol}\sum_{j=1}^{natom(i)}\left(\sum_{\ell=1}^{r^{ij}}\max\{0, g_\ell^{ij}(p^{ij})\}^2\right), \quad (5)$$

where $c = (c^1, \ldots, c^{nmol}) \in \mathbb{R}^{3\times nmol}$ and $\theta = (\theta^1, \ldots, \theta^{nmol}) \in \mathbb{R}^{3\times nmol}$. (Remember the dependence of p^{ij} on the variables (c^i, θ^i) and the constants a^{ij} given by (1)–(2).) Note that $f(c,\theta)$ is nonnegative for all angles and displacements. Moreover, f vanishes if and only if the objectives (3)–(4) are fulfilled. This means that if we find displacements and angles where $f = 0$, the atoms of the resulting molecules fit the desired region and are sufficiently separated. This leads us to define the following unconstrained minimization problem:

$$\text{Minimize } f(c,\theta). \quad (6)$$

For solving (6) a combination of the local optimization solver Gencan [2] with heuristics devised to enhance the convergence to global (i.e. $f = 0$) minimizers is used.

Figure 1 presents examples of systems built with Packmol which illustrate some of the capabilities of the package. The corresponding input files can be obtained at the Packmol site or upon request to the authors.

Packmol is distributed as free software and can be downloaded from `www.ime.unicamp.br/~martinez/packmol`. Packmol has been downloaded more than 15,000 times by at least 9,000 different users. As a reflection of this, its main publication [3] has more than 800 citations registered in the Web of Science core collection (half of them in 2016), being one of the most cited articles written by Brazilian researchers only in all fields of research.

Estimation of the Thickness and the Optical Parameters of Superimposed Thin Films

The software PUMA [1] addresses the reverse engineering problem of estimating the thicknesses and the optical constants of a single thin film or superimposed thin films deposited on a transparent substrate using only transmittance data through the whole stack. Estimations may also be done if the available data correspond to normal reflectance.

The problem of estimating the thickness and the optical constants of thin films using only transmittance (or reflectance) data is very challenging from the mathematical point of view and has a technological and an economic importance. It always represents a very ill-conditioned inverse problem with many local-nonglobal solutions. The ill condition of this reverse engineering process stems from the fact that the available transmittance data for retrieving the structure is incomplete and frequently noisy. So, as in highly underdetermined problems, extremely unstable or physically meaningless solutions are expected.

Several variants of the presented problem have been solved using mathematical optimization models and techniques. The inverse problem was solved for thin and for very thin films using spectral transmittance data only. An extension of the solution of the inverse problem using only reflectance data was also reported. The problem of retrieving the properties of an optical structure that includes more than one dielectric film, deposited either on one side or onto both sides of a transparent substrate of known optical properties, was addressed as well.

PUMA is freely available at `www.ime.usp.br/~egbirgin/puma`. The PUMA Project webpages have been visited more than 20,000 times by 8,000 different users. As a whole, papers related to PUMA have almost 300 citations registered in the Web of Science core collection. In response to users' requests, PUMA has evolved from a software that applies to the recovery of optical constants from transmittance data of systems with a single film to a widely applicable software able to tackle multilayer systems and to recover optical constants from reflectance data as well as from transmittance data.

Synchronization of Complex Systems

In many real-world complex systems, the ability to synchronize is a key property. Without a central controller or external driver, the system organizes itself in a collective state. Spontaneous synchronization is explored in our technologies. In power grids, power stations must keep proper synchronization to avoid blackouts. Wireless networks rely on synchronization among sensors to transmit information. Our everyday life is no different. Pacemaker cells in our hearts adjust their rhythm and behave in unison to deliver the strong electrical pulses that make our hearts beat.

Synchronization is also a double-edged sword. In the brain, epileptic seizures and Parkinson's disease are a strong manifestation of synchronization. Many engineering problems have their root cause in synchronization. A famous example is the London Millennium Bridge, when synchronization between pedestrians and the bridge's lateral motion led to strong bridge oscillations. Only in recent years have we been able to probe the delicate linking structure of real-world networks and its impact on network performance.

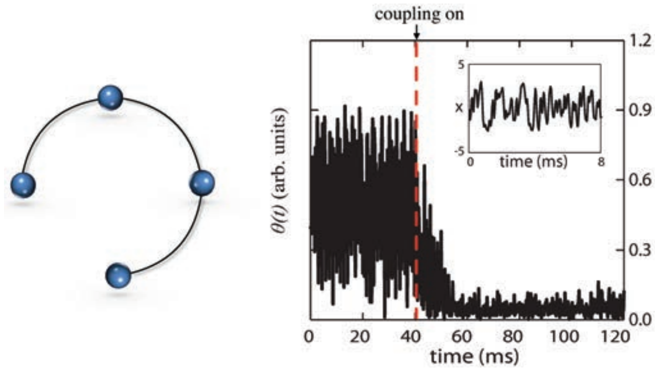

Figure 2. Dynamics of diffusively coupled lasers. In the beginning, the lasers are uncorrelated and voltage fluctuates wildly. When we turn on the coupling, we observe a rapid decay towards synchronization. In the inset, we show the voltage of the laser after they synchronize. The time delay induces a chaotic motion in the synchronized dynamics.

Synchronization of Lasers. When laser power is increased, the laser stability decreases. To create a high-power laser system, one technology is combining many low-power lasers into a single device. The question is how to make the lasers spontaneously behave in unison. We will illustrate the main characteristics of the phenomenon in an experiment described in [4]. The experiment consists of four coupled time-delayed optoelectronic oscillators (lasers) interacting according to a given network motif, as shown in Figure 2. We measure the voltage $x_i(t)$ of each laser and calculate the voltage fluctuation

$$\theta(t) = \sum_{i,j} |x_i(t) - x_j(t)|$$

as a measure of synchronization. When the lasers are uncoupled they behave asynchronously. However, when the coupling is increased above a critical threshold the lasers synchronize, as observed in Figure 2.

Modelling and Results. We now discuss a model that has illustrated how the linking structure affects synchronization. We consider an undirected network of identical elements with diffusive interaction

$$\dot{\mathbf{x}}_i = \mathbf{f}(\mathbf{x}_i) + \alpha \sum_{j=1}^{n} A_{ij}\mathbf{H}(\mathbf{x}_j - \mathbf{x}_i), \quad (7)$$

where $i = 1, 2, ..., n$, $\mathbf{f} : \mathbb{R}^m \to \mathbb{R}^m$ is a smooth vector field, and $\alpha \geq 0$ is the overall coupling strength representing an energy cost per link. The matrix $\mathbf{A}$ describes the network structure; i.e. $A_{ij} = 1$ if i and j are connected and 0 otherwise. The local coupling function $\mathbf{H}$ is smooth satisfying $\mathbf{H}(\mathbf{0}) = \mathbf{0}$. This last condition guarantees that the synchronization subspace $\mathbf{x}_1 = \mathbf{x}_2 = \cdots = \mathbf{x}_n$ is invariant for all values of α. The key question is whether the subspace is attractive. That is, given that the initial difference between states is small, we wish to know whether solutions of the network synchronize:

$$\lim_{t\to\infty} \|\mathbf{x}_i(t) - \mathbf{x}_j(t)\| = 0 \quad \text{for any } i \text{ and } j.$$

The model in (7) captures many aspects of the applications we have discussed so far. For instance, in neuron networks $\mathbf{f}$ represents the isolated neuron dynamics and $\mathbf{H}$ the electric synaptic coupling. The model may also represent networks of biological oscillators, networks of electric circuits with resistive coupling, or networks of lasers. For lasers we should include a time-delay coupling in the function $\mathbf{H}$. This is no restriction, and the present analysis cascades to the time-delay under minor modifications.

An undirected network has a symmetric adjacency matrix. The *degree* k_i of the ith node is the number of connections it receives, $k_i = \sum_j A_{ij}$. The Laplacian $\mathbf{L} = \mathbf{D} - \mathbf{A}$, where $\mathbf{D} = \text{diag}(k_1, \ldots, k_n)$, plays a major role in synchronization analysis. $\mathbf{L}$ is positive semidefinite; its eigenvalues, enumerated in increasing order and repeated according to their multiplicity, $0 = \lambda_1 \leq \lambda_2 \leq \cdots \leq \lambda_n$, dictate the onset of synchronization. The second eigenvalue, λ_2, is bounded away from zero whenever the network is connected. The smallest nonzero eigenvalue is known as the spectral gap. To avoid technical discussions, we won't state a theorem on synchronization, but rather we will discuss the key ideas. Under certain mild assumptions there are $\beta_1 = \beta_1(\mathbf{f}, \mathbf{H})$ and $\beta_2 = \beta_2(\mathbf{f}, \mathbf{H})$ such that if

$$\beta_1 < \alpha\lambda_2 \leq \alpha\lambda_n < \beta_2 \quad (8)$$

the network synchronizes. Hence, the condition in (8) provides a sufficient condition for synchronization, as well as a splitting of the problem in terms of the dynamical quantities $(\mathbf{f}, \mathbf{H})$ and network structure by means of the eigenvalues of the Laplacian. Obtaining β_1 and β_2 is delicate, but it can be done in an algorithmic way.

This field has been very prolific in recent years, and we have come to understand many relations between the network structure and the stability of synchronization. Some of the main things we have learned are:

- *Typically, random networks synchronize better than regular networks.* We compare networks with the mean same degree m and same size n. Let's consider a $2K$ regular network; that is, each node has two 2K connections to its nearest neighbors. If $K \ll n$, then $\lambda_2 \to 0$, whereas in the random network $\lambda_2 \approx m$. Moreover, adding a small fraction of links at random favors synchronization, as it increases λ_2 significantly while keeping λ_n basically unchanged.

- *Networks with heterogeneous degree synchronize poorly.* For example, if the network is random, then roughly $\lambda_n \approx d_{max}$ and $\lambda_2 \approx d_{min}$ so the condition reduces to $d_{max}/d_{min} < \beta_1/\beta_2$. If the network degrees are very disparate it won't be possible to achieve synchronization. Typically, the maximum degree is a function of the network size $d_{max} = d_{max}(n)$. So, this class of system will present a maximum system size for which synchronization is attainable.

These results allow identifying the dynamical importance of a link and thereby have a major impact on the design and control of directed networks. They also shed light on how to plan and design network modifications without destroying the network performance, for instance in power grids.

Generalizations. Although we started with identical nodes, this is no severe restriction, as synchronization is persistent under perturbations of the vector field [5]. An important generalization is to consider directed and weighted networks. Recent work has provided sufficient conditions to guarantee the stability of synchronization in directed networks and weighted networks [5]. In this case, small perturbations in the structure can cause major changes in the dynamics. Understanding the impact of structural modifications, such as changing weights and adding or deleting links, on synchronization remains an open problem.

Concluding Remarks

In this note we described a few applications which, having matured over considerable time, have shown their innovation potential. Currently, researchers of the center are working on other applications in medicine, engineering, and sports. We hope for improved processes in these fields and useful feedback for the development of new mathematics.

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Credits

Photo of Second Brazilian Study Group is courtesy of B. D. Grachet.

Photo of problem-solving group is courtesy of B. D. Grachet and L. Sarno.

Figure 1 is courtesy of L. Martínez.

ABOUT THE AUTHORS

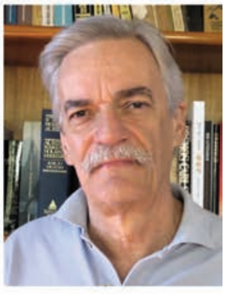
Ernesto G. Birgin is a member of the editorial boards of *Journal of Global Optimization, Computational and Applied Mathematics, Bulletin of Computational Applied Mathematics*, and *Pesquisa Operational.* He has published over seventy papers on computational optimization and applications.

Ernesto G. Birgin

Jose Alberto Cuminato, coordinator of CeMEAI, is a member of the Brazilian Academy of Science and corresponding fellow of the Royal Society of Edinburgh (FRSE), member of the editorial board of *Computational and Applied Mathematics*, and author of over 50 papers on CFD, numerical mathematics, and applications.

Jose Alberto Cuminato

José Mario Martínez, deputy coordinator of CeMEAI, is a member of the Brazilian Academy of Science, former editor in chief of *Computational and Applied Mathematics*, member of the editorial board of *Numerical Algorithms*, and the author of over 180 papers on numerical mathematics, optimization, and applications.



José Mario Martínez

Tiago Pereira is a member of SIAM and author of over thirty papers on dynamical systems and complex networks.

Tiago Pereira

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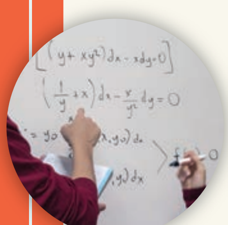

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Deadline for nominations is September 15, 2017.

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Reinhard Laubenbacher Interview

Communicated by Alexander Diaz-Lopez

Reinhard Laubenbacher is a professor in the Department of Cell Biology and director of the Center for Quantitative Medicine at the University of Connecticut Health Center. He is also a professor of computational biology at the Jackson Laboratory for Genomic Medicine. Previously he held faculty positions at Virginia Tech, Wake Forest University, and New Mexico State University. The current interests of his research group include the development of mathematical algorithms and their application to problems in systems biology, in particular the modeling and simulation of molecular networks. An application area of particular interest is cancer systems biology, especially the role of iron metabolism in breast cancer.

Editor's Note: This month graduate student Melinda Lanius is the interviewer.

***Lanius**: When and how did you know you wanted to be a mathematician?*

Laubenbacher: I wish I could say that I knew at an early age that I wanted to be a mathematician, but the fact is that I was actually not very interested in mathematics in high school and not very good at it. But I was interested in philosophy, which ultimately led me to mathematics. After a lot of soul searching, I ended up majoring in mathematics at the University of Munich, with a minor in philosophy. During my three years there, I developed an appreciation for mathematics as a form of abstract art, which I retain to this day. In part, I was inspired by a series of beautiful lectures on Hopf algebras by Bodo Pareigis, who also played an important role in my move to the United States, initially as an exchange student on a Fulbright scholarship. Still, it took a while for me to realize that I could possibly make a living doing mathematics research.

It took a while to realize I could make a living doing math research.

***Lanius**: Who encouraged or inspired you?*

Laubenbacher: The school system in Germany, where I grew up, provided at that time a single branching point to a higher education track after fourth grade. Few working-class kids like me took advantage of this option. It was my elementary school teacher, Frau Koenig, who convinced my parents to let me pursue this option, paid the application fee, and coached me for the entrance exams. Without her, I would surely never have pursued a higher education track.

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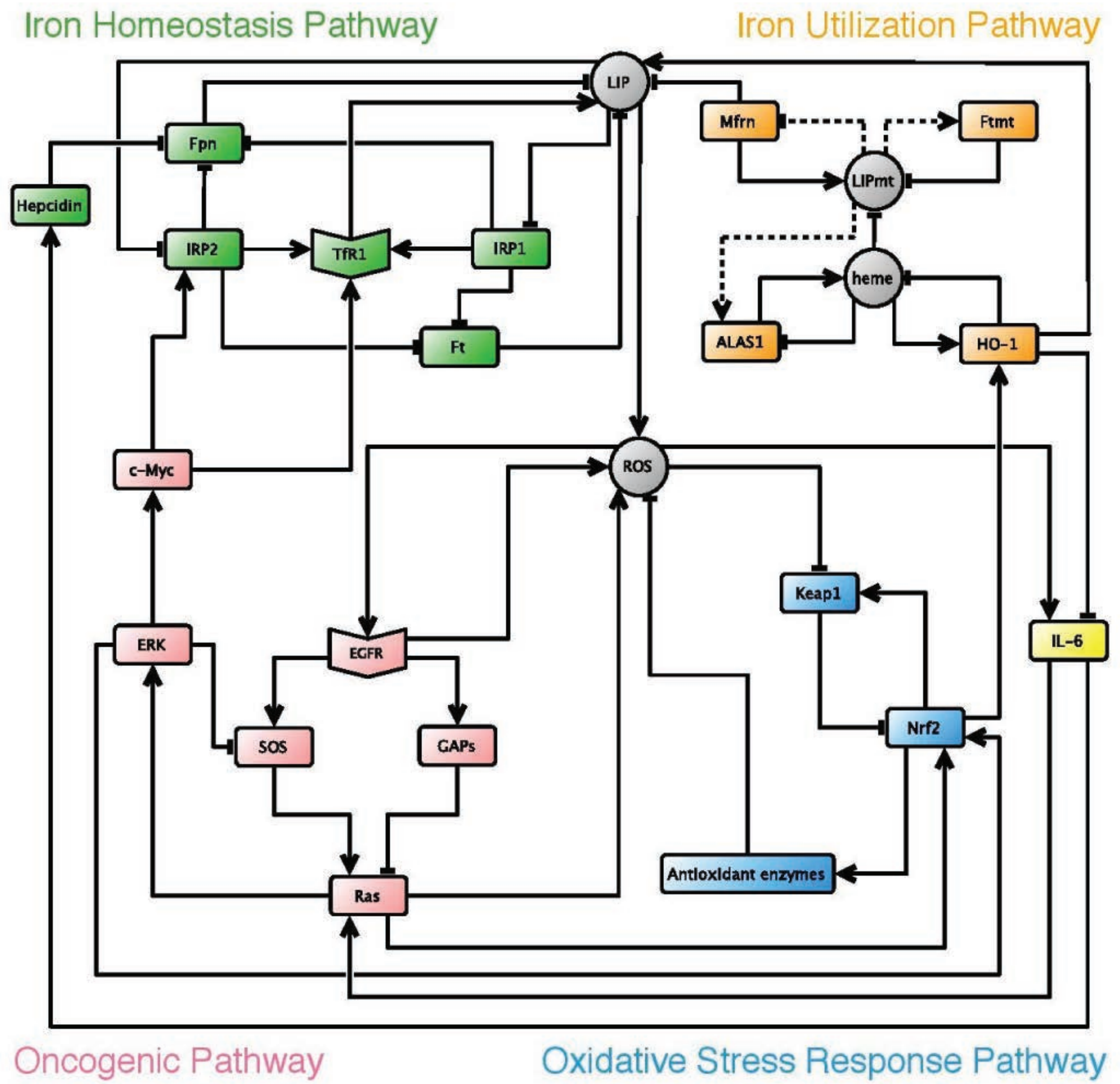


This illustration comes from a collaboration between Laubenbacher's research group and a cancer biology group at UConn Health. It shows a dynamic model of a molecular regulatory network, represented as a graph. The model captures the process by which oncogenes can modify how a cell uses iron and how they can switch a normal cell into one exhibiting a cancer phenotype. The illustration is taken from the paper "Activated oncogenic pathway modifies iron network in breast epithelial cells: A dynamic modeling perspective," by J. Chifman, S. Arat, C. Lopez, S. Torti, and R. Laubenbacher; to appear in *PLoS Computational Biology*, 2017.

I have been very lucky throughout my career in meeting mathematicians and others who have influenced me in many ways, who have been generous with honest advice, and who have provided inspiration through their work. To mention one such person, I had the great fortune to get to know mathematician Bernd Sturmfels, whose work is a wonderful example of an organic symbiosis between what are commonly known as pure and applied mathematics. Throughout his very prolific career he has pursued research at the intersection of algebraic geometry and combinatorics and its applications to statistics, optimization, and the life sciences, among others. He was the reason I switched my research from algebraic *K*-theory to computer algebra soon after I met him.

Another colleague and friend who had a big influence on my work is mathematician David Pengelley, with

The project I am most proud of is Kid's Tech University.

whom I embarked on a wild journey through the history of mathematics and its role in teaching. David has carried on this work and has inspired many others to transform undergraduate mathematics teaching through the use of history and original mathematical sources. My historical work provided some of the motivation for my transition to applied mathematics.

Lanius: *How would you describe your work to a graduate student?*

Laubenbacher: Broadly speaking, my research program consists of three components: the development of mathematical tools and algorithms, their software implementation, and their application to specific health-related problems. Currently, my research group consists of several postdoctoral fellows; graduate and undergraduate students in math, computer science, and biology; a bioinformatician; and a software engineer. We work on a wide range of projects. As an example on the application end, my team works with several other research groups on ways to control the development of resistance to chemotherapy treatment in certain types of breast cancer. We use a mixture of bioinformatics, mathematical modeling, and control theory for this project, together with some new mathematical tools we are developing.

On the software development side, we are currently working to develop a crowd-sourced software package for the analysis of discrete polynomial dynamical systems that uses the novel tool of so-called Docker containers—lightweight software containers that can be used to easily package and connect implemented algorithms in a platform-independent manner.

Mathematically, we use a wide range of tools. One area of expertise we have developed is the construction and use of time-discrete, state-discrete dynamic models, which generalize Boolean networks. Such models can be viewed as maps from an affine space over a finite field to itself, described by a collection of polynomials with coefficients in that field. This makes them amenable to all the tools from computer algebra and algebraic geometry, as well as algebraic combinatorics. There are many very interesting mathematical problems related to such dynamical systems.

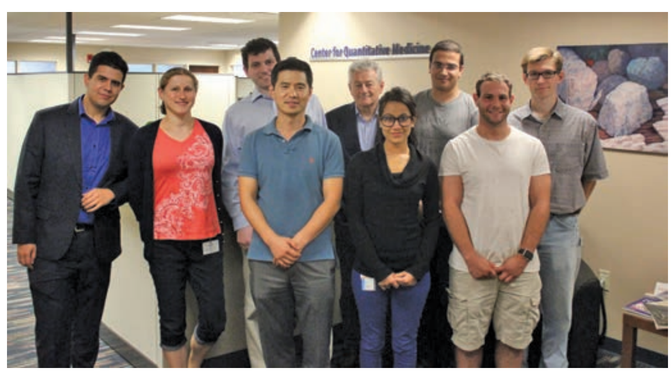
Lanius: *Do you have a favorite past project?*

Laubenbacher: In my previous position at the Virginia Bioinformatics Institute at Virginia Tech, one of my roles for several years was director of Education and Outreach. The project that I am most proud of is Kids' Tech University, an outreach program for nine- to twelve-year-old kids and their guardians. Each year the program enrolls several hundred children at Virginia Tech, which hosts the program, and at other regional sites. The children come to campus on four Saturdays and engage with an internationally known researcher in one of the STEM fields, participate in hands-on activities, and explore what it is like to be a college student. Over a hundred Virginia Tech student volunteers work with the kids on all aspects of the program. The program is continuing, and this semester we have the first volunteer who participated when she was twelve and is now a computer science major. The hypothesis underlying the program is that in order to attract children to STEM careers, they need to get excited about the STEM disciplines, and nobody can convey that excitement better than a researcher. The program has proven to me that we completely underestimate the ability of children in that age range to understand complex scientific issues. Mathematicians who have served as faculty for the program include Erika Camacho, Keith Devlin, and Suzanne Weekes. Of all the work I have done, this program has been the most fun and rewarding for me.

Lanius: *What is a typical workday like?*

Laubenbacher: I have a few different hats I wear. At UConn Health, I am the director of the Center for Quantitative Medicine, a research center that has a very interdisciplinary faculty, ranging from mathematicians to clinicians. My tenure home in the School of Medicine is the Department of Cell Biology. I also have a joint appointment as a professor of computational biology at the Jackson Laboratory for Genomic Medicine, a not-for-profit research organization. I typically spend a couple of days a week there.

As I described earlier, my research group is involved in a number of different projects, with a host of interdisciplinary collaborators for each of them. This necessitates lots of meetings, in person or via phone or Skype. One hour we might talk about a detailed mathematical problem in enumerative combinatorics, and the next hour we might discuss the ambiguity of billing codes for medical procedures and their effect on the construction of patient profiles. I do a fair amount of grant proposal writing, since almost all research in medical schools is grant driven. I actually



Laubenbacher's research group includes postdoctoral fellows, graduate and undergraduate students, a bioinformatician, and a software engineer. They work on a wide range of projects, with an emphasis on the development of mathematical algorithms and their application to problems in systems biology. Front row, left to right: Byoungkoo Lee, Bandita Adhikari, Nick Monteleone. Back row, left to right: Albin Salazar, Anna Konstorum, Russ Posner, Laubenbacher, Abdelrahman Ibrahim, Cory Brunson.

enjoy this part of my job, because it provides a structure to work out new ideas and develop new collaborations.

I spend a fair amount of time reading and reviewing research papers. Together with Alan Hastings, I serve as editor-in-chief of the *Bulletin of Mathematical Biology*, the journal of the Society for Mathematical Biology. In this capacity, I see hundreds of manuscripts a year, which gives me a great view of all the exciting work that is being done in this field.

While I don't have any formal teaching duties, I have lots of opportunities to work with students and postdoctoral researchers on projects, which is tremendously enjoyable. A number of my former students and postdocs have gone on to become established researchers themselves, and I continue to collaborate with some of them. My PhD students typically come from the biomedical sciences PhD program or the MD/PhD program. I also work with students from the mathematics and the computer science and engineering departments, where I have adjunct appointments. For undergraduates, I direct a Research Experiences for Undergraduates program funded by the Division of Mathematical Sciences of the National Science Foundation, entitled "Modeling and Simulation in Systems Biology." That is a highlight of my summers.

Like most mathematicians and scientists, I travel a fair amount to conferences, other universities, and research institutes, and to meet with collaborators. Since my work intersects several different fields, I try to cover key conferences in mathematics, bioinformatics, the life sciences, and medicine.

Having a network of colleagues and friends allows us to reach further than we might by ourselves.

Lanius: *What is the work culture like at UConn Health?*

Laubenbacher: When I moved to UConn in 2013, I had never been part of a school of medicine and was very curious about what the culture is like and what people do. So I spent much of my first year going around and talking to scientists, clinicians, and other healthcare workers. It was a fascinating experience, and everybody was so generous with their time and interested in ways that we could work together. Since research in a medical school typically requires grant funding, everybody is very focused on making their research maximally relevant, innovative, and impactful.

As I mentioned earlier, essentially all of my projects are done within interdisciplinary collaborative teams, for which I might be the lead, co-lead, or provide a support role, depending on the nature of the project and the funding. Working in this way requires everybody to learn something about all the aspects of a project in order to have a common language, to understand the characteristics of the data to be used, to understand what a mathematical or statistical model can and cannot do. So I end up constantly learning new things about biology, medicine and its practice, population health, statistics, bioinformatics, new sequencing technologies, the intricacies of health insurance, and a whole host of other topics. And one learns about the culture in other fields, and how people think and approach problems. By necessity, most of this knowledge is fairly superficial but enough to interact in meaningful ways with professionals in other fields and understand their problems. At the same time, I spend a lot of time explaining mathematical techniques and concepts to my non-mathematical colleagues, and I enjoy the experience of having somebody "get it" in either a conceptual or technical way.

I am free to work on whatever projects I choose or design, as long as I am able to eventually obtain funding for them. Serendipity plays a big role in establishing collaborations and projects, so it is crucial to seek out as many opportunities as possible to talk about one's research and find out what other people do.

Lanius: *How do you balance career and outside interests?*

Laubenbacher: As we all know, scientists in general, and mathematical scientists in particular, tend to be very passionate about their work, which makes it difficult to clearly delineate a boundary between work/career and other interests. And many of us are not very good at saying no to things, so we accumulate increasingly larger workloads over time; I am certainly guilty of that. But down time is a crucial component of any creative activity, because it helps one to clear the mind. In addition to spending some weekends in Boston or New York, my wife and I get much enjoyment from motorcycling through beautiful countryside. It is very relaxing, provides a great thrill, and allows us to spend quality time together.

Lanius: *What obstacles have you encountered and how did you handle them?*

Laubenbacher: In the course of my professional career, I have transitioned several times, from *K*-theory to history of mathematics, to mathematics education, computational algebra, mathematical biology, and biomedicine. Some of those transitions involved physical moves as well. While each has been difficult and challenging for different reasons, each one of them has been an incredible opportunity for growth. The unknown is always scary, and change also comes with self-doubt, worries about one's career, and plenty of anxiety about being a novice again after having been an expert in something. As it turns out, I needn't have worried, since each of the communities I have worked in has been very welcoming and supportive. It was invaluable for me to have friends and colleagues who were supportive during those times, who assured me that I was not just suffering from ADD, who provided a sounding board, and who gave me their honest opinions, whether I liked to hear them or not. The lesson here is that having a network of professional colleagues and friends that provide support allows us to reach much further than we might by ourselves.

Lanius: *What advice do you have for graduate students?*

Laubenbacher: We are living through a time of unprecedented opportunity for mathematical scientists. These opportunities extend far beyond the traditional careers many of us know about. The advent of data science on a big scale, for instance, has everybody looking for professionals with quantitative skills. The mathematical problems are often quite challenging and interesting, and the jobs come with good salaries and lots of flexibility. As my career shows, there are research opportunities in some very unlikely places. It is crucial for a student to know about them. I still meet too many undergraduate and graduate students who have no idea about what is out there and who start very late in their student careers to think about it. Graduate programs need to make an even bigger effort to provide this information to students. A key prerequisite for any professional today in an interdisciplinary environment is excellent communications skills, both verbal and written. Being able to engage people from diverse scientific, mathematical, and cultural backgrounds is a must, and, again, graduate programs need to prepare students for this.

Lanius: *If you could recommend one book to graduate students, what would it be?*

Laubenbacher: There are obviously many great mathematical and scientific choices for this. But I would recommend an old non-mathematical book with the unfortunate title *The Seven Habits of Highly Effective People*, which makes it sound like another self-help book that teaches time management and effective use of Post-it notes. Instead, it is a very thoughtful guide to making one's life as meaningful and impactful as possible.

Lanius: *Any final comments or advice?*

Laubenbacher: Seek and embrace change, continually challenge yourself, and always grow, professionally and personally. Of course, I am not talking about change for the sake of change, but about pushing one's boundaries and doing what feels right even though it might be very hard and maybe even likely to fail. One of my favorite inspirational readings along these lines is Theodore Roosevelt's 1910 speech "Citizenship in a Republic," better known as his "Man in the Arena" speech. It is important to remember that life is a journey, not a destination, in the words of Emerson, and we need to enjoy it as such, with all its highs and lows.

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Pathway illustration is courtesy of Seda Arat and Julia Chifman.
Photo of research group is courtesy of Barbara Styrczula.
Photo of Melinda Lanius is courtesy of Melinda Lanius.

ABOUT THE INTERVIEWER

Melinda Lanius, a Wellesley College graduate, is currently earning her PhD in mathematics at the University of Illinois at Urbana–Champaign.

Melinda Lanius

WHAT IS...

a Virtual Knot?

Daniel S. Silver and Susan G. Williams

Communicated by Cesar E. Silva

Virtual knots generalize classical knots. They were introduced by L. H. Kauffman in 1999.[1] In order to describe virtual knots we must back up a bit.

What is a Knot?

A *knot* k is a circle smoothly embedded in the 3-dimensional sphere $\mathbb{S}^3$. Two knots k_1, k_2 are equivalent, and hence regarded as the same, if there is an orientation-preserving homeomorphism $h : \mathbb{S}^3 \to \mathbb{S}^3$ such that $h(k_1) = k_2$. A basic theorem of topology assures us that such a homeomorphism is isotopic to the identity. Consequently, k_1 and k_2 are the same if we can deform k_1, through a sequence of intermediate knots, into k_2.

The *trivial knot*, also called the *unknot*, is represented by a simple closed circle in the plane. Any other knot is said to be *nontrivial*. A collection of pairwise disjoint knots is a *link*, with equivalence defined in the obvious way.

Johann Benedict Listing, a student of Gauss, and the Scottish physicist Peter Guthrie Tait independently began the first sustained investigations of the subject, in the mid-nineteenth century. Tait's interest arose from the "vortex atom theory" of Lord Kelvin, a fanciful theory in which atoms are infinitesimal knots of frictionless, invisible æther. Classifying knots then became the main goal of knot theory. Without effective tools, it remained so until the second decade of the last century, when penetrating algebraic methods became available. Today there are so many strong invariants of knots that classification is no longer a main objective. Instead the need to understand relationships among invariants has become paramount.

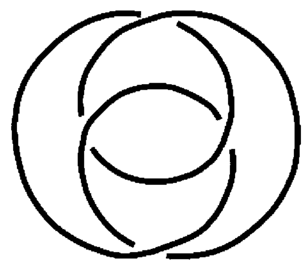

Figure 1. The figure-eight knot, also known as Listing's knot, can be drawn with four crossings.

A knot generically projected on a plane, without triple intersection or tangent points, can be viewed as a regular 4-valent plane graph. If we add a *trompe l'oeil* effect at each vertex, indicating how one strand passes over another, the resulting picture is called a *knot diagram*. A diagram of the figure-eight knot appears in Figure 1.

K. Reidemeister in 1927 (and, independently, J. W. Alexander and G. B. Briggs in 1926) showed that two diagrams represent the same knot if and only if one can be deformed into the other by planar isotopy and a finite number of applications of three types of local changes that leave diagrams unaltered outside of the prescribed regions. The three local changes are called *Reidemeister moves*. See Figure 2.

Reidemeister moves enable us to investigate knots combinatorially. Any quantity assignable to a diagram is a knot invariant if and only if it is unchanged by allowed moves of the diagram. Some of the most powerful knot invariants such as the knot group and the Jones polynomial can be defined and shown to be invariant in this way.

Daniel S. Silver is emeritus professor of mathematics at the University of South Alabama. His e-mail address is silver@southalabama.edu.

Susan G. Williams is emeritus professor of mathematics at the University of South Alabama. Her e-mail address is swilliam@southalabama.edu.

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[1] *An equivalent theory of abstract knot diagrams was formulated independently by N. Kamada.*

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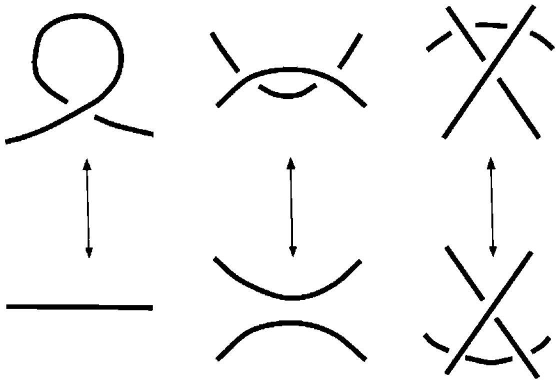

Figure 2. Pictured here are Reidemeister moves on the knot diagrams, which leave the knots themselves unchanged.

Virtual Knots

The combinatorial perspective inspired an entirely new direction for knot theory in 1999. In that year L. H. Kauffman proposed a more general type of knot, a *virtual knot*, described by a decorated 4-valent graph, as before, but with a second type of crossing, a *virtual crossing*, indicated by encircling the vertex. A *virtual knot* is an equivalence class of diagrams, two diagrams being equivalent if and only if one can be deformed into the other by planar isotopy and a finite number of applications of *extended Reidemeister moves*. The latter include the moves of Figure 2 as well as the additional moves in Figure 3.

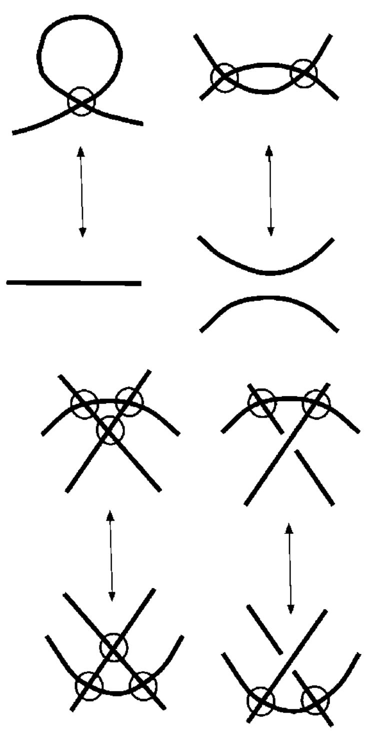

Figure 3. Virtual knots admit additional Reidemeister moves, shown here.

Not allowed are two "forbidden moves," passing an arc of the diagram over or under a virtual crossing, as in Figure 4.

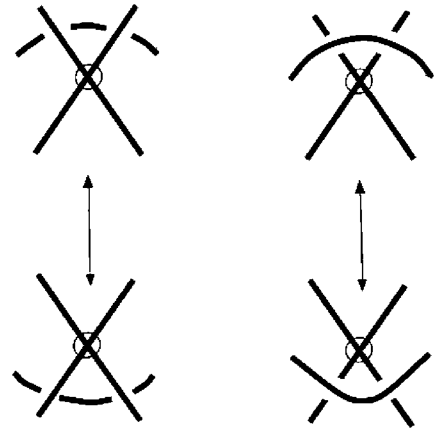

Figure 4. These "forbidden moves" do not preserve virtual knots.

In the new parlance, a *classical knot* is simply a knot that can be represented by a diagram without virtual crossings. (We complete the lexicon by calling a crossing that is not virtual a *classical crossing*.) Virtual crossings can always be introduced into a diagram and then later removed using extended Reidemeister moves. However, a theorem of M. Gourssarov, M. Polyak, and O. Viro assures us that if two classical knots are equivalent as virtual knots, then they are the same classical knots. Happily, virtual knot theory is an extension of the classical theory.

Kauffman's motivation for defining virtual knots came from Gauss's idea for encoding classical knots. A Gauss code for a classical knot diagram is obtained in the following way. First, number the crossings, say $1, \dots, m$. Then beginning at crossing 1, and moving along the diagram in a direction, record the crossings as they are encountered until arriving back at the starting point. In this way each number is recorded twice. A simple example appears in Figure 5.

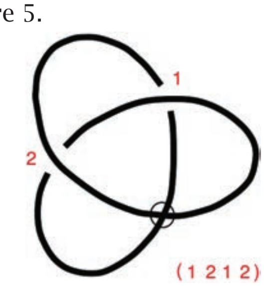

Figure 5. The virtual knot shown here realizes the Gauss code (1212)**.**

Kauffman's inspiration came from the observation that if we wish to achieve an arbitrary permutation of $1, 1, \dots, m, m$, then it is necessary, but also sufficient, that we introduce some virtual, unlabeled crossings into our diagram.

Virtual knots and links can in fact be regarded as Gauss codes (with extra symbols encoding crossing information) modulo a suitable equivalence relation. Again knot theory becomes combinatorial!

Invariants of classical knots that can be defined combinatorially can often be defined for virtual knots. This is true of one of the most important classical knot invariants, the *knot group* of k, denoted here by $\pi(k)$. To define it, consider any diagram for k. Each maximal connected component, or *arc*, of the diagram corresponds to a generator, and each classical crossing determines a relation. We ignore virtual crossings. When the diagram has no virtual crossings, the presentation that we get this way is the well-known *Wirtinger presentation* of the fundamental group $\pi_1(\mathbb{S}^3 \setminus k)$. This is illustrated in Figure 6 for the figure-eight knot. In this case $\pi(k)$ is infinite cyclic if and only if k is trivial.

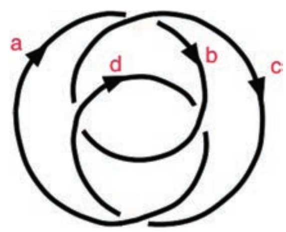

Figure 6. Assigning generators to the arcs of the diagram as shown, we obtain a presentation of the group of the figure-eight knot, $\pi(k) \cong \langle a, b, c, d \mid ac = da, ba = db, ca = bc, dc = bd \rangle$**.**

The group of a classical knot is a strong invariant. However, there are nontrivial virtual knots with infinite cyclic groups. One such knot, commonly called *Kishino's knot*, appears in Figure 7. Applying the second forbidden move of Figure 4 to a diagram obviously does not affect the group. Since using the move along with the allowed virtual knot moves enables us to turn Kishino's knot into the unknot, the reader can check easily that the group of the knot is infinite cyclic. Fortunately, other invariants can show that Kishino's knot is nontrivial.

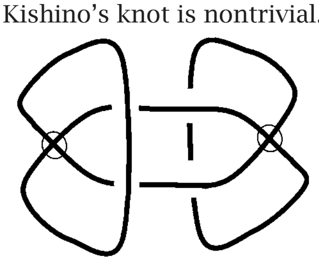

Figure 7. Kishino's knot, depicted here, is a nontrivial virtual knot with the same knot group as the trivial knot.

Pick up a diagram for a virtual knot k and turn it over. (For this it might be helpful to imagine the diagram made of rigid material.) We obtain a diagram of another virtual knot k^*. If k is classical, then k and k^* are the same. However, in general, k^* can be different. In fact their groups can be non-isomorphic. While virtual knot groups have been characterized, both algebraically and topologically, no one has yet characterized the possible pairs $(\pi(k), \pi(k^*))$.

The Jones polynomial is a powerful invariant of classical knots. Discovered by V. Jones in 1984, it sparked new interest in combinatorial knot-theoretic methods. It is an open question whether a nontrivial classical knot can have Jones polynomial equal to 1.

Using Kauffman's bracket polynomial formulation, the Jones polynomial can be defined for virtual knots. Kauffman discovered a method for constructing nontrivial virtual knots with Jones polynomial equal to 1. Could such a knot be shown to be classical, thereby answering the open question?

Why Virtual Knots?

As no evidence of Kelvin's æther was found, the vortex atom theory dissipated, allowing knot theory to step out from the fog. Henri Poincaré saw knot theory as an important paradigm of the codimension-2 placement problem, understanding how a manifold can embed in another manifold with two extra dimensions. The status of the subject climbed even higher in the early 1960s, when W. B. R. Lickorish and A. H. Wallace proved that every closed, orientable connected 3-manifold can be obtained from a link in the 3-sphere by a simple procedure called "spherical modification" or "surgery."

What then is the significance of *virtual* knots? Rather than living in the 3-sphere, virtual knots or links can be regarded as simple closed curves embedded in thickened surfaces $S \times I$ modulo a suitable equivalence relation. From this point of view the classical crossings arise from projecting onto S while the virtual crossings come from projecting S onto the plane.

The main idea is due to N. Kamada, expanded upon by J. S. Carter, S. Kamada, and M. Saito. Neither the genus of the surface nor the embedding is, in general, unique. However, G. Kuperberg showed that when the knot or link is represented by an embedding in a surface of smallest possible genus, then the embedding is unique up to isotopy. Of course, classical knots and links are represented uniquely in the thickened sphere. From this perspective, virtual knot theory might seem a bit less mysterious.

Mathematicians have played with knots for a relatively short period of time. It is possible that one day we will understand that these tangled ropes represent deep and important relations, a vision that so far has eluded us. Relaxing our axioms, as virtual knot theory demands, might just bring that day closer. In the meantime, we will play and enjoy!

Further Reading

1. L. H. Kauffman, Introduction to virtual knot theory, *J. Knot Theory Ramifications* **21** (2012), no. 13, 1240007, 37 pp.
2. V. O. Manturov, Virtual Knots: the State of the Art, *Series on Knots and Everything: Volume 51*, World Scientific, Singapore, 2012.

Photo Credits

Photo of Daniel S. Silver is courtesy of Susan G. Williams.
Photo of Susan G. Williams is courtesy of Daniel S. Silver.

ABOUT THE AUTHORS

Daniel S. Silver's research explores relationships between knot theory and dynamical systems. He also publishes articles on the history of mathematics. No animals were harmed in the preparation of this article.

Daniel S. Silver

Susan G. Williams has a background in ergodic theory and dynamical systems. Her work includes applications of symbolic and algebraic dynamics to knot theory, and lately to graph theory. She has an active interest in origami; when she's not writing papers, she's folding them.

Susan G. Williams

COMMUNICATION

The Mathematics Genealogy Project Comes of Age at Twenty-one

Colm Mulcahy

Communicated by Steven J. Miller

Addressing a Need (and Needing an Address)

The Mathematics Genealogy Project *(MGP)* provides online PhD advisor and mathematical descendant information on over 200,000 mathematicians, a good fraction of the 825,000 authors on MathSciNet® and far more than the 2,700 biographies in the MacTutor History of Mathematics. It wasn't always like that.

In June 1984 the mathematics department at the University of Chicago hosted a conference marking the formal retirement of Irving Kaplansky (1917–2006), the Canadian algebraist who had been among the first to ace the Putnam exam, back in 1938. Kap, as he was known, was hardly ready to sail into the sunset: he was about to take over MSRI as its second director.

At the Chicago meeting much fuss was made of the fact that the honoree had supervised 55 PhDs, including Arlen Brown, Hyman Bass, Donald Ornstein, Joe Rotman, Judy Sally, and my own doctoral advisor, Alex Rosenberg. As I recall, a paper list was circulated that documented these, as well as their PhD students, and so on, to demonstrate Kaplansky's intellectual fecundity. Ironically, Kap's own advisor, Saunders Mac Lane, was also at that meeting. He just laughed when I buttonholed him in a corridor and commented that a list of all *his* descendants would be even more impressive.

Flash forward to the present day: in marked contrast to three decades ago, one's ancestors and descendants can easily be looked up at MGP online,[1] as partially reflected in Figure 1. It shows that Kaplansky was the first of the 42 people whose theses Mac Lane supervised. Kap was also the most productive of these in terms of sheer numbers of descendants, a list that now tops 850. Mac Lane's own doctoral students include logician Anil Nerode, group theorist John Thompson, set theorist Robert Solovay, and algebraist David Eisenbud, each of whom has had over 100 descendants. Both Kaplansky's and Mac Lane's entries link to their MacTutor and MathSciNet listings, a feature common to many of the more noteworthy entries.

Gauss's descendant count is about 78,000.

As with ordinary family trees, there are complications. For example, Eisenbud had two advisors. So did Mac Lane himself: Hermann Weyl and Paul Bernays. The Weyl line leads back through Hilbert and Lindemann to Klein, who also had two advisors. Following both lines, we encounter additional mathematical royalty: Lipschitz, Dirichlet, Poisson and Fourier, Lagrange and Laplace, Euler, d'Alembert, Plücker, and Gauss. Of course, Gauss has a lot to answer for: MGP's current estimate of his descendant count is about 78,000.

Origins of the Species

The Mathematics Genealogy Project was started twenty-one years ago, in 1996, by Harry Coonce, then a mathematician at Mankato State University in Minnesota. He was motivated in part by the difficulty he'd encountered when trying to determine the identity of his own "mathematical grandfather," i.e., his advisor's advisor. It turned out to be Einar Hille, but back then there was nowhere to look this up, neither a library nor a website. (Bruce Reznick recalls that Constance Reid in *The Search for E. T. Bell* said that she couldn't find his advisor's name.) Harry wrote to hundreds of departments that spring, and by the time the original MGP website was launched that September, he had 3,500 doctorate holders listed.

Colm Mulcahy is professor of mathematics at Spelman College, Atlanta. His e-mail address is colm@spelman.edu.

[1] https://www.mathgenealogy.org

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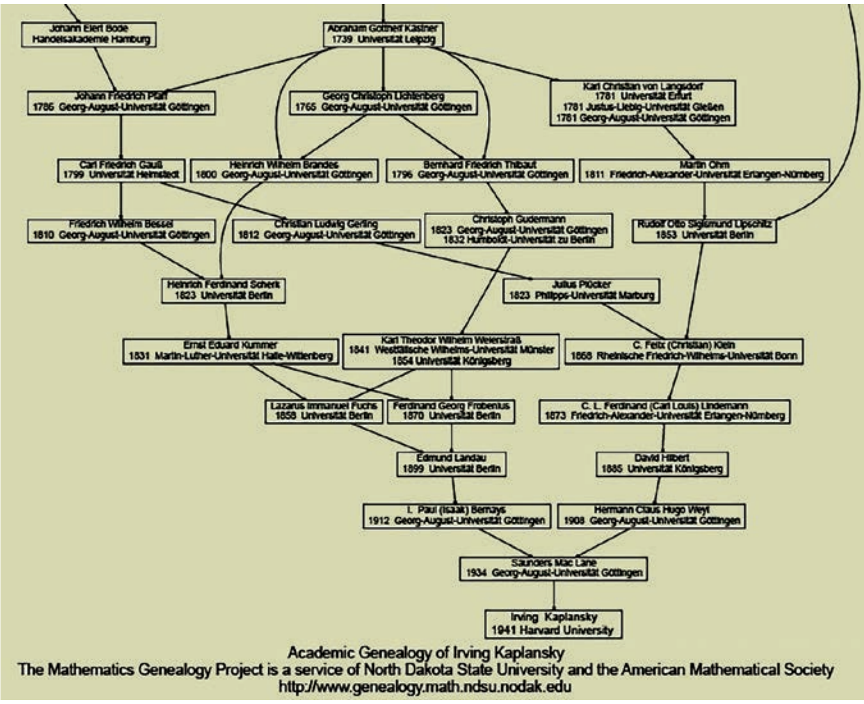


Figure 1. Irving Kaplansky's most recent ancestors from the Mathematics Genealogy Project; the full tree—only a part of which is shown here—now shows 850 descendants and extends back over seven hundred years.

Within a year, the project had grown to include 10,000 entries. When "A Labor of Love: The Mathematics Genealogy Project" by Allyn Jackson appeared in the *Notices* in 2007, the MGP had topped 100,000 people. By then Coonce had retired, found himself a new home at North Dakota State University, and taken onboard an undergraduate assistant who eventually took over the project: Mitch Keller, now a mathematician at Washington and Lee University in Lexington, Virginia.

From shaky beginnings with little or no funding, the project has become a mainstay of the mathematical community. It's now funded by the Clay Institute and the AMS, and in the summer of 2016 the MGP thesis count reached another landmark, surpassing 200,000 entries. Growth has been roughly linear, as shown in Figure 2.

While MGP collects information classified under one of several tags such as PhD, DPhil, or DSc, no such distinction is made in this article. The first American PhD in mathematics (from Yale, 1861) was awarded to Arthur Wright; it was on satellite mechanics. Like over 75 percent of those individuals listed in MGP, yours truly included, Arthur had no descendants at all. The nature of doctoral work and the advisor system—not to mention the present-day expectation of having a PhD as a prerequisite for life in academia—arguably evolved out of older French and German models, and this all took time to take root.

The Inclusion Principle

The MGP has a very inclusive philosophy, welcoming submissions in mathematics education, statistics, computer science, or operations research, using a dropdown 2010 Mathematics Subject Classification list to select thesis areas. Hence, in theory, all dissertations in theoretical physics, geophysics, biology, astronomy, statistics, computer science, and/or operations research could end up being listed. There are already about 2,000 each flagged as "Systems theory, control" and "Biology and other natural sciences"; about 3,400 as "Operations research, mathematical programming"; and over 18,000 as "Computer science."

The "Extrema" page at the site lists the Top 75 Advisors (numerically), all of whom put Kaplansky in the shade, although many of those listed raise other questions. In first place is Chinese electrical engineer C.-C. Jay Kuo, whose own PhD from MIT is classified as "Information and communication, circuits." In the past quarter century at the University of Southern California, he is credited with supervising 137 doctorates. In second place is French numerical analyst Roger Temam with 119 students since 1972, and in third place is economist and computer scientist Andrew Whinston (with Erdős number 2), who has had 104 students since 1970. Kolmogorov, in position thirteen with 82 PhD students, may be the first name recognized by most mathematicians.

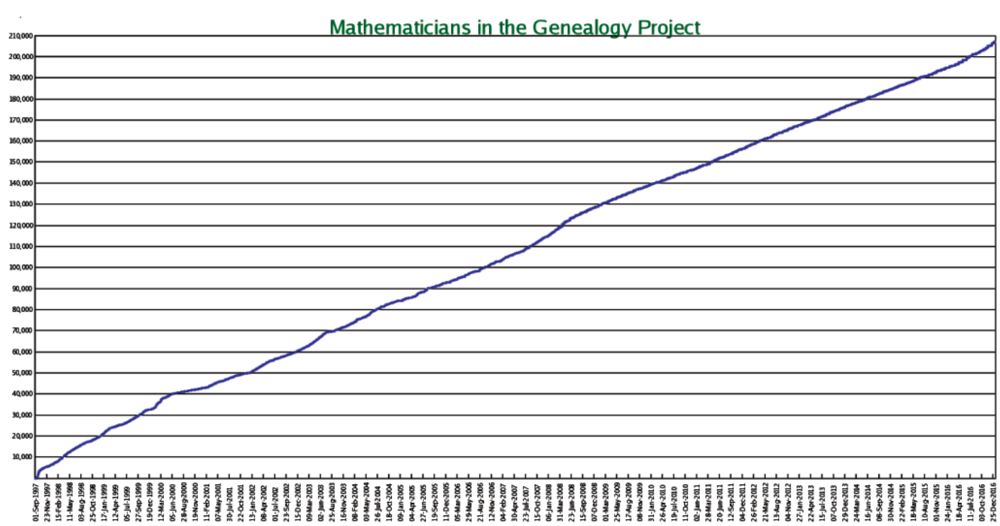


Figure 2. The growth of Math Genealogy listings.

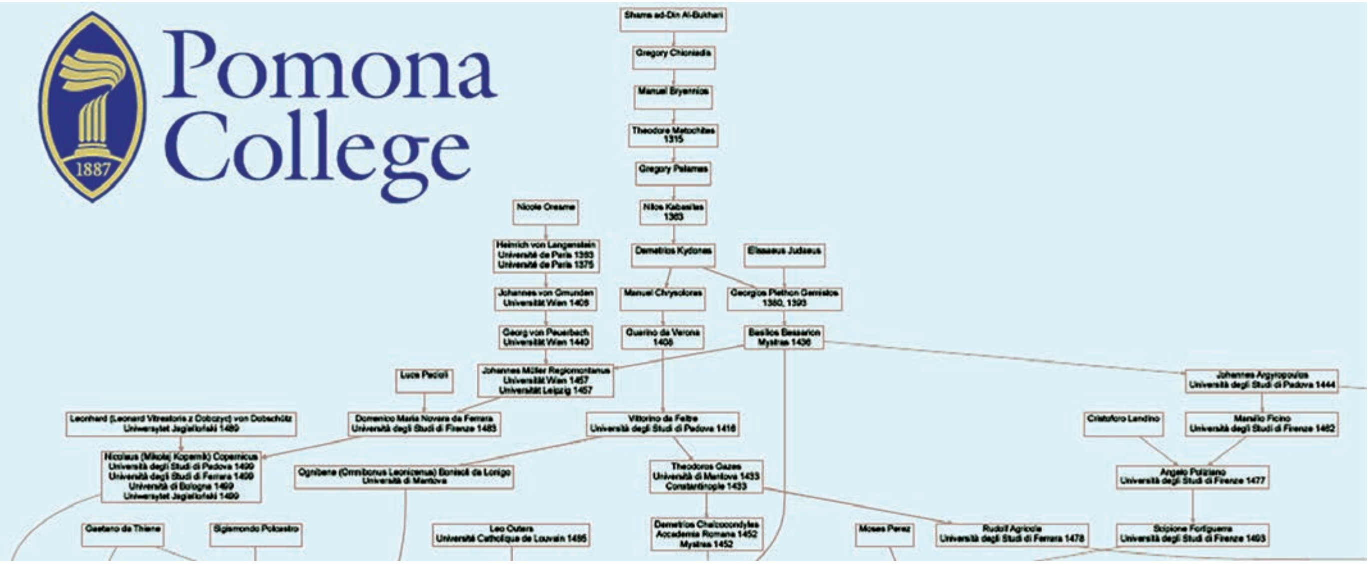


Figure 3. The start of the ancestry of the Pomona faculty from a larger custom poster from the Mathematics Genealogy Project.

Hilbert had 75, Blackwell 66, and Stanley 60. Kaplansky's 55 sees him come in at position eighty-seven.

Poster Children and Relative Value

Both individuals and departments with an interest in their heritage like to see the highlights displayed in family trees, and MGP offers customized mathematical genealogy posters (for a fee). Mitch notes, "Individual posters have proved popular for birthday and retirement conferences as well as graduation gifts." Stephan Garcia of Pomona College agrees: "We just purchased a huge MGP poster for the whole department a few weeks ago." (See Figure 3.) Likewise, Michael Wolf of Rice says, "When I was department chair, I did purchase a departmental version so as to visually depict the intellectual heritage of the department to visitors."

So who uses MGP other than for casual browsing or ancestral bragging? Certainly, *Wikipedia* editors: many of the *Wikipedia* pages on modern-era mathematicians include an external link to the corresponding MGP entry, and some of the information listed derives from what is found at that link. Then there are academic journal editors. Norman Richert, managing editor of *Mathematical Reviews*, is on the advisory board of MGP. He shares the views of other editors with regard to the usefulness of MGP in "giving a picture of who people are and where they fit in the mathematical spectrum," as well as when trying to avoid possible conflicts of interest. He raises another point. "As I think about authors in terms of inviting them to be reviewers, I am interested if they have a degree (many more PhD students are publishing papers during their studies than in the past); the MGP links on the author profile pages in MathSciNet answer that with high (but not 100 percent) probability."

The value of MGP to the community is enormous.

Janet Beery (University of Redlands) and Carol Mead (archivist for the Archives of American Mathematics at UT–Austin) used MGP in gathering information for their *Convergence* article "Who's That Mathematician? Images from the Paul R. Halmos Photograph Collection" (over sixty webpages). Carol says, "It's a great reference tool for me. I use it to identify or verify someone. And, as a non-mathematician, it helps me learn more about mathematicians I'm not familiar with." Lev Borisov of Rutgers adds, "I think it will be an invaluable tool for math historians. I can also imagine it being useful to social scientists and government agencies."

Hatched, Matched, and Dispatched

The three mainstays of traditional genealogy are the documentation of birth, parenthood, and death, and the academic versions of the first two are reflected in the MGP. However, while neither life nor death details are recorded there, the site still proves useful for obituary writers, just as ordinary family trees do. "When a mathematician dies, we like to include where he or she got the PhD, when it was granted, and sometimes who the advisor was," notes AMS Public Awareness Officer Mike Breen, who has written many of the "In Memory of…" items on the AMS website. "We like to include the advisor when he or she is someone that many will recognize. I think it allows the reader some insight into the person's history, just as MGP itself does. Someone who is two generations from Kolmogorov, for example, deserves mention."

Norman Richert again: "The value of MGP to the community is enormous. Mathematics research has always involved a web of people. The collaboration graph in MathSciNet gives indications of this web. And so does the advisor/student graph in MGP. Mathematicians have long been interested in these connections, possibly more than any other science. There was a time in the early days when some seemed to think it was a silly hobby of Harry. Most people, I think, have come to appreciate its value; certainly, the AMS has."

Limits

Naturally, there are limits to MGP's usefulness. It can only go back so far in time, and it only tracks a certain formal type of mathematical training. Like traditional genealogy, MGP also tends to turn a blind eye to off-the-record progeny. There are quite a few people who feel that somebody other than their official supervisor was their real mathematical father or mother, and as in ordinary families "parents" and "children" don't always see eye-to-eye about the exact relationship. There are several reasons why the formal record may not match the reality, ranging from institutional to personal, and in most cases such anomalies are likely to remain undocumented online.

Furthermore, younger people tend to be less interested than their elders in genealogy of any sort, and they don't always respond to nudges to get themselves added to MGP. As in all spheres of STEM record keeping, it is important that underrepresented groups in mathematics are as present as possible in MGP, even if their minority status is invisible to a casual viewer: no age, gender, nationality, photo, or identifying information other than name is indicated for the entries. (The country flag shown for each degree represents today's country designation for the degree-granting institution.) For these reasons alone, it is especially important that advisors and departments regularly submit, correct, and update information at MGP.

Finally, there is the question of accuracy: anybody can submit data to MGP, and in most cases it is accepted on faith. There are certainly instances where X is believed to have been a student of Y "with high probability," although it cannot be proved; sometimes neither the theses in question nor the corresponding official records survive.

Structure and Support

Those curious about the structure of the graph that MGP forms can find some information at the website. Around 2008, Bud Brown of Virginia Tech noticed that the MGP graph is nonplanar and drew the subgraph in Figure 4 showing this fact.

As of July 2016, about 90 percent of the entries of MGP formed a single connected component, of which about 75 percent was taken up by roughly 7,300 root vertices (people with no listed advisor) and roughly 137,000 leaves (people with no documented students). Then there are isolated vertices, such as that of Irish mathematician William Rowan Hamilton. He seems to have been included merely as a courtesy: he didn't have a PhD (or formal descendants). Problematically, his flagless entry includes "Advisor: Unknown" and "No students known," the first perhaps suggesting that it's just a case of doing more digging. The designation "None" would be more helpful in both cases, and in general it would be nice to have a way to distinguish between (possibly empty) lists of academic offspring that

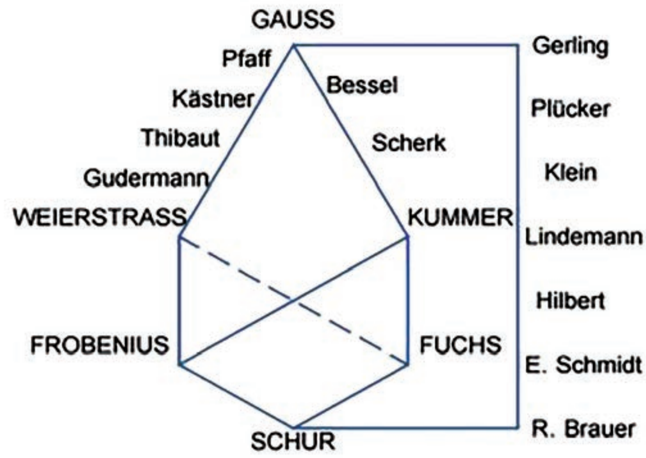


Figure 4. ***Proof without words.*** **The MGP graph is nonplanar, as it contains this subgraph homeomorphic to $K_{3,3}$, connecting Gauss, Frobenius, and Fuchs to Weierstrass, Kummer, and Schur.**

are known to be complete and ones for which more data might conceivably be added down the road.

Some mathematics departments provide (implicit) structured support for MGP by proudly displaying online lists of all their successful graduate students, going back to the earliest times, two notable examples being those at the University of British Columbia[2] and University College Cork in Ireland.[3] Of course, that leaves to others the nontrivial work of submitting the relevant (missing) thesis information to MGP, and in the case of UCC, yours truly has had a go at it.

Most universities' websites provide search engines to track the existence (and sometimes also the text) of dissertations, although that can be limited to more recent degrees. Frustratingly, many do not allow searches by subject or advisor; indeed, some institutions seem to keep no record of either. Caltech's site `thesis.library.caltech.edu` is one of the best, even allowing searches by advisor or committee members. It might make a nice student project at such institutions to ensure that the appropriate theses are all added to MGP.

While MGP is entirely dependent on voluntary submissions of data to become larger and more accurate, it also needs financial support. Managing Director Mitch Keller notes that "Everyone involved with the MGP is grateful for the support of the mathematical community over the past twenty plus years, and we look forward to continuing to be a valuable resource for many years to come. The MGP has long used donated funds to employ student workers to help process data. Since the project moved to NDSU in 2002, these have mostly been graduate assistants doing work in addition to their regular teaching duties. The budget since 2008–2009 has ranged from $6,000 to $9,000 annually, with roughly half of that being payroll costs for the data graduate assistants each year. The rest

[2] `https://www.math.ubc.ca/Grad/gradAlumni.shtml`

[3] `www.ucc.ie/en/matsci/postgraduate/`

is typically travel and printing of posters. We are working on increasing the amount of donations received each year to further improve the project. Right now, our backlog stands at a month because of staffing limitations that are largely funding related, and we are already needing to start thinking about the costs of attending ICM in 2018."

Donations to support the ongoing work of the MGP are encouraged, either as one-time gifts (perhaps even a legacy gift) or as recurring donations. Using the Donate button on the main page sidebar menu is one way to contribute.

Credits

Figures 1–3 are courtesy of the Mathematics Genealogy Project.
Figure 4 is courtesy of Ezra Brown.
Photo of Colm Mulcahy is courtesy of Colm Mulcahy.

Colm Mulcahy

ABOUT THE AUTHOR

Colm Mulcahy of Spelman College, Atlanta, is the author of the book *Mathematical Card Magic: Fifty-Two New Effects* (A K Peters/CRC Press, 2013), vice president of Gathering 4 Gardner, and the creator and curator of the online Annals of Irish Mathematics and Mathematicians.

2017 Award for an Exemplary Program or Achievement in a Mathematics Department

Participants in the University of Illinois Urbana–Champaign Mathematics Bootcamp.

The Department of Mathematics at the University of Illinois Urbana–Champaign is the recipient of the 2017 Award for an Exemplary Program or Achievement in a Mathematics Department.

Citation

The American Mathematical Society is pleased to recognize the Department of Mathematics at the University of Illinois with the 2017 Award for Exemplary Program or Achievement in a Mathematics Department. The efforts in expanding mathematics through various programs at both the undergraduate and graduate levels and improving the representation of women and underrepresented minorities in the Department of Mathematics at the University of Illinois have been exemplary.

The Mathematics Department at Illinois has created a successful internship program for their graduate students. The program includes a "computational mathematics boot camp" that trains students in computational skills and in the ways of thinking that arise in applied and interdisciplinary work. Then the program places students in private sector internships, in government labs, and in scientific labs across the university. Also, the department has a strong record of forming innovative programs to improve the mathematics education of undergraduate students. A recurring theme is to get students actively doing mathematics. They have implemented a Merit Program for Emerging Scholars, based on Uri Treisman's model, that focuses on helping underrepresented and first-generation college students succeed in mathematics. This model is founded on building learning communities among students and through intensive, collaborative, active-learning discussion sections. In addition, the Mathematics Department at Illinois has implemented active learning on a large scale reaching more than 8,000 students each year across their calculus and linear algebra courses. Finally, the Department has created the Illinois Geometry Lab that provides a community for undergraduate research. In the Illinois Geometry Lab, students work in small groups on semester-long research projects mentored by graduate students and faculty.

Further, the Department has made conscious and consistent efforts to increase the representation of women and minorities in their graduate program. The percentage of women in the PhD program has increased from 28 percent ten years ago to 38 percent today (with sixty-two women now in the program), and the percentage of US underrepresented minority students has risen from 4 percent to 22 percent of all US students in the last six years. The Department has an active Association for Women in Mathematics chapter with outreach, social, and academic activities. In addition, faculty members attend SACNAS and Field of Dreams as part of their effort to recruit graduate students from underrepresented minority groups.

DOI: http://dx.doi.org/10.1090/noti1519

FROM THE AMS SECRETARY

We are happy to present the AMS Award for Exemplary Program or Achievement in a Mathematics Department to the Department of Mathematics at the University of Illinois for the many ways in which it has supported and expanded mathematics through varied innovative programs and improved the representation of women and underrepresented minorities.

About the Award

The Award for an Exemplary Program or Achievement in a Mathematics Department was established by the AMS Council in 2004 and was given for the first time in 2006. The purpose is to recognize a department that has distinguished itself by undertaking an unusual or particularly effective program of value to the mathematics community, internally or in relation to the rest of society. Departments of mathematical sciences in North America that offer at least a bachelor's degree in mathematical sciences are eligible. Through the generous support of an anonymous donor, the award carries a cash prize of US$5,000.

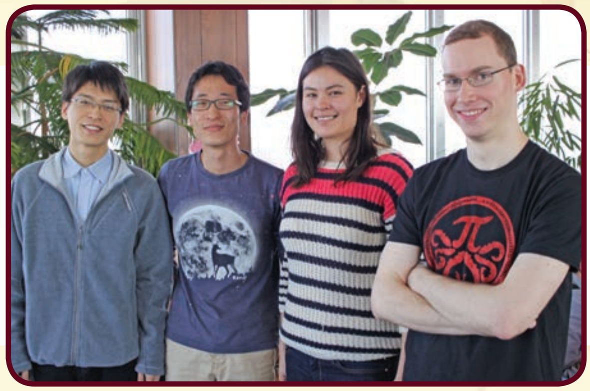
The award is presented by the AMS Council acting on the recommendation of a selection committee. For the 2017 award, the members of the selection committee were: Michael Dorff (chair), Erica Flapan, Eric Grinberg, Rhonda Hughes, and Cesar Silva.

The previous recipients of the award are Harvey Mudd College (2006); University of California, Los Angeles (2007); University of Iowa (2008); University of Nebraska, Lincoln (2009); North Carolina State University (2010); University of Arizona (2011); Bryn Mawr College (2012); University of Texas at Arlington (2013); Williams College (2014); Iowa State University (2015); and California State University at Northridge (2016).

—Exemplary Program Award Selection Committee

Photo Credit

The Bootcamp photo is courtesy of the Department of Mathematics at the University of Illinois at Urbana–Champaign.



2017 AMS Award for Impact on the Teaching and Learning of Mathematics

KRISTIN L. UMLAND has received the 2017 AMS Award for Impact on the Teaching and Learning of Mathematics.

Kristin L. Umland

Citation

Kristin Umland is a mathematician and mathematics educator who worked in the Mathematics and Statistics Department at the University of New Mexico for almost two decades before leaving to work with Illustrative Mathematics (IM), a nonprofit organization she helped establish in 2013. While on the faculty at the University of New Mexico, she worked to improve the mathematics courses for both elementary and secondary pre-service teachers, adding rigor as well as more relevant material for the students. Dr. Umland has also been deeply involved in supporting the national K–12 mathematics community in the transition to the Common Core State Standards in Mathematics (CCSS-M). Most notably she is the vice president for Content Development at IM, where she is focused on the very practical issue of developing high-quality resources to help teachers realize the goals of the CCSS-M in their classrooms. Initially conceived as a project to accompany the CCSS-M effort, it has grown to include resources that can improve K–12 mathematics learning more broadly. It has enormous potential to support the improvement of K–12 mathematics education by putting high quality resources only a click away from the K–12 math teachers across the country. She has been praised for her breadth of vision, combined with an incredible attention to detail.

IM was started by William McCallum, lead of the writing team of the CCSS-M, to illustrate the new standards with task examples. Working together with Dr. Umland, they took this idea deeper by developing the vision of an open, online resource created by a community of mathematicians, mathematics educators and teachers that would help teachers learn about the standards and their progressions. Since 2011, Dr. Umland has been one of the driving forces behind IM. In her role as vice president for Content Development, she has been instrumental in forming a community of one hundred editors and five hundred fifty reviewers who have created over 1,200 highly vetted tasks illustrating the standards. The public success of IM measured by its use around the country is staggering: The website sees 170,000 sessions per month (on average) with 5,000 to 10,000 sessions per day. Since 2012, `illustrativemathematics.org` has had over four million visitors viewing tasks over fourteen million times. One day alone, February 9, 2015, saw over 60,000 page-views. What makes this effort so valuable is not just the final product of a powerful resource for millions of educators in the US, but the process of creating and working with the tasks serves as highly effective professional development for hundreds of educators, who are gaining deep knowledge of mathematics while creating the tasks and discussing and using them together.

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Biographical Sketch

Kristin Umland received her PhD in mathematics in 1996 from the University of Illinois at Chicago, under the direction of Stephen D. Smith. She taught her first mathematics class at the University of New Mexico in the spring of 1996, joining the tenure stream faculty in 2002. In her time at the University of New Mexico, she taught twenty-four different courses ranging from Intermediate Algebra to Measure Theory, as well as many courses for elementary and secondary teachers.

In the summer of 2003, she visited the Vermont Mathematics Initiative at the invitation of Ken Gross. Her observations of Ken's work with elementary teachers was inspirational and set her on her current path working to improve K–12 mathematics teaching and learning. In 2004 she received a grant to provide mathematics professional development for middle school teachers in New Mexico. Over the next six years, approximately 600 teachers participated in content-based professional development, supported through this grant.

While on the faculty at the University of New Mexico, she worked as a mathematics expert on a number of education research projects, including evaluating the mathematical quality of state standards; measuring teachers' mathematical knowledge for teaching; and comparing measures of teachers' mathematical knowledge, the mathematical quality of instruction, and measures of student growth. She worked on a project, funded by the National Science Foundation, to document the impact of Math Teachers' Circles on middle school mathematics teachers. During this time, she also worked on several policy-related projects. She was an associate professor until leaving in 2016 to work full time as vice president for IM Content Development.

In her time at IM, she has worked on a wide range of projects aimed at improving the quality of mathematics resources used by teachers, curriculum and assessment developers, and policy makers. She is currently working with a team of mathematicians and mathematics teachers to develop an open education resource middle school mathematics curriculum that will be freely available to all teachers starting in the summer of 2017.

Response

I confess that I was not aware of the AMS Award for Impact on the Teaching and Learning of Mathematics, so imagine my surprise upon learning that I had received the award! And once I learned of Ken Gross' important role in its creation and the people who had received it in previous years, I was very humbled. Just as Ken Gross is a model to me for how mathematicians can work to improve K–12 mathematics, so, too, are Paul Sally and Jim Lewis. It is truly an honor to receive this award.

About the Award

The Award for Impact on the Teaching and Learning of Mathematics was established by the AMS Committee on Education (COE) in 2013. The US$1,000 award is given annually to a mathematician (or group of mathematicians) who has made significant contributions of lasting value to mathematics education. Priorities of the award include recognition of (a) accomplished mathematicians who have worked directly with pre-college teachers to enhance teachers' impact on mathematics achievement for all students, or (b) sustainable and replicable contributions by mathematicians to improving the mathematics education of students in the first two years of college. The endowment fund that supports the award was established in 2012 by a contribution from Kenneth I. and Mary Lou Gross in honor of their daughters Laura and Karen. The award is presented by the COE acting on the recommendation of a selection subcommittee. For the 2017 award, the members of the subcommittee were Erica Flapan, Tara Holm (Chair), Manmohan Kaur, and Kay Somers.

Previous recipients of the Impact Award are Paul J. Sally, Jr. (2014), W. James Lewis (2015), and Michael Gage and Arnold Pizer (2016).

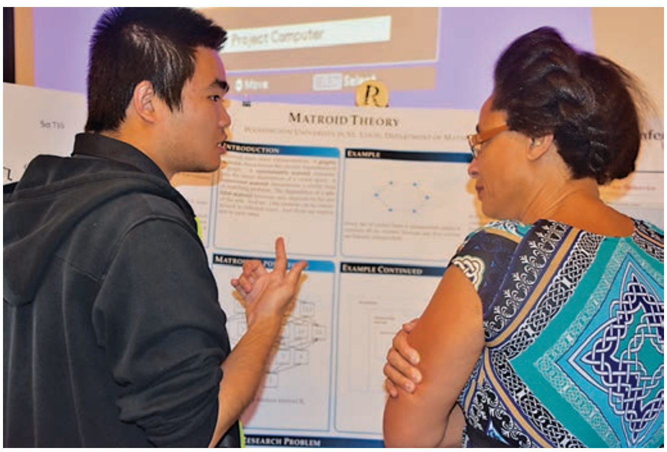
—AMS Committee on Education

Photo Credit

Photo of Kristin Umland is courtesy of Kristin Umland.

2017 Award for Mathematics Programs That Make a Difference

Allyn Jackson



The Field of Dreams conference gives students a chance to discuss mathematics, as at this poster session.

Each year, the AMS Committee on the Profession (CoProf) chooses outstanding programs to be designated as Mathematics Programs That Make a Difference. For 2017 CoProf has selected the Math Alliance.

Citation

Be it resolved that the American Mathematical Society and its Committee on the Profession recognize the National Alliance for Doctoral Studies in the Mathematical Sciences (the Math Alliance) for its programs over the last 10 years promoting participation by groups underrepresented in doctoral programs in the mathematical sciences.

Now based at Purdue University, the Math Alliance began in 2001 as a partnership of three Iowa State Regents universities and four Historically Black Colleges and Universities and has grown into a national network of institutions and faculty that mentor minority students in both undergraduate and graduate programs. It holds the annual Field of Dreams Conference, attended in 2015 by 174 undergraduates and 130 faculty from over 115 institutions. In addition, Alliance Mentors work at the predoctoral, masters, PhD, and post-doctoral level to help students succeed in their studies and progress on to the next level. In 2015–16 the program listed 552 faculty mentoring over 600 active scholars. The Alliance has expanded its network 30-fold over the last 10 years, and has recently been used as a model for a similar program in physics by the American Physical Society.

One of the supporting letters for the nomination, by a former Alliance Scholar, credits the Alliance with helping to "mold an African-American female from rural Louisiana who had never considered going to graduate school into a NSF postdoctoral fellow." Another, by the chair of a participating institution, describes "a community aspect of the Alliance that is hard to capture in numerical data—an aspect that is best experienced at one of the annual Field of Dreams Conferences or in a department with a nontrivial number of minority graduate students.''

The AMS commends the Math Alliance for its commitment to and success in increasing minority participation in doctoral programs nationwide.

Program Description

In the 1990s the mathematics department at the University of Iowa embarked on an effort to recruit and retain graduate students from members of groups underrepresented in mathematics. Through careful attention to mentoring and by observing what helped the students succeed, the department underwent a transformation that refocused its commitment to serving all students well. Seeking to expand these efforts, it formed a partnership with the math departments on the other two Iowa State Regents campuses—Iowa State University and the University of Northern Iowa—and with several historically black colleges and universities. The success of this work was recognized by the AMS Award for an Exemplary Program or Achievement in a Mathematics Department, which went to the University of Iowa in 2008 and to Iowa State University in 2015.

Allyn Jackson is senior writer and deputy editor of the Notices. *Her e-mail address is* axj@ams.org.

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It is from these roots that the Math Alliance has grown. That it started in Iowa, where the population is predominantly white, and in math departments with predominantly white faculty has provided an example and an inspiration that many other departments have begun to follow.

The main purpose of the Math Alliance is to ensure that students from underrepresented groups who have the ambition and desire to pursue graduate study in the mathematical sciences have an opportunity to do so in a supportive environment. The Alliance helps students realize their potential for graduate work in these fields and nurtures them in their journey to becoming math science professionals. More broadly, the goal of the Alliance is to spark a spiritual transformation within mathematical sciences departments so that they set aside the traditional model of weeding students out and embrace an inclusive model of helping all students succeed.

While originally focused on minority groups, today the Math Alliance aims to serve a wider collection of "underrepresented" students: those who are US citizens or permanent residents and who come from ethnic groups, families, and/or regions that have had little prior experience with doctoral study in the mathematical sciences. This shift reflects a deeply held value of the Math Alliance community and an understanding that many citizens come from backgrounds that have historically lacked opportunities to pursue STEM careers. For example, the Math Alliance has worked closely with the math department at Eastern Tennessee State University, which sent approximately twenty of their students to the most recent Field of Dreams conference. While most of these students are not from minority backgrounds, they come from a region of the country that is underrepresented in the math sciences. As a result of this broadening of focus, about 85 percent of the students served by the Alliance are from minority backgrounds, and it is expected that this number will vary as the profession evolves.

The Math Alliance has a nationwide network of mentors, organized regionally, who are at institutions with a substantial proportion of undergraduates from underrepresented groups. These mentors nominate undergraduate math sciences majors and master's students to become Alliance Scholars, who then become eligible for various Alliance programs. In addition to advising and supporting the students, the mentors share ideas with other like-minded faculty to help spread the Math Alliance spirit.

Each Alliance Scholar is paired with at least one mentor and has the opportunity to participate in Alliance summer research experiences for undergraduates programs. Alliance Scholars attend the annual Field of Dreams conference, which has been held each fall since 2007. Drawing about two hundred students and about one hundred faculty members, Field of Dreams has become a magnet for minority students interested in mathematics or statistics as well as a recruiting event for Alliance institutions. Other quantitative fields, such as engineering and business, are also represented. At the conference, students build friendships, get to know mentors, find out how to prepare for and apply to graduate school, and learn about career opportunities. In addition to helping students, Field of Dreams strengthens ties among Math Alliance mentors.

Field of Dreams participants have a lot of fun, even when posing for group photos. Laughing at the front of the group is Math Alliance director Phil Kutzko. At right kneeling is executive director David Goldberg.

The Alliance has worked with faculty in graduate programs across the nation to build Alliance Graduate Program Groups. These are groups of faculty in departments that have made a commitment to the Alliance spirit of helping all students succeed and of providing a friendly, welcoming community within the department. Today there are thirty-five Graduate Program Groups, and several other departments have applied to join.

One of the most successful programs of the Math Alliance is called Facilitated Graduate Applications Process (F-GAP). Its purpose is to provide undergraduate seniors and master's students with the advice and assistance needed to successfully apply to graduate programs. Each student is paired with a faculty member at a Graduate Program Group who serves as the Alliance Doctoral Mentor. The student, the doctoral mentor, and the predoctoral mentor form the graduate mentoring team, which helps the student decide which doctoral programs to apply to and assists the student with all aspects of the application process. F-GAP has placed more than two hundred students in math sciences graduate programs over the last three years.

In 2016 the Math Alliance moved to its present home at Purdue University. One of the founders of the Math Alliance, Philip Kutzko, of the University of Iowa, is the director, and David Goldberg, of Purdue University, is the executive director.[1] Edray Goins, who also serves as the president of the National Association of Mathematicians, is the associate director of the Math Alliance. The work of the Math Alliance has received support from the National Science Foundation since 2002. One of the present goals is to institutionalize the Math Alliance to make it a self-supporting organization, and the move to Purdue,

[1] *The September 2016 issue of the* Notices *carried an interview with David Goldberg; the interview was conducted by* Notices *associate editor Harriet Pollatsek.*

Institutions from all over the country send representatives to the Field of Dreams conference.

which has generously provided bridging support, may be seen as a move in this direction.

Math Alliance website: `mathalliance.org`

About the Award

CoProf created the Mathematics Programs That Make a Difference designation in 2005 as a way to bring recognition to outstanding programs that successfully address the issue of underrepresented groups in mathematics. Each year CoProf identifies one or two exemplary programs that:

1. aim to bring more individuals from underrepresented minority backgrounds into some portion of the pipeline beginning at the undergraduate level and leading to an advanced degree and professional success in mathematics or retain them in the pipeline,
2. have achieved documentable success in doing so, and
3. are replicable models.

The CoProf subcommittee making the selection for this year's awards consisted of Al Boggess, Duane Cooper, Pamela Gorkin, and William McCallum (Chair).

Previously designated Mathematics Programs That Make a Difference are:

- the graduate program at the University of Iowa and the Summer Institute in Mathematics for Undergraduates/Research Experience for Undergraduates at Universidad de Puerto Rico, Humacao (2006);
- Enhancing Diversity in Graduate Education (EDGE) and the Mathematical Theoretical Biology Institute (2007);
- the Mathematics Summer Program in Research and Learning (Math SPIRAL) at the University of Maryland and the Summer Undergraduate Mathematical Science Research Institute at Miami University (Ohio) (2008);
- the Department of Statistics at North Carolina State University and the Department of Mathematics at the University of Mississippi (2009);
- the Department of Computational and Applied Mathematics at Rice University and the Summer Program in Quantitative Sciences, Harvard School of Public Health (2010);
- the Center for Women in Mathematics at Smith College and the Department of Mathematics at North Carolina State University (2011);
- the Mathematical Sciences Research Institute (2012);
- the Nebraska Conference for Undergraduate Women in Mathematics (2013);
- the Carleton College Summer Mathematics Program and the Rice University Summer Institute of Statistics (the latter now at the University of Nevada at Reno) (2014);
- the Center for Undergraduate Research in Mathematics at Brigham Young University and the Pacific Coast Undergraduate Mathematics Conference (2015);
- the Department of Mathematics at Morehouse College (2016).

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2017 Joint Policy Board for Mathematics Communications Awards

Arthur Benjamin

Siobhan Roberts

Two Communications Awards of the Joint Policy Board for Mathematics (JPBM) were presented at the Joint Mathematics Meetings in Atlanta, Georgia, in January 2017.

Arthur Benjamin received the JPBM Communications Award for Public Outreach, and Siobhan Roberts was presented the Award for Expository and Popular Books. The JPBM Communications Award is presented annually to reward and encourage journalists and other communicators who, on a sustained basis, bring mathematical ideas and information to non-mathematical audiences. JPBM represents the American Mathematical Society, the American Statistical Association, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics. The award carries a cash prize of US$1,000.

Citation: Arthur Benjamin

The 2017 JPBM Communications Award for Public Outreach is given to Art Benjamin for his books aimed at general audiences, his TED Talk on "mathemagic," and his popular "Great Courses" for the Teaching Company. Arthur Benjamin's work demonstrates his ability and commitment to share the joy of mathematics and excites and engages audiences at all levels.

DOI: http://dx.doi.org/10.1090/noti1525

Biographical Sketch of Arthur Benjamin

Arthur Benjamin earned his BS in applied mathematics from Carnegie Mellon and his PhD in mathematical sciences from Johns Hopkins University. Since 1989, he has taught at Harvey Mudd College, where he is the Smallwood Family Professor of Mathematics and past chair. In 2000, he received the Haimo Award for Distinguished Teaching of the Mathematical Association of America, and he served as the MAA's Pólya Lecturer from 2006 to 2008.

His research interests include combinatorics and number theory, with a special fondness for Fibonacci numbers. Many of these ideas appear in his book (coauthored with Jennifer Quinn), *Proofs That Really Count: The Art of Combinatorial Proof,* published by MAA. In 2006, that book received the Beckenbach Book Prize of the MAA. Professors Benjamin and Quinn were the editors of *Math Horizons* magazine from 2004 through 2008.

Benjamin is also a magician who performs his mixture of math and magic to audiences all over the world, including the Magic Castle in Hollywood. He has demonstrated and explained his calculating talents in his book and DVD course, *Secrets of Mental Math*, and on numerous television programs, including the *Today Show*, CNN, and the *Colbert Report*. He has been featured in *Scientific American, Omni, Discover, People, Esquire, The New York Times, The Los Angeles Times*, and *Reader's Digest*. He has given three TED talks, which have been viewed over twelve million times. *Princeton Review* recently profiled him in the book *The Best 300 Professors*. *Reader's Digest* calls him "America's Best Math Whiz." His newest book is called *The Magic of Math: Solving for X and Figuring Out WhY*.

Response from Arthur Benjamin

I am deeply humbled to be selected for this prize. Nearly all of the previous recipients of this award are heros of mine, and it is truly an honor to be recognized among such a distinguished group.

I have loved numbers all of my life. As a kid, I marveled at the fact that you could do an arithmetic problem many different ways and, if you were careful, you would always get the same answer. I found that consistency of math to be absolutely beautiful then, and I still do today. As a professor, I encourage my students to solve problems or prove theorems in multiple ways to build a deeper understanding of the subject.

In my classes, my writing, and my public appearances, I try to emphasize the fun and magical side of mathematics, and I would love to see more of this appear in the precollege curriculum. Since students have such easy access to powerful computational tools, we can and should replace some of the more laborious parts of our curriculum with math that is more relevant or elegant.

I would not have received this award without the support and inspiration of many people. I would like to thank my parents for encouraging me to pursue my mathematical and magical passions. I owe a debt of gratitude to Martin Gardner for setting such a high standard. Thanks to the MAA for spreading the joy of mathematics through its publications and activities. I will always cherish my work with Jennifer Quinn for our collaboration on articles and books and for being my coeditor of *Math Horizons*. I am so grateful to my students and colleagues at Harvey Mudd College who make it a joy to come to work every day. Last but not least, I thank my wife Deena and daughters Laurel and Ariel for their love, for their support, and for adding so much magic to my life.

Citation: Siobhan Roberts

The 2017 JPBM Communications Award for Expository and Popular Books is presented to Siobhan Roberts for her engaging biographies of eminent mathematicians and articles about mathematics that are appreciated by the general public and scientific audiences alike. The acclaimed biographies *King of Infinite Space* (about H. S. M. Coxeter) and *Genius at Play* (about John Horton Conway) bring her subjects to life and make the importance of their mathematical accomplishments accessible to all.

Biographical Sketch of Siobhan Roberts

Siobhan Roberts is an award-winning science journalist and biographer based in Toronto, Canada. Siobhan writes for the *New Yorker*'s "Elements," *Nautilus*, and *Quanta*, and at various times has contributed to the *Guardian, Smithsonian, The New York Times, Science Times, The Globe and Mail*, and *The Walrus*, among other publications. She is an occasional Director's Visitor at the Institute for Advanced Study in Princeton.

While writing her latest book, *Genius at Play: The Curious Mind of John Horton Conway*, she was a Fellow at the Leon Levy Center for Biography at the City University of New York Graduate Center in New York City. Her first book, *King of Infinite Space: Donald Coxeter, The Man Who Saved Geometry*, won the Euler Prize for expanding the public's view of mathematics. She also wrote and produced a documentary film about Coxeter, *The Man Who Saved Geometry*, for TV Ontario's *The View from Here*.

Response from Siobhan Roberts

Writing, like mathematics, is about discovery: following one's curiosity; questioning; persevering through the "stuckedness" with an iterative process of trial and error to reach a desired (or altogether unexpected) destination. Writing about mathematics and science is double the fun, especially since my background is predominantly in the arts. It's a serious enterprise with a steep learning curve, especially in these beleaguered times, when the *Oxford English Dictionary* declares "post-truth" the word of the year. "Tell all the truth but tell it slant…" wrote Emily Dickinson—it's a gradual, circuitous process finding "the Truth's superb surprise." Now we need to persevere in our efforts to tell it straight. I am honored to receive the JPBM Communications Award, and I look forward to many more mathematical adventures.

Previous recipients of the JPBM Communications Award are:

- James Gleick (1988)
- Hugh Whitemore (1990)
- Ivars Peterson (1991)
- Joel Schneider (1993)
- Martin Gardner (1994)
- Gina Kolata (1996)
- Philip J. Davis (1997)
- Constance Reid (1998)
- Ian Stewart (1999)
- John Lynch and Simon Singh (special award, 1999)
- Sylvia Nasar (2000)
- Keith J. Devlin (2001)
- Claire and Helaman Ferguson (2002)
- Robert Osserman (2003)
- Barry Cipra (2005)
- Roger Penrose (2006)
- Steven H. Strogatz (2007)
- Carl Bialik (2008)
- George Csicsery (2009)
- Marcus du Sautoy (2010)
- Nicolas Falacci and Cheryl Heuton (2011)
- Dana Mackenzie (2012)
- John Allen Paulos (2013)
- Danica McKellar (2014)
- Nate Silver (2015)
- Museum of Mathematics (Public Outreach) and Simon Singh (Expository and Popular Books) (2016)

—*JPBM Announcement*

Photo Credits

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Photo of Siobhan Roberts is by Christopher Wahl.

Big Is Beautiful: Illinois Wins Exemplary Program Award

Allyn Jackson

Eighty thousand credit hours. Twenty-six thousand student classes. Twelve hundred math majors, two hundred twenty-five graduate students, seventy tenure-stream faculty, and twenty postdocs. These numbers capture one aspect of the mathematics department at the University of Illinois at Urbana–Champaign: It is big. The department has faced all the challenges typical in departments of its kind, including shrinking resources, pressure from other departments over math requirements, steep increases in undergraduate enrollments, and heightened expectations for teaching quality.

Far from tottering under the weight of these responsibilities, Illinois has thrived. The department's large size brings a wealth of expertise and creativity to bear on the challenges it faces. The faculty have set in motion innovations that have increased the quality of the education it delivers at all levels, stimulating the enthusiasm of both students and faculty. Long a successful department, Illinois has become one that is truly outstanding. For these achievements, the mathematics department at the University of Illinois has received the AMS Award for an Exemplary Program or Achievement in a Mathematics Department.

bringing the department to a new level of excellence

An Influential Department

Neither an Ivy Leaguer nor a member of the coastal elite, the University of Illinois at Urbana–Champaign nevertheless possesses a mathematics department that has long been prominent on the mathematical scene. The department's large size allows it to maintain research strength across all areas of mathematics. A list of the research publications of the math faculty during 2010–15 runs to sixty-six pages and contains over one thousand entries. A major PhD producer, the department in recent decades has turned out between 1.5 percent and 2 percent of all math doctorates in the nation. The department publishes a journal, the *Illinois Journal of Mathematics*, founded in 1957 by Illinois mathematicians Reinhold Baer and Joseph L. Doob, along with Abraham Taub, George Whitehead, and Oscar Zariski.

Another way to gauge the department's influence is through its extensive service to the mathematical community. Two Illinois mathematicians served as AMS president: Doob (1963–64) and Arthur Byron Coble (1933–34). Robert M. Fossum served as AMS secretary from 1989 to 1999 and might hold the record for serving on the largest number of AMS committees (the current AMS secretary, Carla Savage, got her PhD at Illinois). Philippe Tondeur served as director of the Division of Mathematical Sciences of the National Science Foundation (NSF) from 1999 until 2002, a period in which math was named an NSF "priority area" and received double-digit increases.

Yet another example is Paul T. Bateman, a larger-than-life figure with outsize energy and enthusiasm who served as AMS associate secretary and was on the Board of Trustees. He joined the Illinois faculty in 1950 and remained active through his retirement in 1989 and until his death in 2012. Bateman built up the department in ways big and small, raising its research profile, hosting annual grill parties, and organizing a softball team known as the P. T. Batsmen. From 1965 to 1980 he served as head and presided over a dramatic expansion of the department.

In the 1990s, as faculty hired during the Bateman era began to retire, the department hired several new faculty per year for several years running. Not seeking to reproduce its past research strengths, the department

Allyn Jackson is senior writer and deputy editor of the Notices. *Her e-mail address is* axj@ams.org.

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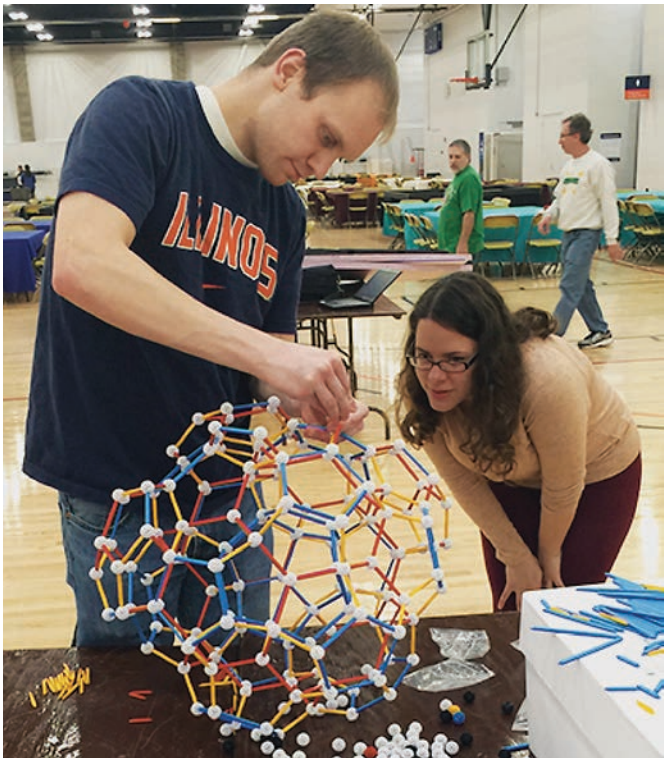

Illinois Geometry Lab volunteers Matthew Romney and Vanessa Rivera Quiñones creating materials for outreach work.

instead focused simply on getting outstanding mathematicians. Many of the people hired in that period have now emerged as leaders in the department's recent achievements. They have capitalized on the longstanding traditions and experience at Illinois to bring the department's functions to a new level of excellence.

Responding to Shifting Student Needs

Like many math departments across the country, Illinois has seen an increase in the number of math majors, though the increase at Illinois has been particularly sharp, up from 800 five years ago to 1,200 today. According to Randy McCarthy, director of undergraduate studies, this increase is not due to more students preparing for graduate school or for careers in secondary school. Rather, it has been fueled in large part by students who are doing "math plus," that is, a double major in mathematics plus another subject, such as computer science, engineering, or economics. Students value the addition of math for the insight it brings into the sophisticated modeling and statistical tools that are pervasive in quantitative areas. Also, the 2008 financial crisis raised uncertainties about job prospects after college. Students used to be able to count on good grades leading to a good job, McCarthy said. "Nowadays, they are much less confident they are going to get that job, and they are looking for an edge. They feel math gives them a competitive edge."

The Illinois department has excelled in responding to such shifts in the needs and expectations of its students. One innovation in this direction is the Illinois Geometry Lab (IGL). The IGL was founded by Jayadev Athreya, who has since moved to the University of Washington (where he has opened a similar lab); currently the director is Jeremy Tyson. The IGL offers undergraduates the opportunity to work on semester-long projects under the guidance of faculty. Not all of the projects are in geometry, and many focus on applications of mathematics to other subjects, but they all have a large computational component. Topics have ranged from modeling taxi routes in New York City, to studying properties of knots with a large number of crossings, to solving problems related to lithium-ion battery design, to investigating randomness in number theory. The students learn what it's like to work on a team and struggle with open-ended problems. This builds communication skills, as do the end-of-semester talks the students present before the entire lab.

The IGL has a second purpose: to showcase mathematics to the general public and to K–12 students. The lab conducts about twenty-five public outreach activities each year, which have IGL students toting the lab's 3-D printer to places like farmers' markets and schools. There are also events in which K–12 students visit the IGL. Reaching thousands of people, these events have stoked enthusiasm for mathematics among the general public—and among the IGL students. "The students who get involved in IGL projects are interested in doing collaborative, interactive things," said department chair Matthew Ando. "They have a lot of energy, and they like to communicate about mathematics. It's turned out to be a very strong community for outreach." Currently about sixty undergraduates participate in IGL projects. With funding from NSF and from donors, the department plans to increase this number by supporting more postdocs who can initiate IGL projects.

Another departmental innovation began around ten years ago, when complaints came from the engineering school about calculus classes. One of the complaints was an oft-heard one: engineering students need a calculus class that specifically prepares them for engineering applications. Another was that many engineering students with good scores on the AP Calculus BC Exam did poorly when placed directly into multivariable calculus. The math department collaborated with the engineering school to develop a new course, team-taught by mathematicians and engineers. Together they developed problem sets based on science and engineering applications, which students work on in teams in active-learning mode during discussion sections. They also strategically reorganized the syllabus so that the course covers the traditional Calculus 1 and Calculus 2 in a single semester. And instead of easing students in with familiar material, the course starts off with Taylor series. "So we disrupt their idea that they know the material really well," Ando said. "That gets their attention!"

The students "feel math gives them a competitive edge."

An active-learning classroom in action.

"We learned a lot from developing and teaching that course," Ando continued. "And then this marvelous thing happened." As faculty rotated through the course, they became "infected" by the active-learning model. This model had actually been used for twenty-five years in the department's Merit Program for Emerging Scholars. Based on the ideas of Uri Treisman, the program recruits students who have strong academic records and come from traditionally "underserved" populations, which include minority groups underrepresented in mathematics as well as first-generation college students. Merit students attend regular lectures, but instead of traditional one-hour discussion sections, they participate in two-hour "workshops" in which they collaborate on problem sets.

Faculty became "infected" by the active-learning model.

The success of the Merit students and of those in the new engineering calculus class got the department to thinking. "People realized that the active-learning model of the engineering calculus course would work in other larger courses," recalled associate chair Scott Ahlgren. Around this same time, climbing student enrollments and budget constraints led the department to consolidate its approximately 100 calculus classes, which had around 30–35 students apiece, into large lecture classes with 30-student discussion sections. The sections are conducted entirely in active-learning mode, with groups of 4 students collaborating on problem sets as TAs circulate around, giving hints and encouraging students to talk to each other. All students have a stake in participating: Everyone must write up a solution set, but from each group only one set, chosen at random, will be graded.

After ten years of patient work on large-lecture calculus, the courses are working smoothly and efficiently. In that time, the department's total teaching load went from 20,000 student-courses a year to 26,000 today. So the department has begun extending the large-lecture model to other courses, such as linear algebra. The faculty remain wistful about the loss of small classes but have found that the large-lecture model brings some unexpected advantages. In the days of the small calculus classes, "You would just pick up your book and go teach," Ando said. "Thirty students—what could go wrong?" With the large-lecture courses taught by two or three faculty, "we learned how to collaborate with each other." When someone who has not taught the course before comes in to teach it, he or she learns the ropes from colleagues and inherits a wealth of experience. "We have a lot materials, we have videos, a bunch of worksheets, and instructions for TAs on how to run the sections," Ahlgren said. "We can pass on the knowledge of how to run this operation. This process has grown organically." Ahlgren also noted that the collaboration has brought greater consistency to the courses.

In addition to providing a model for improving its large-lecture classes, the collaboration with the engineering school has changed how the math department is perceived on campus. Richard Laugesen, the department's director of graduate studies, said that twenty years ago engineering faculty members would often grumble that the mathematicians weren't interested in applied topics and paid no attention to the needs of engineering students. "We don't hear any of that now," Laugesen remarked. "They understand that we are engaged and we want to work with them to find solutions for their students."

The department meets needs of students in many other ways. Its Actuarial Science Program enrolls almost 400 undergraduate majors and is growing at the graduate level to address increasing demand in risk management. The department also has a distance-learning program called NetMath, founded twenty-five years ago by Debra Woods and the late Jerry Uhl, which provides opportunities for high school students and nontraditional students. Most recently, NetMath has offered summer courses for Illinois undergraduates.

Graduate students relaxing in the common room.

"We Want You to Succeed"

Melinda Lanius majored in math at Wellesley College and had no idea what area she might specialize in when she joined the PhD program at Illinois. Halfway around the world, Caglar Uyanik did his undergraduate work at Middle East Technical University in Ankara, Turkey, one of that nation's premier public research universities. He wanted to do geometric group theory and decided on Illinois for graduate school because of its strength in that area. These two very different students, with very different starting points, are now close to finishing their PhDs. Both thrived in the Illinois department. Uyanik spoke of the friendliness of both the graduate students and the faculty, noting that there is "more solidarity than competition" among the students. Lanius said, "You can figure out what type of mathematician you want to be while at Illinois, and then there is a ton of support to help you prepare for and realize that choice."

The PhD program is "very streamlined."

Serving well the broad range of graduate students who enter the PhD program is a major focus at Illinois. Attrition is low; if the department recruits twenty-five new students in the doctoral program, said Laugesen, usually twenty-four are back the second year. "That's a reason we tell students, 'Come to Illinois. We are investing in you, and we want you to succeed.'" In recent years, the department has worked hard to increase diversity in its graduate student population. Today the graduate student body is 38 percent women, up from about 25 percent a decade ago. "That's something that we feel has really changed the tone of the PhD program," Laugesen noted. The department's Association for Women in Mathematics (AWM) chapter, founded in 2011, runs a host of activities that are open to all students and that have deepened the sense of community in the department. Through tireless recruiting at events like SACNAS meetings and the Field of Dreams conferences, the department has also increased the number of students from minorities underrepresented in mathematics, who now account for 22 percent of the US citizens in the PhD program.

The program is "very streamlined," Laugesen said. Instead of a qualifying or comprehensive examination that students must pass early on, the program requires satisfactory grades in basic coursework in the first year and a half. One required course is Math 499, which is essentially a seminar in which faculty members give informal talks about their areas of research to help students get oriented toward choosing an advisor. The foreign language requirement, which was a hindrance to some students, has been eliminated. The department has developed a timetable that spells out the milestones toward the degree and when a student should reach them. By the end of the second year, students are expected to have found an advisor and have begun working on a thesis proposal. "This all helps emphasize that it is a research-focused degree," Laugesen said. "The courses are a foundation to help them figure out what they want to do. But the emphasis is on getting them connected with an advisor and getting them into research."

Each fall Laugesen meets with every single doctoral student—all 160 of them—to monitor their progress and help them clear obstacles they may have encountered. In the spring, each student must present a formal progress report. "It's remarkable the effect [the timetable] has," Laugesen said. "When there is no goal or requirement or deadline, then a lot of people will drift. When they know what they have to accomplish, they tend to get it done." Through the systematic use of the timetable, the department has seen the time-to-degree decrease.

One of the biggest innovations the department has made is to give students opportunities that prepare them for careers outside academia. With funding from the NSF, the department created PI4 (Program for Interdisciplinary and Industrial Internships at Illinois), which provides training and internships for PhD students. The program includes a "Summer Computational Boot Camp" in which students pick up programming skills. They are then placed in internships in companies or laboratories or in other departments on the Illinois campus where mathematical thinking can make a contribution to research. The number of summer internships has grown from six in 2013 to a total of thirty-one in 2016. The internships do not slow the progress towards the PhD. "In fact, quite the reverse," Laugesen noted. "Students who aim at an industry career tend to finish a little quicker because they are very motivated."

Using the Illinois Geometry Lab's 3-D printer, undergraduate student Hiroshi Fuii designed and printed colorful plastic models to illustrate how circles, ellipses, hyperbolas, and parabolas arise as conic sections. When stacked together the pieces of the model form a cone. The cross sections revealed by the slices range through the full set of "conic sections." Faculty member Steven Bradlow used the models in a course on curves that he taught at the African Institute of Mathematical Sciences in January 2013.

Laugesen and two of his colleagues, Yuliy Baryshnikov and Lee DeVille, described the PI4 program in an article that appeared in the March 2017 issue of the *Notices* (`https://tinyurl.com/bardevlau`). The article notes that currently around 1,900 mathematical sciences PhDs are produced every year in the United States, while each year only about 1,000 tenure-track positions are under recruitment. Inevitably, many new PhDs seek employment outside academia, but mathematics faculty do not always have relevant experience to guide them. "There are ways in which mathematics is useful in the world that twenty or twenty-five years ago, when I was in graduate school, we just never would have imagined," Laugesen said. Programs like PI4 provide a model that other departments can use to better prepare their graduate students for the many new opportunities that are opening up outside academia.

A Healthy and Mature Department

Like many math departments at state institutions, Illinois operates under considerable budget pressure and uncertainty. But the faculty has been entrepreneurial in seeking support for the many things they do. In addition to grants for programs like PI4, more than half of the faculty hold individual or small-group research grants. The department is the hub of a large research network called GEAR (GEometric structures And Representation varieties), led by Steve Bradlow and supported by a US$2.5-million NSF grant. NetMath contributes to the department in many ways, for example, by supporting teaching assistantships and fellowships for graduate students, as well as research experiences for undergraduate students. Donors support a variety of programs, such as lecture series, scholarships, and named professorships.

The drive and enthusiasm of the faculty rub off on the students. For example, Lanius and other students created a summer math camp for high school students, now held annually on the Illinois campus. She has served as an officer in the department's AWM chapter, organizing social events for the entire mathematics graduate student population that help students to bond and support each other during the year. The chapter also has its own colloquium series, with talks accessible to first- and second-year graduate students, and offers professional development workshops on topics like creating a website and how to give an "elevator pitch." Last fall the AWM chapter officers came to Ando with a list of several activities that they hoped the department would fund. "They have such initiative," Ando remarked. "We are not a wealthy department, but if somebody comes to ask for funds for such worthy activities, you turn around and find the money." To capitalize on the enthusiasm of the undergraduate majors, the department has created "Mathematics Ambassadors," a program that each year designates around twenty math majors who exemplify academic strength, leadership ability, and commitment to the department. The ambassadors participate in outreach events and act as an advisory group for the undergraduate program.

preparing students for careers outside academia

Students, faculty, and staff gathered in front of Altgeld Hall, home of the Illinois mathematics department.

What is the secret to the department's success? "We have a particularly healthy and mature department," McCarthy said. "We don't have a lot of turf wars or people arguing among each other." The faculty members place a strong emphasis on research but at the same time are very student oriented. Many of them have received teaching awards (as have many graduate students serving as TAs). The faculty's shared commitment to students serves to shift discussions away from narrow self-interest and toward the question, What is best for the students? That the department is so big reinforces the shared focus on students. "We have such a critical mass, we are so large, that once you have that attitude, it tends to be self-stabilizing," said McCarthy. Even when faculty members go through an upheaval, it doesn't last long because everyone remembers the pleasant steady-state environment that usually prevails. "There is a strong desire to return back to that healthy norm," McCarthy said.

As big as the Illinois department is, Ando believes the AMS award his department has received actually reflects the achievements of an even bigger group. Having served as chair for five years, he has visited many other departments doing similar things. "There are great things going on in mathematics departments across the country," he said. "I hope that this award will help draw attention to the efforts and achievements of the whole mathematics community."

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Photo of colorful plastic models is courtesy of Laura Schaposnik. All remaining photos are courtesy of the Department of Mathematics at the University of Illinois at Urbana–Champaign.

CALL FOR NOMINATIONS

The selection committees for these prizes request nominations for consideration for the 2018 awards, which will be presented at the Joint Mathematics Meetings in San Diego, CA, in January 2018. Information about past recipients of these prizes may be found in the April 2014 (pp. 399–410), April 2015 (pp. 423–428), and April 2016 (pp. 422–437) issues of the *Notices*, and at www.ams.org/profession/prizes-awards/prizes.

ALBERT LEON WHITEMAN MEMORIAL PRIZE

The Albert Leon Whiteman Memorial Prize now is awarded every third year, for notable exposition on the history of mathematics. The ideas expressed and understandings embodied in that exposition should reflect exceptional mathematical scholarship.

AWARD FOR DISTINGUISHED PUBLIC SERVICE

This award, which is made every two years, recognizes a research mathematician who has made a distinguished contribution to the mathematics profession during the preceding five years.

CHEVALLEY PRIZE IN LIE THEORY

The Chevalley Prize prize, awarded in even-numbered years, recognizes notable work in Lie Theory published during the preceding six years; a recipient should be at most twenty-five years past the PhD.

NOMINATION PERIOD: MARCH 1–JUNE 30, 2017.

FRANK NELSON COLE PRIZE IN ALGEBRA

The Cole Prize in Algebra, which recognizes a notable paper in algebra published during the preceding six years, is awarded every three years. To be eligible, papers must be either authored by an AMS member or published in a recognized North American journal.

GEORGE DAVID BIRKHOFF PRIZE IN APPLIED MATHEMATICS

The George David Birkhoff Prize is awarded jointly by the AMS and SIAM for an outstanding contribution to applied mathematics in its highest sense. The award was first made in 1968 and now is presented every third year.

LEVI L. CONANT PRIZE

The Levi L. Conant Prize is presented annually for an outstanding expository paper published in either the *Notices* or the *Bulletin of the American Mathematical Society* during the preceding five years.

Further information about AMS prizes can be found at the Prizes and Awards website: **www.ams.org/profession/prizes-awards/prizes**

Further information and instructions for submitting a nomination can be found at the prize nominations website: **www.ams.org/profession/prizes-awards/nominations**

For questions contact the AMS Secretary at secretary@ams.org

Nomination Period: March 1–June 30, 2017.

2016 AMS CONTRIBUTORS LIST

Catherine A. Roberts
AMS Executive Director

Dear AMS Members and Friends,

Thank you for your gifts to the American Mathematical Society in 2016.

In my first year as Executive Director I've been fortunate to observe your generosity first-hand, and I am moved by your dedication to and vision for the Society.

I particularly want to thank long-time donors to the AMS. More than one thousand people who donated to the Society last year have done so for more than fifteen years; of those, over six hundred people have given for twenty years or more. The Society thanks you for your steady support of mathematics. Many good things stand on the longevity of your giving.

Other exciting notes from 2016 include Thomas C. Hales endowing the new Bertrand Russell Prize of the AMS. Stuart A. Geman, Donald E. McClure, and David B. Mumford created the Ulf Grenander Prize in Stochastic Theory and Modeling. The Society became the home of the Mark Green and Kathryn Kert Green Fund for Inclusion and Diversity, which is most welcome in these times. We also received generous gifts from several donors who chose to remain anonymous. Their philanthropy is providing essential support to graduate students, early-career mathematicians, and to the mathematics community at large. On behalf of the many beneficiaries, I thank you.

The Society is grateful for bequests received from the estates of Roy L. Adler, Isidore Fleischer, Bettie C. and James F. Hannan, Franklin P. Peterson, and Barbara and Paul T. Schaefer. Thank you to everyone who is making a provision in their will, no matter the size, to the AMS. Your commitment to mathematics will continue for years to come.

Please enjoy reading this report. Our Society benefits from each of you acknowledged herein.

Catherine A. Roberts
Executive Director

Thomas S. Fiske Society

Members of the Thomas S. Fiske Society uphold the future of mathematics by including the American Mathematical Society in their estate plans. The following Fiske Society members have created a personal legacy in support of the mathematical sciences by naming the AMS in their will, retirement plan, or other gift planning vehicle.

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In Tribute

The following friends, colleagues, and family members are all being specially honored by a donation in support of mathematics. These gifts are a tangible homage to those who have passed on, or a way to honor people still living. The AMS is pleased to list the commemorated individuals and the 2016 donors who made these gifts possible.

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The people and businesses listed below made gifts to the AMS between January 1–December 31, 2016. On behalf of all those who benefit from this generosity, the AMS extends its thanks to everyone who chose to support mathematics through the AMS during the past year. Donors who have contributed $1,000 or more in one year are further acknowledged on the AMS Donor Wall of Honor at the Society's Headquarters. We are pleased to recognize each donor in the following listing.

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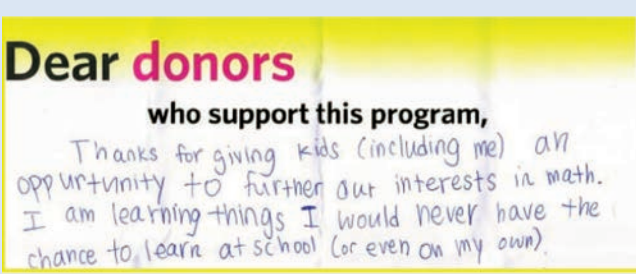

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American Mathematical Society

CALL FOR NOMINATIONS

NEW

BERTRAND RUSSELL PRIZE OF THE AMS

The Bertrand Russell Prize of the AMS was established in 2016 by Thomas Hales.

The prize looks beyond the confines of our profession to research or service contributions of mathematicians or related professionals promoting good in the world. It recognizes the various ways that mathematics furthers fundamental human values. The mission of the American Mathematical Society includes:

- Promoting the uses of mathematical research
- Advancing the status of the profession of mathematics
- Fostering an awareness and appreciation of mathematics and its connections to other disciplines and everyday life

This prize is designed to promote these goals. Mathematical contributions that further world health, our understanding of climate change, digital privacy, or education in developing countries, are some examples of the type of work that might be considered for the prize.

The US$5,000 prize is awarded every three years. The first award will be made in 2018.

Further information about AMS prizes can be found at the Prizes and Awards website:
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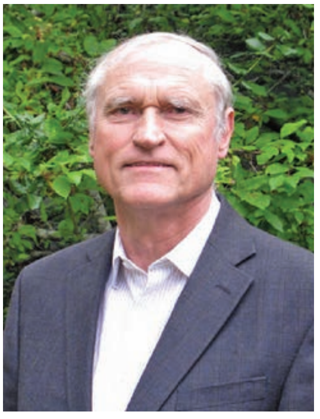
Nomination Period: March 1–June 30, 2017

Fefferman and Schoen Awarded 2017 Wolf Prize in Mathematics

Charles Fefferman



Richard Schoen

CHARLES FEFFERMAN of Princeton University and RICHARD SCHOEN of the University of California, Irvine, have been awarded the 2017 Wolf Prize in Mathematics by the Wolf Foundation.

The prize citation reads: "Charles Fefferman has made major contributions to several fields, including several complex variables, partial differential equations and subelliptic problems. He introduced new fundamental techniques into harmonic analysis and explored their application to a wide range of fields including fluid dynamics, spectral geometry and mathematical physics. This had a major impact on regularity questions for classical equations such as the Navier-Stokes equation and the Euler equation. He solved major problems related to the fine structure of solutions to partial differential equations."

"Richard Schoen has been a pioneer and a driving force in geometric analysis. His work on the regularity of harmonic maps and minimalsurfaces had a lasting impact on the field. His solution of the Yamabe problem is based on the discovery of a deep connection to general relativity. Through his work on geometric analysis Schoen has contributed greatly to our understanding of the interrelation between partial differential equations and differential geometry. Many of the techniques he developed continue to influence the advance of non-linear analysis."

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Biographical Sketch: Charles Fefferman

Charles Fefferman was born in Washington, DC, in 1949. Showing exceptional ability in mathematics as a child, he entered the University of Maryland in 1963, at the age of fourteen, having bypassed high school. He published his first mathematics paper in a journal at the age of fifteen. In 1966, at the age of seventeen, he received his BS in mathematics and physics and was awarded a three-year NSF fellowship for research. He received his PhD from Princeton University in 1969 under the direction of Elias Stein. After spending the year 1969–1970 as a lecturer at Princeton, he accepted an assistant professorship at the University of Chicago. He was promoted to full professor in 1971—the youngest full professor ever appointed in the United States. He returned to Princeton in 1973. He has been the recipient of a Sloan Foundation Fellowship (1970) and a NATO Postdoctoral Fellowship (1971). He was awarded the Fields Medal in 1978. His many awards and prizes include the Salem Prize (1971); the inaugural Alan T. Waterman Award (1976); the Bergman Prize (1992); and the Bôcher Memorial Prize of the AMS (2008). He was elected to the American Academy of Arts and Sciences in 1972, the National Academy of Sciences in 1979, and the American Philosophical Society in 1989. He became an honorary member of the London Mathematical Society in 2009.

Biographical Sketch: Richard Schoen

Richard Schoen was born in Celina, Ohio, in 1950. He received his PhD in 1977 from Stanford University under Leon Simon and Shing-Tung Yau. While still a graduate student at Stanford, he accepted a position as instructor of mathematics at the University of California, Berkeley. In 1978 he became assistant professor at New York University. With a Sloan Foundation Fellowship, he spent the year 1979–1980 as a visiting member at the Institute for Advanced Study, Princeton. In 1980 he became professor of mathematics at Berkeley, and in 1984 he moved to the University of California, San Diego. He was awarded a MacArthur Fellowship in 1983. He returned to Stanford in 1987, where he is currently Anne T. and Robert M. Bass Professor of Humanities and Sciences. His honors include election to the American Academy of Arts and Sciences (1988) and the National Academy of Sciences

(1991); selection as a Fellow of the American Association for the Advancement of Science (1995); and a Guggenheim Fellowship (1996). He was awarded the Bôcher Memorial Prize of the AMS in 1989. He has held visiting positions at the Institute for Advanced Study, the Courant Institute of New York University, and Harvard University.

About the Prize

The Wolf Prize is an international award granted by the Wolf Foundation. It carries a cash award of US$100,000. The science prizes are given annually in the areas of agriculture, chemistry, mathematics, medicine, and physics. Laureates receive their awards from the President of the State of Israel in a special ceremony at the Knesset Building (Israel's Parliament) in Jerusalem. The list of previous recipients of the Wolf Prize in Mathematics is available on the website of the Wolf Foundation, `www.wolffund.org.il`.

—Wolf Fund Announcement

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2017 Breakthrough Prizes Awarded

Jean Bourgain

Joseph Polchinski

Andrew Strominger

Cumrun Vafa

Breakthrough Prize in Mathematics

Jean Bourgain of the Institute for Advanced Study, Princeton, New Jersey, has been selected as the recipient of the 2017 Breakthrough Prize in Mathematics by the Breakthrough Prize Foundation. Bourgain was honored for "major contributions across an incredibly diverse range of areas, including harmonic analysis, functional analysis, ergodic theory, partial differential equations, mathematical physics, combinatorics, and theoretical computer science." The prize carries a cash award of US$3 million.

The *Notices* asked Terence Tao of the University of California Los Angeles to comment on the work of Bourgain (Tao was on the Breakthrough Prize committee and was also one of the nominators of Bourgain). Tao responded: "Jean Bourgain is an unparalleled problem-solver in analysis who has revolutionized many areas of the subject by introducing new techniques and ideas. Some of his earliest contributions include his solution of the $\Lambda(p)$ problem in Fourier analysis, his advances on the Kakeya and restriction problems in harmonic analysis and the application of related estimates to nonlinear partial differential equations, and his numerous works in high dimensional geometry, for instance in establishing the reverse Santaló inequality with Milman or the restricted invertibility theorem with Tzafriri. In the last decade, Bourgain's investigations into the sum-product phenomenon have led to deep new exponential sum estimates in number theory (which in some regimes can even improve on what can be obtained from the results of Weil and Deligne on the Riemann hypothesis over finite fields), as well as the development (with Gamburd and Sarnak) of the affine sieve that has proven to be a powerful tool for analyzing thin groups. Most recently, with Demeter and Guth, Bourgain has established several important decoupling theorems in Fourier analysis that have had applications to partial differential equations, combinatorial incidence geometry, and analytic number theory, in particular solving the Main Conjecture of Vinogradov, as well as obtaining new bounds on the Riemann zeta function."

DOI: http://dx.doi.org/10.1090/noti1509

Biographical Sketch: Jean Bourgain

Jean Bourgain was born in 1954 in Oostende, Belgium. He received his PhD (1977) and his habilitation (1979) from the Free University of Brussels. He was a professor at the University of Brussels and at the University of Illinois at Urbana–Champaign, moving in 1985 to the Institut des Hautes Études Scientifiques in Paris. Ten years later, he became a professor at the Institute for Advanced Study in Princeton, where he is currently the IBM von Neumann Professor of Mathematics. In 1994, he received the Fields Medal. His other distinctions include the Salem Prize (1983), the Élie Cartan Prize of the French Academy of Sciences (1990), the Ostrowski Prize (1991), the Shaw Prize in Mathematical Sciences (2010), and the Crafoord Prize in Mathematics of the Royal Swedish Academy of Sciences (2012).

Breakthrough Prize in Fundamental Physics

Joseph Polchinski of the Kavli Institute for Theoretical Physics, University of California Santa Barbara, and Andrew Strominger and Cumrun Vafa, both of Harvard University, were awarded the Breakthrough Prize in Fundamental Physics for their "serious advances in string theory, the alleged but still unproven theory of everything, and what it might mean for black holes and the universe." They will share the cash award of US$3 million.

The *Notices* asked Edward Witten of the Institute for Advanced Study in Princeton to comment on the work of Polchinski, Strominger, and Vafa. Witten responded: "Polchinski, Strominger, and Vafa are known for deep and far-reaching contributions to the understanding of quantum field theory and string theory, with implications for a variety of areas of physics and mathematics.

"Polchinski's single most celebrated contribution, dating back to the early to mid-1990s, has been the theory of D-branes. Certain string theories that semiclassically have closed strings only—meaning that the world history of the string is a two-manifold without boundary—turn out in a full quantum treatment to also have open strings, corresponding to world histories with boundary. D-branes provided a crucial link between string theory and gauge theory and have had dramatic consequences—developed in part in some of Polchinski's later papers—for the understanding of quantum 'dualities' among string theories and field theories. For physicists, these dualities are an essential part of understanding what happens when quantum effects are strong and a semiclassical approximation is no longer useful. Mathematically, they have many much-studied manifestations, ranging from mirror symmetry to the geometric Langlands correspondence.

"The single most celebrated contribution of Strominger and Vafa involved the quantum mechanics of black holes. In the early 1970s, Jacob Bekenstein and Stephen Hawking had interpreted the area of the horizon of a black hole as a form of entropy. This led many physicists to suspect that when the black hole is studied quantum mechanically, its horizon area would equal the logarithm of the number of its quantum states. For a long time, however, it was impossible to demonstrate this through any sort of concrete computation. At first, a suitable quantum gravity theory in which one might do the computation was not available, and later, when string theory emerged, such a calculation was technically out of reach. The first such calculation was accomplished by Strominger and Vafa in a dramatic 1996 paper. Their main technical tool was to interpret the quantum states of a black hole, in an appropriate context, in terms of the elliptic genus of the moduli space of vector bundles on a $K3$ surface. The connection between black holes and vector bundles was deduced from the link between string theory and gauge theory that is provided by D-branes.

"Many other contributions by Strominger and Vafa have been influential in mathematics as well as physics. Only a few examples can be cited here. In the mid-1980s, Strominger was one of the initiators of the use of Calabi-Yau manifolds to construct models of particle physics and made many of the important contributions in this area. One milestone was his discovery, with Brian Greene and David Morrison, of a link between singularities of a Calabi-Yau manifold and phase transitions in physics. Vafa was one of the originators of the concept of mirror symmetry between a complex manifold and a symplectic manifold and contributed many key ideas in this subject. He also introduced *F*-theory, an extension of string theory using elliptic fibrations. With Rajesh Gopakumar, Vafa introduced in 1998 what mathematically would be called a categorification of the Gromov-Witten invariants; the following year, with Hirosi Ooguri, he developed an analog of this for knot theory.

"Polchinski's other work defies easy summary. He introduced a new point of view about the renormalization group in condensed matter physics and relativistic field theory. He has made many penetrating contributions to the understanding of gauge/string duality and its implications for our understanding of gauge theories. And in recent years, initially with Ahmed Almheiri, Donald Marolf, and James Sully, he introduced and developed the baffling and highly influential 'firewall' paradox involving quantum black holes, which still today presents a deep challenge to our understanding of fundamental physics."

Biographical Sketch: Joseph Polchinski

Joseph Polchinski was born May 16, 1954, in White Plains, New York. He received his PhD from the University of California Berkeley in 1980 under Stanley Mandelstam. He was professor at the University of Texas at Austin (1984–1992) before joining U Cal Santa Barbara and the Kavli Institute. Among his honors are the Dannie Heineman Prize for Mathematical Physics (2007), the Dirac Medal (2008), and the Physics Frontiers Breakthrough Prize (2013). He is the author of the two-volume textbook *String Theory* (1998).

Biographical Sketch: Andrew Strominger

Andrew Strominger was born in 1955 and received his PhD in 1982 from the Massachusetts Institute of Technology under the supervision of Roman Jackiw. He held a faculty position at the University of California Santa Barbara before joining the faculty of Harvard University in 1997. His honors include the Physics Frontiers Breakthrough Prize (with Cumrun Vafa, 2012), the Klein and Dirac Medals (2014), and the Dannie Heineman Prize for Mathematical Physics (2016).

Biographical Sketch: Cumrun Vafa

Cumrun Vafa was born in Tehran, Iran, in 1960 and received his PhD from Princeton University under the direction of Edward Witten. His honors include the AMS Leonard Eisenbud Prize (2008), the Dirac Medal of the ICTP (2008), the Breakthrough Prize in Fundamental Physics (with Andrew Strominger, 2012), and the Dannie Heineman Prize for Mathematical Physics (2016).

About the Prize

The Breakthrough Prize in Mathematics was created by Mark Zuckerberg and Yuri Milner in 2013. It aims to recognize major advances in the field, to honor the world's best mathematicians, to support their future endeavors, and to communicate the excitement of mathematics to the general public. The prize is accompanied by a cash award of US$3 million. Previous winners are Simon Donaldson, Maxim Kontsevich, Jacob Lurie, Terence Tao, Richard Taylor (2015), and Ian Agol (2016).

The Breakthrough Prize in Fundamental Physics was founded in 2012 by Yuri Milner to recognize those individuals who have made profound contributions to human knowledge. It is open to all physicists—theoretical, mathematical, experimental—working on the deepest mysteries of the Universe. The inaugural Breakthrough Prize ceremony was held March 20, 2013, in Geneva, Switzerland, where the Prize was won by Alexander Polyakov. Two Special Fundamental Physics Prizes of $3 million were awarded to Stephen Hawking and to seven CERN scientists with leading roles in the discovery of the the Higgs boson.

—Breakthrough Prize Committee Announcement

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Photo of Andrew Strominger is courtesy of Marina Werbeloff, Harvard University.
Photo of Joseph Polchinski is courtesy of KITP.
Photo of Cumrun Vafa is courtesy of Hayward Photography.

American Mathematical Society

CALL FOR NOMINATIONS

AMS AWARD FOR MATHEMATICS PROGRAMS THAT MAKE A DIFFERENCE

DEADLINE: SEPTEMBER 15, 2017

Photos by Kate Awtrey, JMM 2017 photographer.

This award recognizes programs that:

1. aim to bring more persons from underrepresented backgrounds into some portion of the pipeline beginning at the undergraduate level and leading to advanced degrees in mathematics and professional success, or retain them once in the pipeline;

2. have achieved documentable success in doing so; and

3. are replicable models.

Preference will be given to programs with significant participation by underrepresented minorities.

Beginning in 2018, this recognition includes an award of US$1,000, provided by the Mark Green and Kathryn Kert Green Fund for Inclusion and Diversity.

One award will be made in 2018. The AMS Committee on the Profession selects the recipient.

Nomination process: Letters of nomination may be submitted by one or more individuals. Nomination of the writer's own program or department is permitted.

The nomination should describe the specific program being nominated as well as the achievements that make the program an outstanding success, and it should include clear and current evidence of that success. The letter of nomination should not exceed two pages, with supporting documentation not to exceed three more pages. Up to three supporting letters may be included in addition to these five pages.

Send nominations to:
Programs That Make a Difference
c/o Director of Education and Diversity
American Mathematical Society
201 Charles Street
Providence, RI 02904
or via email to AED-MPS@ams.org

Recent Winners:

2017: The National Alliance for Doctoral Studies in the Mathematical Sciences (Math Alliance)

2016: Department of Mathematics, Morehouse College

2015: Pacific Coast Undergraduate Math Conference (PCUMC); Center for Undergraduate Research in Mathematics (CURM)

2014: Carleton College Summer Math Program; Rice University Summer Institute of Statistics

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Mathematics Opportunities

Listings for upcoming math opportunities to appear in Notices may be submitted to `notices@ams.org`.

Travel Grant Program for ICM 2018

The International Congress of Mathematicians (ICM) Organizing Committee, the Instituto de Matemática Pura e Aplicada (IMPA), and the Brazilian Mathematical Society will offer 500 travel grants for mathematicians from developing countries to attend the ICM in Rio de Janeiro, Brazil, in 2018. The deadline for applications is **July 20, 2017**. For details, see the website `www.icm2018.org/portal/en/news23`.

—From an ICM announcement

AWM ADVANCE Grant for Research Networks for Women

The Association for Women in Mathematics (AWM) has received a five-year, US$750,000 ADVANCE grant for research networks for women in mathematics. Workshops at the annual Joint Mathematics Meetings and SIAM Meetings will bring together women from one of the Research Collaboration Networks to showcase their work and encourage continued collaboration and mentoring. AWM will also organize biennial Research Symposia, with high-profile plenary speakers and special sessions in research areas linked to the networks. Most conferences so far have taken place at Banff International Research Station (BIRS), Banff, Alberta, Canada. Proposals may be submitted to Magnhild Lien by **July 1, 2017**. For more information, see the website `awmadvance.org`.

—AWM announcement

*NSF Postdoctoral Research Fellowships

The National Science Foundation (NSF) awards Mathematical Sciences Postdoctoral Research Fellowships in areas of the mathematical sciences, including applications to other disciplines. Awards are either Research Fellowships or Instructorships. The Research Fellowship provides full-time support for any eighteen academic-year months in a three-year period. The Research Instructorship provides either two academic years of full-time support or one academic year of full-time and two academic years of half-time support. The deadline for proposals is **October 18, 2017**. See `www.nsf.gov/funding/pgm_summ.jsp?pims_id=5301&org=NSF`.

—NSF announcement

*Research Training Groups in the Mathematical Sciences

The National Science Foundation (NSF) Research Training Groups in the Mathematical Sciences program provides funds for the training of US students and postdoctoral researchers. The deadline for full proposals is **June 6, 2017**. See `www.nsf.gov/funding/pgm_summ.jsp?pims_id=5732`.

—NSF announcement

International Mathematics Competition for University Students

The Twenty-Fourth International Mathematics Competition for University Students will be held July 31–August 6, 2017, at American University in Blagoevgrad, Bulgaria. Students completing their first, second, third, or fourth years of university education are eligible. See `www.imc-math.org.uk/`.

—John Jayne, University College London

**The most up-to-date listing of NSF funding opportunities from the Division of Mathematical Sciences can be found online at:* `www.nsf.gov/dms` *and for the Directorate of Education and Human Resources at* `www.nsf.gov/dir/index.jsp?org=ehr`. *To receive periodic updates, subscribe to the DMSNEWS listserv by following the directions at* `www.nsf.gov/mps/dms/about.jsp`.

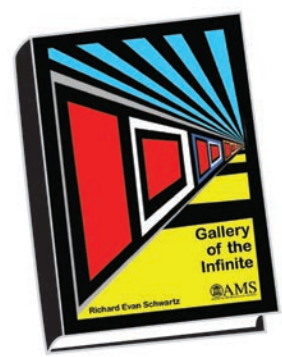
BOOK REVIEW

Math Graphics: A Review of Two Books

Judith Roitman

The Thrilling Adventures of Lovelace and Babbage: The (Mostly) True Story of the First Computer
Sydney Padua
Pantheon, 2015
US$19.68, 320 pages
ISBN-13: 978-0307908278

Gallery of the Infinite
Richard Evan Schwartz
American Mathematical Society, 2016
US$29.00, 187 pages
ISBN-13: 978-1-4704-255-79



Way back in 2010 in these pages I had the pleasure of reviewing the graphic historical novel of early twentieth-century logic and set theory *Logicomix: An Epic Search for Truth* by Apostolos Doxiadis and Christos H. Papadimitriou (writers) and Alexos Papadatos and Annie Di Donna (artists).[1] Now we have Sydney Padua's graphic fantasy *The Thrilling Adventures of Lovelace and Babbage* and Richard Evan Schwartz's graphic exposition of cardinality and uncountability, *Gallery of the Infinite*.

All three of these books escape the overmuscled art that dominates the comic mass market, but their art is otherwise quite different. *Logicomix* is quasi-realistic in a highly two-dimensional way. *Lovelace and Babbage* consists of exuberant black and white semi-caricature. *Gallery of the Infinite*, created via InkScape (described on its webpage as "a professional vector graphics editor"), is made of severely flattened somewhat abstract shapes in colors that when not black can best be described as strident.

Lovelace and Babbage began life as a web comic, which you can find at `sydneypadua.com`. I stumbled across it some time ago and was delighted to hear that it had turned into a book. The website contains links to things like primary sources and animations of Babbage's analytical engine. The book is replete with extensive and highly informative footnotes and endnotes (some of which themselves have footnotes). Padua's writing exuberantly brings the Victorian age alive. For example, Lovelace's family background (her father was Lord Byron) is concisely described: "It's not easy being the daughter of a celebrity mad genius deviant sex god."

Short, somewhat steampunk science fiction vignettes

Padua's first chapter is a fifteen-page introduction to the historical Lady Ada Lovelace and the historical Charles Babbage, with a quick summary of Babbage's difference engine (gears and steam would have made it run if it ever had been built) and two panels that get to

Judith Roitman is professor emerita at the University of Kansas. Her e-mail address is `jroitman@ku.edu`.

[1] *The review appeared in the December 2010* Notices.

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DOI: http://dx.doi.org/10.1090/noti1522

[2] *Some explanation of this equation would have been useful.*

[3] *It was published as notes to her translation of L. F. Menabrea's "Sketch of the Analytical Engine invented by Charles Babbage Esq." in* Taylor's Scientific Memoirs; *you can find a link at the website* `findingada.com/about/ada-lovelace-links`.

These two pages from *The Thrilling Adventures of Lovelace and Babbage* capture the exuberant style of the book. Here Ada Lovelace suddenly realizes that logic itself is mathematical and therefore subject to mathematical analysis and investigation. The author, Sydney Padua, does a remarkable job of making intellectual intensity palpable.

its mathematical heart: Lovelace exclaims in one panel, "It can tabulate accurately and to an **unlimited extent** all s*eries* whose general term is comprised by the formula $\Delta^7 U_x = 0$\$!!!"[2] and in the next continues, "Indeed, **all** other series which are capable of tabulation by the **method of differences**!!," to which Babbage replies, "**Exactly**!" Then we get to the analytical engine, which would have been programmed with punch cards (similar to the Jacquard loom); Lovelace writes what would have been a seminal paper[3] if anyone had paid attention; and there are two wonderful pages in which while writing this paper she realizes, ten years before George Boole's *Foundational Laws of Thought*, that logic was itself mathematical, i.e., that mathematics "might act upon other things besides *number*…The **engine** could analyze **all subjects in the universe**! A new, a vast, and a powerful **language** is developed for the future use of analysis, in which to wield its **truths**!"

The drawings are very much alive.

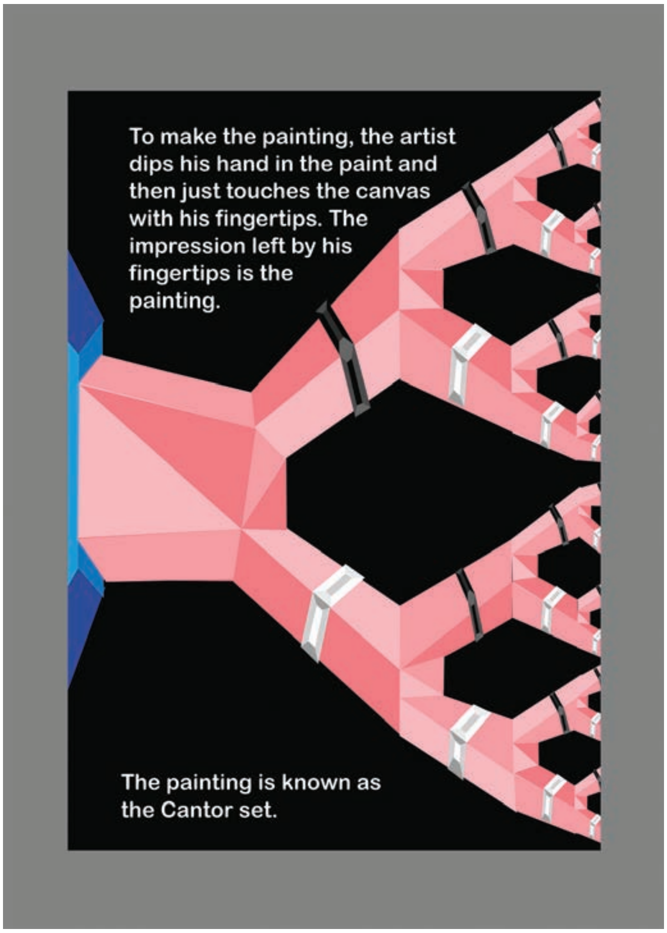
Padua then proceeds to invent the two-dimensional Pocket Universe, in which time is circular and in which the rest of the book takes place as a series of short, somewhat steampunk science fiction vignettes: Lovelace appears in disguise to interrupt Coleridge, ruining the poem *Kubla Khan* (the famous Person from Porlock); Lovelace and Babbage use the Engine to produce an Economic Model that runs amok; Luddites attacking the Engine are mollified by tea and a lecture from Babbage; the physical manuscript of George Eliot's *The Mill on the Floss* is uploaded to the cloud and destroyed in the process; George Boole comes to tea, and takes what later became Boolean algebra so seriously that when offered "coffee or tea" he answers, "Yes"; William Hamilton comes by to discuss quaternions, leading to the discussion of a possible third dimension, which later Lovelace stumbles into while encountering various figures from Alice's Wonderland—Charles Dodgson appears at the end of this story. There is an appendix that includes many primary documents and an extended explanation of the Analytical Engine. Finally, there is a graphic epilogue.

What is one to make of this? Padua's day job is as an animator, and the drawings are very much alive, so alive that, despite a relative lack of shading, the notion that this book takes place in a two-dimensional universe seems absurd. A lot of what goes on in the Pocket Universe doesn't quite make sense (although all of it has connections to our world, as the footnotes and endnotes document), and much of it happens at a kind of fever pitch. We learn a surprising amount about the Victorian intellectual milieu.[4] Clear portraits are drawn of Babbage as an impractical, somewhat benignly boorish dreamer; of Lovelace as a

[4] *In large part due to the footnotes, endnotes, and footnotes to the endnotes.*

driven, extraordinarily sharp genius who, if the day is to be saved, will be the one to save it; and of an enduring intellectual partnership. Padua has created a kind of dream of her own, of Victorian science and mathematics and (remember Ada's father) literature, and of a woman who broke free of convention. Check the website for a taste, and, if you like it, buy the book.

Gallery of the Infinite is a very different book. The back cover claims that it "is suitable for anyone with an interest in the infinite, from advanced middle-school students to inquisitive adults." Having been gobsmacked by Cantor's diagonal argument in seventh grade via George Gamow's *One, Two, Three…Infinity*, I was very happy to be given an opportunity to review this book. Gamow updated! Why not?



In this picture from *Gallery of the Infinite*, the Cantor tree (the tips of whose infinite branches become the Cantor set) is represented as the hand of an artist with so many fingers that each finger branches into two other fingers, which then branch into two other fingers…and so on.

Schwartz goes through the basics: cardinality via bijection; the countability of whole numbers, integers, rationals; Schroeder-Bernstein; Cantor's diagonal argument… . And also some nonbasics: the mathematical universe based on the empty set ("from this point of view, numbers are just organized emptiness"); brief mention of the axioms of ZF; and speculation about how maybe none of this makes sense because there might be a flaw in the axiom system (accompanied by a wild-eyed figure looking a little like a beardless Esenin-Volpin[5] (the resemblance might just be my imagination). But this is a *graphic* book, where the text essentially accompanies the pictures and not vice versa. Do the pictures support the text? And does the text accomplish its purpose?

My first impression was that the art was jarring and the presentation creepy: to explain why various sets are countable (the integers, the rationals,…), we are given sharks and chickens—chickens!—with infinitely many teeth in various configurations (the poor chicken wears braces). After a straightforward presentation of Cantor's diagonal argument, we have an artist with so many fingers that each finger branches into two other fingers (the Cantor tree). There is a set of playing cards with staring baboons, more chickens, and what looks like eyes surrounded by buzz-saws. There is a cat with fangs. There is an eye that turns into a Sierpinski carpet. If I were reading this back in seventh grade I might have been having nightmares. Or I might have thought it was really cool. Speaking as an old lady set-theorist, I thought some of the explanations unnecessarily complicated and some of the more general comments without enough context to be understood by a beginner. But what do I know? My artistic preference is elsewhere, and intellectually I know too much to know if this book works.

We are given sharks and chickens!

So I decided I needed some assistance. Why not ask some of the folks for whom the book actually is written what they thought of it? I enlisted a smart houseguest who doesn't know much math and some high school math club members and their friends. I gave them a questionnaire asking about the art, the text, and whether the art supported the text.

The kids all claimed to understand everything; the houseguest gave up at the notion of different sizes of infinity. The art got mixed reviews: it got in the way; it didn't get in the way; it helped a lot; it helped with bijection, but in other places was distracting. A particularly intriguing comment was that "there is so much black that it darkens the tone, giving learning about math a negative connotation." After which the same commentator said, "Well done throughout." All the commentators wanted to know more, although in one case it was despite the book. The kids would all recommend it to a friend; the houseguest would not. One of the kids was creeped out by the branching fingers—"That was not something I wanted to think about"—and thought the art should "just go Cubist, man!" One high school student thought the book was more appropriate for middle school kids. The houseguest thought the tone was somewhat self-indulgent. My

[5]*He denied the existence not only of infinite sets but of very, very large ones.*

thirty-six-year-old son also had a quick look at the art, and he immediately said, “Video game graphics!” Of course.

Richard Evan Schwartz has published other children’s books. In 2010 A K Peters put out *You Can Count on Monsters* about prime factorization (the monsters are the prime numbers), whose illustrations, from the online sample, are straightforward diagrams. In 2015 the AMS published his *Really Big Numbers: The First 100 Numbers and Their Characters*, whose pictures, from the online sample, are gentle with light colors. He also has self-published a number of children’s books, including, most intriguingly for me, *The Transporter Problem,* about a serious philosophical problem (if Scottie beams you down from the *Enterprise*, exactly who is it that arrives?) and whose illustrations have the same jagged edginess as those in *Gallery of the Infinite*.

Would I recommend *Gallery of the Infinite*? No. But I would not recommend Pokémon either, which places me in a definite minority. I am an old lady, and in matters like this the culture has passed me by. Will you like it? Maybe. Some of the kids thought it was great. So if you know of or are a smart, young—that is, under forty—person who doesn’t know any set theory, would like to know about it, likes what my generation used to call comics, and likes strange art in garish colors, you might consider this book.

I do have one caveat, which has nothing to do with the text or the art. *Gallery of the Infinite* started to fall apart after six people besides me had read it. Really? AMS is the publisher. I expect better quality control, and so should you.

Note: Valuable assistance in reviewing *Gallery of the Infinite* was received from Nora Agah, Dennis Duermeier, Emmaleigh Hancock, Ben Lombardo, Janet Stefanov, and Jaja Wang.

Credits

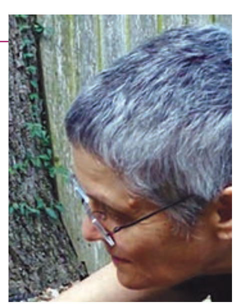
Images excerpted from *The Thrilling Adventures of Lovelace and Babbage* by Sydney Padua. Copyright ©2015 by Random House. Excerpted by permission of Pantheon Books, a division of Random House LLC.

Images from *Gallery of the Infinite* are courtesy of Richard Evan Schwartz. ©2016 Richard Evan Schwartz.

Photo of Judith Roitman is courtesy of Geraldine Dotson.

ABOUT THE REVIEWER

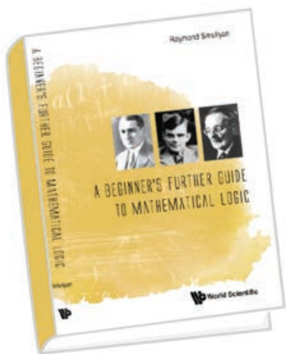
Judith Roitman tends to lead several lives simultaneously. Relevant to this review are: her life doing set theory in the guise of general topology and Boolean algebra, and her life as a poet. She has absolutely no ability to create visual art (“how do you even start a painting/sculpture/drawing?’’ she asks her artist friends) but finds it deeply satisfying to look at.



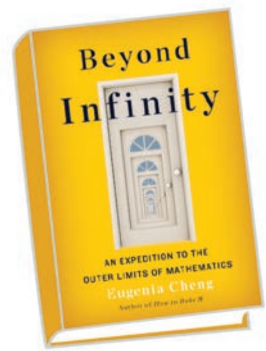
Judith Roitman

BOOKSHELF

New and Noteworthy Titles on Our Bookshelf
May 2017



A Beginner's Further Guide to Mathematical Logic, by Raymond Smullyan (World Scientific, November 2016). Raymond Smullyan, who died in February of this year at the age of ninety-seven, was a logician, math popularizer, magician, and pianist. Over his long life, Smullyan wrote about thirty books, ranging from academic titles in logic, to explorations of religion and philosophy, to collections of recreational math writings. The latter group includes *What Is the Name of This Book? The Riddle of Dracula and Other Logical Puzzles* (1978), a classic that was reprinted in 2011 as a Dover edition. Martin Gardner called the book "The most original, most profound, and most humorous collection of recreational logic and math problems ever written." Smullyan kept writing up to the time of his death, publishing six books just in the past five years. One of these was *A Beginner's Guide to Mathematical Logic* (World Scientific, 2014), which treats propositional and first-order logic, formal systems and recursion, and Gödel's incompleteness results. The book highlighted here, *A Beginner's Further Guide to Mathematical Logic*, is the sequel. In the preface, Smullyan wrote: "I originally intended both volumes to be a single volume, but I felt that at my age (now 96), I could pass away at any time, and I wanted to be sure that I would at least get the basic material out." The *Beginner's Further Guide* expands on ideas from the first book and presents some metamathematical applications, as well as a treatment of combinatory logic. Among the many tributes to Smullyan that appeared after his death is one by Ken Regan, which appears in the blog "Gödel's Lost Letter and P = NP" (`RJLipton.wordpress.com`). Regan recounts going into a bookstore in Oregon and happening upon copies of Smullyan's 1959 PhD thesis, *Theory of Formal Systems*, which appeared in the Princeton Annals series in 1961. For US$20, Regan bought the thesis and enjoyed Smullyan's clear and concrete presentations. He also discovered that, in the thesis, Smullyan anticipated ideas from complexity theory.



Beyond Infinity: An Expedition to the Outer Limits of Mathematics, by Eugenia Cheng (Basic Books, March 2017). When Raymond Smullyan wrote his first math popularization in 1978, women mathematicians were rare—and women math popularizers were rarer still. (If you know of a woman mathematician who wrote a popular math book before, say, 1990, please post a comment about it on the *Notices* website, `ams.org/notices`.) Today, along with an increasing number of women mathematicians has come an increase in women math popularizers. Most write for periodicals—examples include Erica Klarreich, who contributes regularly to *Quanta* magazine, and Evelyn Lamb, who blogs for *Scientific American*. Some also write books, like Hannah Fry, author of *The Mathematics of Love* (reviewed by Mark Colyvan in the August 2016 *Notices*) and Eugenia Cheng, author of *How to Bake Pi* (reviewed by Jeremy Martin in the October 2016 *Notices*). Cheng's latest book *Beyond Infinity* explores the notion of infinity as it arises in various contexts and guises. She writes in a leisurely, down-to-earth style about this mysterious and often-confounding subject. Predictably, Hilbert's Hotel makes an appearance in the book, but Cheng also comes up with some novel devices for talking about infinity, such as time travel, how children grow, and the structure of puff pastry. The book presents a different way of seeing mathematics—without the "formulae being thrown at you, and stressful tests and unpalatable problems to solve." Math is like a boat trip, Cheng tells us: "It's not just about getting to the destination… It's about the fun, the mental exertion, communing with mathematical nature and seeing the mathematical sights."

Suggestions for the BookShelf can be sent to `notices-booklist@ams.org`.

We try to feature items of broad interest. Appearance of a book in the *Notices* BookShelf does not represent an endorsement by the *Notices* or by the AMS. For more, visit the AMS Reviews webpage `www.ams.org/news/math-in-the-media/reviews`.

Mathematics People

2017 AWM Awards

The Association for Women in Mathematics (AWM) presented several awards at the Joint Mathematics Meetings in Atlanta, Georgia, in January 2017.

Helen G. Grundman

Helen G. Grundman of Bryn Mawr College and the American Mathematical Society was honored with the Gweneth Humphreys Award for Mentorship of Undergraduate Women in Mathematics. According to the prize citation, she "has an impressive record of mentoring female undergraduate students, many of whom have now earned graduate degrees in mathematics, physics, computer science, or other professional programs. Not only has she mentored students from her classes, but her guidance has extended to students of all levels seeking advice on coursework, summer research programs, senior theses, and careers." Grundman was recently appointed AMS's Director of Education and Diversity, in which position she will provide leadership for the Society's current and future programs supporting education and promoting diversity, particularly at the graduate level.

Catherine Kessel

Catherine Kessel, an editor and consultant, received the Louise Hay Award for Contributions to Mathematics Education. The prize citation reads in part: "Dr. Kessel's clear, crisp scholarship has shaped the reports of investigations ranging from studies of mathematics curricula in East Asia to characterizations of East Asian teachers' shared knowledge of mathematics teaching (with implications for the professional development of US mathematics teachers) to the design and development of mathematics standards in the US. As a mathematician who possesses a unique ability for editing text, Dr. Kessel transforms what mathematicians write into a form readable by mathematics educators and the general public, without sacrificing precision. She also transforms what mathematics education researchers write into a form readable by mathematicians unfamiliar with the education literature."

Hannah Larson

Hannah Larson of Harvard University was awarded the Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman. She is a Herchel Smith Harvard Undergraduate Science Research Fellow and Barry M. Goldwater Scholarship recipient at Harvard, and, according to the prize citation, she "has been doing 'jaw-dropping' mathematical work since she was a high school student when she won the Davidson Fellowship for her work on fusion categories." She has already published eight mathematics papers, including an extension of Borcherds' Fields Medal work on moonshine.

Sarah McClain Fleming of Williams College was named runner-up for the prize.

Honorable mentions went to

- Lea Kenigsberg (Stony Brook University)
- Gwyneth Moreland (University of Michigan)
- Yen Nhi Truong Vu (Amherst College).

The AWM also gave several awards for service to the Association and its programs and activities. The recipients were:

- Katie Kavanagh, Clarkson University
- Michelle Manes, University of Hawaii
- Maura Mast, Fordham University
- Marie Vitulli, University of Oregon.

—From AWM announcements

Peter Hintz

2017 Clay Research Fellows Chosen

Peter Hintz of the University of California Berkeley and Akhil Mathew of Harvard University have been appointed Clay Research Fellows for 2017


Akhil Mathew

by the Clay Mathematics Institute (CMI).

Hintz received his PhD in 2015 from Stanford University under the supervision of András Vasey. He studies hyperbolic partial differential equations arising in general relativity using methods from microlocal analysis, spectral and scattering theory, and dynamical systems. His recent work concerns the stability of black holes in expanding spacetimes. He is a Miller Research Fellow for the years 2015–2017 at Berkeley, mentored by Maciej Zworski. Hintz has been appointed a Clay Research Fellow for a term of three years beginning July 1, 2017.

Mathew will receive his PhD in 2017 from Harvard University under the supervision of Jacob Lurie. His research focuses on homotopy theory, higher categories, and their applications, especially to derived algebraic geometry and algebraic *K*-theory. Some of his past work studied various generalizations of faithfully flat descent in stable homotopy theory and their role in describing certain invariants of structured ring spectra. Mathew has been appointed a Clay Research Fellow for a term of five years beginning July 1, 2017.

—From a CMI announcement

2017 MAA Awards


Janet Heine Barnett

The Mathematical Association of America (MAA) awarded several prizes at the Joint Mathematics Meetings in Atlanta, Georgia, in January 2017.

Janet Heine Barnett (Colorado State University—Pueblo);

Caren Diefenderfer (Hollins University); and

Tevian Dray (Oregon State University) were honored with Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching of Mathematics. Barnett served as a Peace Corps volunteer in the Central African Republic (1982–1984) before beginning her graduate studies in mathematics, and it was in Africa that she met her mathematician husband, George Heine. The couple now lives in her native home town of Pueblo, Colorado, where they share their passions for mathematics and history, as well as dance, yoga, and travel, with the diverse student population at Colorado State University—Pueblo.


Caren Diefenderfer


Tevian Dray

Diefenderfer is an an avid reader who enjoys swimming, knitting, and playing steel drums—"but not all at the same time!"

Dray and his physicist wife, Corinne Manogue, have collaborated on many projects, including two children: a mechanical engineer and a mathematics educator. Dray tells the *Notices* that he "still thinks colored chalk is the best technological advance ever made for teaching."


Tim Chartier

Tim Chartier of Davidson College was awarded the Beckenbach Book Prize for his book *When Life Is Linear: From Computer Graphics to Bracketology* (MAA Press, 2015). The prize is intended to recognize the author(s) of a distinguished, innovative book published by the MAA and to encourage the writing of such books. Chartier and his wife are professional mimes who trained in master classes with Marcel Marceau. They travel around the world with their "mime and math" presentation.


Robert D. Hough

Robert D. Hough of the State University of New York, Stony Brook, was awarded the David P. Robbins Prize for his article "Solution of the Minimum Modulus for Covering Systems," *Annals of Mathematics* **181** (2015), no. 1. The prize is given for a paper that reports on novel research in algebra, combinatorics, or discrete mathematics, has a significant experimental component, and is on a topic which is broadly accessible.


Mark F. Schilling

Mark F. Schilling of California State University Northridge was awarded the Chauvenet Prize for his article "The Surprising Predictability of Long Runs," *Mathematics Magazine* **85** (2012). The Chauvenet Prize is awarded to the author or authors of an outstanding expository article on a mathematical topic. Schilling tells the *Notices*, "I enjoy mountain biking in the local mountains around Los Angeles, either alone or with some of my colleagues."

Martha J. Siegel

MARTHA J. SIEGEL of Towson University was honored with the Gung and Hu Award for Distinguished Service to Mathematics "for her remarkable leadership in guiding the national conversation on undergraduate mathematics curriculum, particularly as it is affected by fields in applied mathematics, and especially from the perspective of the Mathematical Association of America and its mission." Outside of mathematics, Siegel loves listening to classical music, doing crossword puzzles, reading, and adult coloring books.

Ian Stewart

IAN STEWART of the University of Warwick was awarded the Euler Book Prize for *In Pursuit of the Unknown: 17 Equations That Changed the World* (Basic Books, New York, 2012). The prize is intended to recognize authors of exceptionally well-written books with a positive impact on the public's view of mathematics and to encourage the writing of such books. Stewart is an honorary wizard at Unseen University in Terry Pratchett's Discworld. As a student he was lead guitarist in a rock band. He still plays electric guitar, but only to himself through headphones.

—From MAA announcements

Cleveland Awarded 2016 Parzen Prize

WILLAM S. CLEVELAND of Purdue University has been awarded the 2016 Emanuel and Carol Parzen Prize for Statistical Innovation "for innovative, influential, and outstanding research in statistical methodology and computational methods for statistics, including time series analysis, nonparametric local regression (loess), statistical graphics and data visualization including scatterplot brushing and trellis displays, and many other contributions to statistical and computational methods; leadership in developing modern methods at the interface of computer science and statistics for the analysis of and visualization of large and complex data sets." The prize is awarded in even-numbered years to North American statisticians who have made outstanding and influential contributions to the development of applicable and innovative statistical methods.

—Department of Statistics, Texas A&M University

New Horizons in Mathematics Prizes

The New Horizons in Mathematics Prizes have been awarded to

- MOHAMMED ABOUZAID of Columbia University "for distinguishing cotangent bundles of exotic spheres, constructing the wrapped Fukaya category with Paul Seidel, and other decisive contributions to symplectic topology and mirror symmetry";
- HUGO DUMINIL-COPIN of the University of Geneva "for brilliant solutions to multiple landmark problems in probability, particularly regarding critical phenomena for Ising-type models";
- BENJAMIN ELIAS of the University of Oregon and GEORDIE WILLIAMSON of Kyoto University "for pioneering work in geometric representation theory, including the development of Hodge theory for Soergel bimodules and the proof of the Kazhdan-Lusztig conjectures for general Coxeter groups."

The New Horizons Prizes carry a cash award of US$100,000.

—From a Breakthrough Prize Committee announcement

Compositio Mathematica Prizes Awarded

The Compositio Prize is awarded every third year by the Foundation Compositio Mathematica in recognition of an outstanding piece of mathematical research that is published in the journal *Compositio Mathematica* during a three-year period.

Bhargav Bhatt

BHARGAV BHATT of the University of Michigan was awarded the prize for the period 2011–2013 for his paper "Derived Splinters in Positive Characteristic," *Compositio Mathematica* **148** (2012), no. 6. His paper presented a proof of the fact that regular rings are derived splinters as conjectured by Johan de Jong. The paper introduces the notion of derived splinter: a ring (or scheme) that in the derived category splits off from the cohomology of a proper cover. Also shortlisted for the prize were:

- DIETER KOTSCHICK and STEFAN SCHREIEDER, "The Hodge Ring of Kähler Manifolds," *Compositio Mathematica* **149** (2013), no. 4.
- JUNE HUH, "The Maximum Likelihood Degree of a Very Affine Variety," *Compositio Mathematica*, **149** (2013), no. 8.

—Gerard van der Geer, President
Foundation Compositio Mathematica

Sloan Fellows

The Alfred P. Sloan Foundation has announced the names of the recipients of the 2017 Sloan Research Fellowships. Each year the foundation awards fellowships in the fields of mathematics, chemistry, computational and evolutionary molecular biology, computer science, economics, neuroscience, physics, and ocean sciences. Grants of US$60,000 for a two-year period are administered by each Fellow's institution. Once chosen, Fellows are free to pursue whatever lines of inquiry most interest them, and they are permitted to employ fellowship funds in a wide variety of ways to further their research aims.

Following are the names and institutions of the 2017 awardees in the mathematical sciences.

- Mark Davenport, Georgia Institute of Technology
- John Duchi, Stanford University
- Semyon Dyatlov, Massachusetts Institute of Technology
- Tom Goldstein, University of Maryland, College Park
- Wei Ho, University of Michigan
- Daniel Kane, University of California San Diego (Fellow in Computer Science)
- Thomas Koberda, University of Virginia
- Chi Li, Purdue University
- Gang Liu, Northwestern University
- Han Liu, Princeton University
- Yifeng Liu, Northwestern University
- Jonathan Luk, Stanford University
- Aaron Pixton, Massachusetts Institute of Technology
- Maksym Radziwill, McGill University
- Benjamin Rossman, University of Toronto
- Steven Sam, University of Wisconsin, Madison
- Nicholas Sheridan, Princeton University
- Pierre Simon, University of California Berkeley
- Andrew Suk, University of Illinois at Chicago
- Caroline Uhler, Massachusetts Institute of Technology
- Chelsea Walton, Temple University

—From a Sloan Foundation announcement

National Academy of Engineering Elections

The National Academy of Engineering (NAE) has elected a number of new members and foreign associates for 2017. Following are the new members whose work involves the mathematical sciences.

- Whitfield Diffie of Black Ridge Technology for the invention of public key cryptography and for broader contributions to privacy.
- Leonidas J. Guibas of Stanford University for contributions to data structures, algorithm analysis, and computational geometry.
- Arkadi Nemirovski of the Georgia Institute of Technology for the development of efficient algorithms for large-scale convex optimization problems.
- Stéphane Mallat of Ecole Normale Supérieure (foreign member) for contributions to the fast wavelet transform and multiresolution signal processing.

—From an NAE announcement

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Inside the AMS

AMS Department Chairs Workshop Held

The annual AMS Department Chairs Workshop was held on January 3, 2017, just prior to the Joint Mathematics Meetings in Atlanta, Georgia. More than 40 department leaders from across the country participated in the workshop, which this year focused on faculty development, legal issues and difficult situations, diversity and inclusiveness, and the process of developing curriculum and adding new majors or changing existing majors.

The workshop was led by Malcolm Adams, University of Georgia; Matthew Ando, University of Illinois at Urbana–Champaign; Krista Maxson, University for Science and Arts of Oklahoma; and Douglas Mupasiri, University of Northern Iowa.

Math department leaders from across the country participate in the 2017 Chairs Workshop.

The workshop format helps to stimulate discussion and allows for sharing ideas and experiences, creating an environment that enables attending chairs to address departmental matters from new perspectives.

The next AMS Department Chairs Workshop will be held January 9, 2018, in San Diego, California. Please watch for more information on this workshop online and in *Notices* in the next few months.

—*AMS Washington Office*

AMS Holds Congressional Briefing on Capitol Hill

The American Mathematical Society's annual Congressional Briefing was given on December 13, 2016, by Mac Hyman, Professor of Mathematics at Tulane University. The briefing, titled "How Mathematical Models Predict Emerging Epidemics," was held for Congressional members and staff.

Mac Hyman delivering the 2016 briefing.

Hyman explained in this briefing that public health workers are reaching out to scientists for better models that can help guide mitigation efforts to stop the spread of emerging infections. Mathematicians are responding by deriving equations for virtual computer worlds that can be used to anticipate the spread of new diseases and evaluate the effectiveness of different approaches to bringing an epidemic under control. He described what current models can, and cannot, do and shared his personal experiences in collaborating with public health workers to mitigate the spread of Zika, Ebola, HIV/AIDS, chlamydia, and influenza.

The AMS holds annual US congressional briefings as a means to communicate information to policymakers. Speakers discuss the importance of mathematics research and present their work in layman's terms to Congressional staff as a way to inform members of Congress of the impact mathematics has on today's important issues.

—*AMS Washington Office*

Classified Advertisements

Positions available, items for sale, services available, and more

CHINA

**Tianjin University, China
Tenured/Tenure-Track/Postdoctoral Positions at The Center for Applied Mathematics**

Dozens of positions at all levels are available at the recently founded Center for Applied Mathematics, Tianjin University, China. We welcome applicants with backgrounds in pure mathematics, applied mathematics, statistics, computer science, bioinformatics, and other related fields. We also welcome applicants who are interested in practical projects with industries. Despite its name attached with an accent of applied mathematics, we also aim to create a strong presence of pure mathematics. Chinese citizenship is not required.

Light or no teaching load, adequate facilities, spacious office environment, and strong research support. We are prepared to make quick and competitive offers to self-motivated hard workers, and to potential stars, rising stars, as well as shining stars.

The Center for Applied Mathematics, also known as the Tianjin Center for Applied Mathematics (TCAM), located by a lake in the central campus in a building protected as historical architecture, is jointly sponsored by the Tianjin municipal government and the university. The initiative to establish this center was taken by Professor S. S. Chern. Professor Molin Ge is the honorary director, Professor Zhiming Ma is the director of the Advisory Board. Professor William Y. C. Chen serves as the director.

TCAM plans to fill in fifty or more permanent faculty positions in the next few years. In addition, there are a number of temporary and visiting positions. We look forward to receiving your application or inquiry at any time. There are no deadlines.

To apply, send your resume to `zhangry@tju.edu.cn`.

For more information, please visit `www.cam.tju.edu.cn` or contact Ms. Debbie Renyuan Zhang at `zhangry@tju.edu.cn`, telephone: 86-22-2740-5389.

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SOUTH AFRICA

**Gottfried Wilhelm Leibniz
Basic Research Institute
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The Gottfried Wilhelm Leibniz Basic Research Institute, which operates as a PBO, invites exceptional researchers in mathematics and/or quantum physics to apply for shorter or longer term support. Contact `eerosinger@hotmail.com`.

00007

Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services. The publisher reserves the right to reject any advertising not in keeping with the publication's standards. Acceptance shall not be construed as approval of the accuracy or the legality of any advertising.

The 2017 rate is $3.50 per word with a minimum two-line headline. No discounts for multiple ads or the same ad in consecutive issues. For an additional $10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified ads.

Upcoming deadlines for classified advertising are as follows: April 2017—February 3, 2017; May 2017—March 9, 2017; June/July 2017—May 9, 2017; August 2017—June 6, 2017; September 2017—July 7, 2017; October 2017—August 4, 2017; November 2017—September 5, 2017; December 2017—September 28, 2017;.

US laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the US cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to US laws. Details and specific wording may be found on page 1373 (vol. 44).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the US and Canada or 401-455-4084 worldwide for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02904; or via fax: 401-331-3842; or send email to `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.

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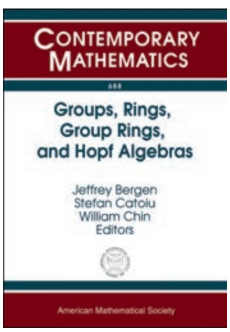
Algebra and Algebraic Geometry



Groups, Rings, Group Rings, and Hopf Algebras

Jeffrey Bergen, *DePaul University, Chicago, IL*, **Stefan Catoiu**, *DePaul University, Chicago, IL*, and **William Chin**, *DePaul University, Chicago, IL*, Editors

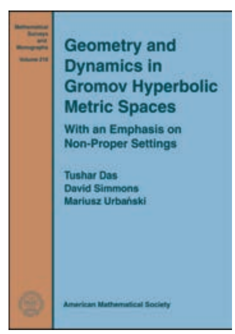
This volume contains the proceedings of the International Conference on Groups, Rings, Group Rings, and Hopf Algebras, held October 2–4, 2015 at Loyola University, Chicago, IL, and the AMS Special Session on Groups, Rings, Group Rings, and Hopf Algebras, held October 3–4, 2015, at Loyola University, Chicago, IL. Both conferences were held in honor of Donald S. Passman's 75th birthday.

Centered in the area of group rings and algebras, this volume contains a mixture of cutting edge research topics in group theory, ring theory, algebras and their representations, Hopf algebras and quantum groups.

Contents: **J. P. Bell**, **K. Wu**, and **S. Wu**, The Dixmier-Moeglin equivalence for extensions of scalars and Ore extensions; **J. Bergen**, Nagata-Higman and rings with involution; **X. Chen**, **Z. Chen**, and **M. Ding**, On left symmetric color algebras; **M. Dokuchaev** and **A. Zalesski**, On the automorphism group of rational group algebras of finite groups; **A. Elduque** and **M. Kochetov**, Graded simple modules and loop modules; **G. Glauberman**, Symmetric groups and fixed points on modules: An application of group theory to topology; **J. Z. Goncalves**, Free unit groups in group rings and division rings: My collaboration with Don Passman; **A. G. Hales** and **I. B. S. Passi**, Group rings and Jordan decomposition; **M. Iovanov** and **A. Sistko**, On the Toeplitz-Jacobson algebra and direct finiteness; **A. Jacoby** and **M. Lorenz**, Frobenius divisibility for Hopf algebras; **A. Khare**, Generalized nil-Coxeter algebras, cocommutative algebras, and the PBW property; **W. Kimmerle** and **L. Margolis**, p-subgroups of units in $\mathbb{Z}G$; **L. Krop**, On the classification of finite-dimensional semisimple Hopf algebras; **A. I. Lichtman**, Zero divisors in group rings of wreath products of groups; **I. M. Musson**, The lattice of submodules of a multiplicity-free module; **C. Polcino Milies**, Star group identities on units of group algebras; **A. K. Srivastava**, A note on group algebras of locally compact groups; **P. Tingley**, Elementary construction of Lusztig's canonical basis.

Contemporary Mathematics, Volume 688

May 2017, 281 pages, Softcover, ISBN: 978-1-4704-2805-1, LC 2016042009, 2010 *Mathematics Subject Classification:* 16Dxx, 16Gxx, 16Sxx, 16S34, 16Wxx, 17Bxx, 20Cxx, 20Dxx, **AMS members US$88.80**, List US$111, Order code CONM/688



Geometry and Dynamics in Gromov Hyperbolic Metric Spaces

With an Emphasis on Non-Proper Settings

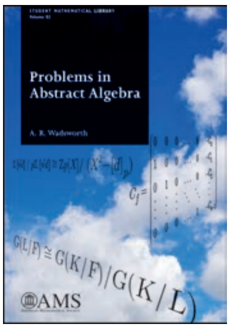
Tushar Das, *University of Wisconsin, La Crosse, WI*, **David Simmons**, *University of York, United Kingdom*, and **Mariusz Urbański**, *University of North Texas, Denton, TX*

This book presents the foundations of the theory of groups and semigroups acting isometrically on Gromov hyperbolic metric spaces. Particular emphasis is paid to the geometry of their limit sets and on behavior not found in the proper setting. The authors provide a number of examples of groups which exhibit a wide range of phenomena not to be found in the finite-dimensional theory. The book contains both introductory material to help beginners as well as new research results, and closes with a list of attractive unsolved problems.

Contents: *Preliminaries:* Algebraic hyperbolic spaces; $\mathbb{R}$-trees, CAT(-1) spaces, and Gromov hyperbolic metric spaces; More about the geometry of hyperbolic metric spaces; Discreteness; Classification of isometries and semigroups; Limit sets; *The Bishop–Jones theorem:* The modified Poincaré exponent; Generalization of the Bishop–Jones theorem; *Examples:* Schottky products; Parabolic groups; Geometrically finite and convex-cobounded groups; Counterexamples; ℝ-trees and their isometry groups; *Patterson–Sullivan theory:* Conformal and quasiconformal measures; Patterson–Sullivan theorem for groups of divergence type; Quasiconformal measures of geometrically finite groups; Open problems; Index of defined terms; Bibliography.

Mathematical Surveys and Monographs, Volume 218

May 2017, 281 pages, Hardcover, ISBN: 978-1-4704-3465-6, LC 2016034629, 2010 *Mathematics Subject Classification:* 20H10, 28A78, 37F35, 20F67, 20E08; 37A45, 22E65, 20M20, **AMS members US$92.80**, List US$116, Order code SURV/218



Problems in Abstract Algebra

A. R. Wadsworth, *University of California, San Diego, CA*

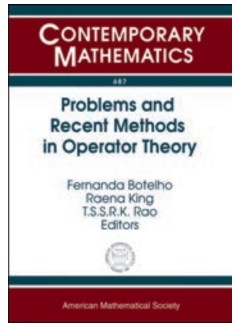
This is a book of problems in abstract algebra for strong undergraduates or beginning graduate students. It can be used as a supplement to a course or for self-study. The book provides more variety and more challenging problems than are found in most algebra textbooks. It is intended for students wanting to enrich their learning of mathematics by tackling problems that take some thought and effort to solve. The book contains problems on groups (including the Sylow Theorems, solvable groups, presentation of groups by generators and relations, and structure and duality for finite abelian groups); rings (including basic ideal theory and factorization in integral domains and Gauss's Theorem); linear algebra (emphasizing linear transformations, including canonical forms); and fields (including Galois theory). Hints to many problems are also included.

Contents: Integers and integers mod *n*; Groups; Rings; Linear algebra and canonical forms of linear transformations; Fields and Galois theory; Suggestions for further reading; Bibliography; Index of notation; Subject and terminology index.

Student Mathematical Library, Volume 82

June 2017, 269 pages, Softcover, ISBN: 978-1-4704-3583-7, LC 2016057500, 2010 *Mathematics Subject Classification:* 00A07, 12-01, 13-01, 15-01, 20-01, **AMS members US$41.60**, List US$52, Order code STML/82

Analysis



Problems and Recent Methods in Operator Theory

Fernanda Botelho, *University of Memphis, TN*, **Raena King**, *Christian Brothers University, Memphis, TN*, and **T. S. S. R. K. Rao**, *Indian Statistical Institute, Bangalore, India*, Editors

This volume contains the proceedings of the Workshop on Problems and Recent Methods in Operator Theory, held at the University of Memphis, Memphis, TN, from October 15–16, 2015 and the AMS Special Session on Advances in Operator Theory and Applications, in Memory of James Jamison, held at the University of Memphis, Memphis, TN, from October 17–18, 2015.

Operator theory is at the root of several branches of mathematics and offers a broad range of challenging and interesting research problems. It also provides powerful tools for the development of other areas of science including quantum theory, physics and mechanics. Isometries have applications in solid-state physics. Hermitian operators play an integral role in quantum mechanics very much due to their "nice" spectral properties. These powerful connections demonstrate the impact of operator theory in various branches of science.

The articles in this volume address recent problems and research advances in operator theory. Highlighted topics include spectral, structural and geometric properties of special types of operators on Banach spaces, with emphasis on isometries, weighted composition operators, multi-circular projections on function spaces, as well as vector valued function spaces and spaces of analytic functions.

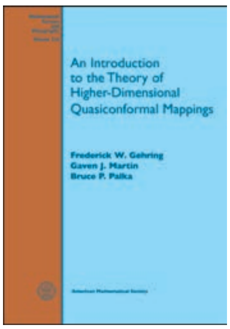
This volume gives a succinct overview of state-of-the-art techniques from operator theory as well as applications to classical problems and long-standing open questions.

Contents: **R. Fleming**, From Helgermites to Lipschitz: Remembering Jim Jamison; **T. Abe**, A Mazur-Ulam theorem for normed gyrolinear spaces; **S. Aryal**, **H. Choi**, and **F. Jafari**, Sparse Hamburger moment multisequences; **S. Bandyopadhyay** and **A. I. Singh**, Polynomial representation of quantum entanglement; **S. Basu**, On span of small combination of slices points in Banach spaces; **F. Botelho** and **J. Jamison**, Surjective isometries on absolutely continuous vector valued function spaces; **I. Chalendar** and **J. R. Partington**, Compactness, differentiability and similarity to isometry of composition semigroups; **F. Colonna** and **M. Tjani**, Weighted composition operators from Banach spaces of analytic functions into Bloch-type spaces; **C. C. Cowen** and **E. A. Gallardo-Gutiérrez**, A new proof of a Nordgren, Rosenthal and Wintrobe theorem on universal operators; **C. Farsi**, **E. Gillaspy**, **A. Julien**, **S. Kang**, and **J. Packer**, Wavelets and spectral triples for fractal representations of Cuntz algebras; **N. J. Gal**, The isometric equivalence problem; **O. Hatori**, Extension of isometries in generalized gyrovector spaces of the positive cones; **D. Ilišević**, Generalized *n*-circular projections on JB*-triples; **R. King**, Hermitian operators on $H^1_{\mathcal{H}}$; **B. Miller**, Kernels of adjoints of composition operators with rational symbols of degree two;

T. Miura and **H. Takagi**, Surjective isometries on the Banach space of continuously differentiable functions; **L. Molnár**, The arithmetic, geometric and harmonic means in operator algebras and transformations among them; **B. Randrianantoanina**, On sign embeddings and narrow operators on L_2; **T. S. S. R. K. Rao**, Into isometries that preserve finite dimensional structure of the range; **J. E. Stovall** and **W. A. Feldman**, Associating linear and nonlinear operators; **D. Thompson**, Normality properties of weighted composition operators on H^2.

Contemporary Mathematics, Volume 687

May 2017, approximately 237 pages, Softcover, ISBN: 978-1-4704-2772-6, 2010 *Mathematics Subject Classification:* 46B20, 46E15, 46L05, 46L70, 47B15, 47B20, 47B38, 47B49, 47L05, 81P40, **AMS members US$88.80**, List US$111, Order code CONM/687



An Introduction to the Theory of Higher-Dimensional Quasiconformal Mappings

Frederick W. Gehring, **Gaven J. Martin**, *Massey University, Auckland, New Zealand*, and **Bruce P. Palka**, *National Science Foundation, Arlington, VA*

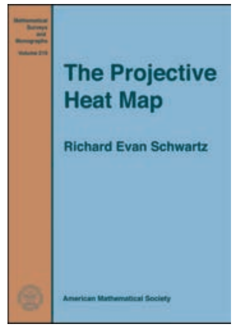
This book offers a modern, up-to-date introduction to quasiconformal mappings from an explicitly geometric perspective, emphasizing both the extensive developments in mapping theory during the past few decades and the remarkable applications of geometric function theory to other fields, including dynamical systems, Kleinian groups, geometric topology, differential geometry, and geometric group theory. It is a careful and detailed introduction to the higher-dimensional theory of quasiconformal mappings from the geometric viewpoint, based primarily on the technique of the conformal modulus of a curve family. Notably, the final chapter describes the application of quasiconformal mapping theory to Mostow's celebrated rigidity theorem in its original context with all the necessary background.

This book will be suitable as a textbook for graduate students and researchers interested in beginning to work on mapping theory problems or learning the basics of the geometric approach to quasiconformal mappings. Only a basic background in multidimensional real analysis is assumed.

Contents: Introduction; Topology and analysis; Conformal mappings in Euclidean space; The moduli of curve families; Rings and condensers; Quasiconformal mappings; Mapping problems; The Tukia-Väisälä extension theorem; The Mostow rigidity theorem and discrete Möbius groups; Basic notation; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 216

May 2017, 430 pages, Hardcover, ISBN: 978-0-8218-4360-4, LC 2016029235, 2010 *Mathematics Subject Classification:* 30C65, 30C62, **AMS members US$92.80**, List US$116, Order code SURV/216



The Projective Heat Map

Richard Evan Schwartz, *Brown University, Providence, RI*

This book introduces a simple dynamical model for a planar heat map that is invariant under projective transformations. The map is defined by iterating a polygon map, where one starts with a finite planar N-gon and produces a new N-gon by a prescribed geometric construction. One of the appeals of the topic of this book is the simplicity of the construction that yet leads to deep and far reaching mathematics. To construct the *projective heat map*, the author modifies the classical affine invariant *midpoint map*, which takes a polygon to a new polygon whose vertices are the midpoints of the original.

The author provides useful background which makes this book accessible to a beginning graduate student or advanced undergraduate as well as researchers approaching this subject from other fields of specialty. The book includes many illustrations, and there is also a companion computer program.

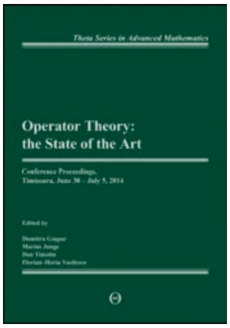
Contents: Introduction; *Part 1:* Some other polygon iterations; A primer on projective geometry; Elementary algebraic geometry; The pentagram map; Some related dynamical systems; *Part 2:* The projective heat map; Topological degree of the map; The convex case; The basic domains; The method of positive dominance; The Cantor set; Towards the quasi horseshoe; The quasi horseshoe; *Part 3:* Sketches for the remaining results; Towards the solenoid; The solenoid; Local structure of the Julia set; The embedded graph; Connectedness of the Julia set; Terms, formulas, and coordinate listings; References.

Mathematical Surveys and Monographs, Volume 219

May 2017, 196 pages, Hardcover, ISBN: 978-1-4704-3514-1, LC 2016037737, 2010 *Mathematics Subject Classification:* 26A18, 37E30, 37B05, 51M15, **AMS members US$92.80**, List US$116, Order code SURV/219

New AMS-Distributed Publications

Analysis



Operator Theory: The State of the Art

Conference Proceedings, Timişoara, June 30–July 5, 2014

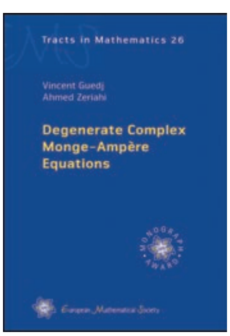
Dumitru Gaspar, *West University of Timişoara, Romania*, **Marius Junge**, *University of Illinois, Urbana, IL*, **Dan Timotin**, *Romanian Academy, Institute of Mathematics, Bucharest, Romania*, and **Florian-Horia Vasilescu**, *University of Lille I, Villeneuve d'Ascq, France*, Editors

This volume contains the proceedings of the 25th International Conference in Operator Theory, held in Timişoara, Romania, between June 30 and July 5, 2014. Leading experts in the field have contributed several survey papers. The subjects covered include truncated moment problems and comparison of projections in a C^*-algebra.

A publication of the Theta Foundation. Distributed worldwide, except in Romania, by the AMS.

International Book Series of Mathematical Texts

February 2017, 167 pages, Hardcover, ISBN: 978-606-8443-07-2, 2010 *Mathematics Subject Classification:* 00B25, 30-06, 46-06, 47-06, **AMS members US$39.20**, List US$49, Order code THETA/21



Degenerate Complex Monge–Ampère Equations

Vincent Guedj, *Université Paul Sabatier, Toulouse, France*, and **Ahmed Zeriahi**, *Université Paul Sabatier, Toulouse, France*

Complex Monge–Ampère equations have been one of the most powerful tools in Kähler geometry since Aubin and Yau's classical works, culminating in Yau's solution to the Calabi conjecture. A notable application is the construction of Kähler–Einstein metrics on some compact Kähler manifolds. In recent years degenerate complex Monge–Ampère equations have been intensively studied, requiring more advanced tools.

The main goal of this book is to give a self-contained presentation of the recent developments of pluripotential theory on compact Kähler manifolds and its application to Kähler–Einstein metrics on mildly singular varieties. After reviewing basic properties of plurisubharmonic functions, Bedford–Taylor's local theory of complex Monge–Ampère measures is developed. In order to solve degenerate complex Monge–Ampère equations on compact Kähler manifolds, fine properties of quasi-plurisubharmonic functions are explored, classes of finite energies defined, and various maximum principles established. After proving Yau's celebrated theorem as well as its recent generalizations, the results are then used to solve the (singular) Calabi conjecture and to construct (singular) Kähler–Einstein metrics on some varieties with mild singularities.

This book is accessible to advanced students and researchers of complex analysis and differential geometry.

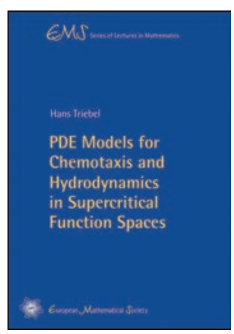
This item will also be of interest to those working in differential equations.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

EMS Tracts in Mathematics, Volume 26

January 2017, 496 pages, Hardcover, ISBN: 978-3-03719-167-5, 2010 *Mathematics Subject Classification:* 32W20, 32U20, 32Q20, 35D30, 53C55, 32U15, 32U40, 35B65, **AMS members US$84**, List US$105, Order code EMSTM/26

Differential Equations



PDE Models for Chemotaxis and Hydrodynamics in Supercritical Function Spaces

Hans Triebel, *University of Jena, Germany*

This book deals with PDE models for chemotaxis (the movement of biological cells or organisms in response of chemical gradients) and hydrodynamics (viscous, homogeneous, and incompressible fluid filling the entire space). The underlying Keller–Segel equations (chemotaxis), Navier–Stokes equations (hydrodynamics), and their numerous modifications and combinations are treated in the context of inhomogeneous spaces of Besov–Sobolev type. The author pays special attention to mapping properties of related nonlinearities. Further models are considered, including (deterministic) Fokker–Planck equations and chemotaxis Navier–Stokes equations.

These notes are addressed to graduate students and mathematicians with a working knowledge of basic elements of the theory of function spaces, especially of Besov–Sobolev type, and an interest in mathematical biology and physics.

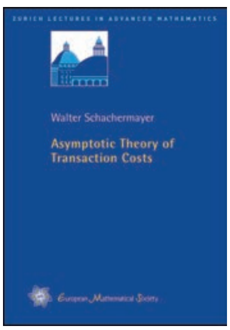
This item will also be of interest to those working in analysis.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

EMS Series of Lectures in Mathematics, Volume 27

March 2017, 138 pages, Softcover, ISBN: 978-3-03719-172-9, 2010 *Mathematics Subject Classification:* 35-02, 46-02, 76-02, 92-02, 35K05, 35Q30, 35Q92, 42B35, 46E35, 76D05, 92C15, 92C17, **AMS members US$30.40**, List US$38, Order code EMSSERLEC/27

Probability and Statistics



Asymptotic Theory of Transaction Costs

Walter Schachermayer, *University of Vienna, Austria*

A classical topic in mathematical finance is the theory of portfolio optimization. Robert Merton's work from the early seventies had enormous impact on academic research as well as on the paradigms guiding practitioners. One of the ramifications of this topic is the analysis of (small) proportional transaction costs, such as a Tobin tax.

These lecture notes present some striking recent results of the asymptotic dependence of the relevant quantities when transaction costs tend to zero. An appealing feature of the consideration of transaction costs is that it allows us for the first time to reconcile the no arbitrage paradigm with the use of non-semimartingale models, such as fractional Brownian motion. This leads to the culminating theorem of the present lectures, which roughly reads as follows: For a fractional Brownian motion stock price model we always find a shadow price process for given transaction costs. This process is a semimartingale and can therefore be dealt with using the usual machinery of mathematical finance.

This item will also be of interest to those working in applications.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Zurich Lectures in Advanced Mathematics, Volume 23

March 2017, 160 pages, Softcover, ISBN: 978-3-03719-173-6, 2010 *Mathematics Subject Classification:* 62P05, 91G10; 60G44, **AMS members US$30.40**, List US$38, Order code EMSZLEC/23

MATHEMATICS CALENDAR

This section contains new announcements of worldwide meetings and conferences of interest to 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. New announcements only are published in the print Mathematics Calendar featured in each *Notices* issue.

An announcement will be published in the *Notices* if it contains a call for papers and specifies the place, date, subject (when applicable). A second announcement will be published only if there are changes or necessary additional information. Asterisks (*) mark those announcements containing revised information.

In general, print announcements of meetings and conferences carry only the date, title and location of the event.

The complete listing of the Mathematics Calendar is available at: www.ams.org/meetings/calendar/mathcal

All submissions to the Mathematics Calendar should be done online via: www.ams.org/cgi-bin/mathcal/mathcal-submit.pl

Any questions or difficulties may be directed to mathcal@ams.org.

April 2017

18 – 22 **LMS Invited Lecture Series 2017: Function Theory by Hilbert Space Methods— Jim Agler (UCSD).**
Location: *Newcastle University School of Mathematics and Statistics, Herschel Building, Newcastle University, Newcastle upon Tyne NE1 7RU United Kingdom.*
URL: www.mas.ncl.ac.uk/~nek29/lmslectures2017/function_theory.html

20 – 21 **The Seventh Annual Meeting of the Lebanese Society for the Mathematical Sciences, LSMS-2017**
Location: *University of Balamand, Lebanon.*
URL: www.lsms.net/lsms2017

24 – 28 **ICERM Semester Program Workshop: Water Waves**
Location: *ICERM/Brown University, Providence, RI.*
URL: https://icerm.brown.edu/programs/sp-s17/w3

27 – 28 **National Meeting of Women in Financial Mathematics**
Location: *Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, CA.*
URL: www.ipam.ucla.edu/programs/special-events-and-conferences/national-meeting-of-women-in-financial-mathematics

27 – 28 **Women in PDEs @ Karlsruhe**
Location: *Karlsruhe Institute of Technology, Karlsruhe, Germany.*
URL: womeninpdes.waves.kit.edu

28 – May 2 **JDG 2017: Conference on Geometry and Topology**
Location: *Harvard University Science Center, Cambridge, Massachusetts.*
URL: math.harvard.edu/jdg/index.html

May 2017

5 – 6 **Workshop on Operator Theoretic Aspects of Ergodic Theory**
Location: *Pädagogische Hochscule Vorarlberg, Feldkirch, Austria.*
URL: phv.www4.vobs.at/index.php?id=656

12 – 14 **Cornell Topology Festival**
Location: *Cornell University, Ithaca, New York.*
URL: www.math.cornell.edu/~festival

22 – 24 **Conference on Applied Mathematics**
Location: *Lahore University Of Management Sciences, Lahore, Pakistan.*
URL: https://casm.lums.edu.pk/casm-cam2017

22 – 26 **CBMS Conference on Sparse Approximation and Signal Recovery Algorithms**
Location: *New Mexico State University, Las Cruces, New Mexico.*
URL: www.math.nmsu.edu/~jlakey/cbms2017.html

29 – December 8 **Data Sciences: Bridging Mathematics, Physics, and Biology**
Location: *Institute for Mathematical Sciences, National University of Singapore.*
URL: www2.ims.nus.edu.sg/Programs/017data/index.php

June 2017

5 – 9 **ICERM Topical Workshop: Probabilistic Scientific Computing: Statistical Inference Approaches to Numerical Analysis and Algorithm Design**
Location: *ICERM/Brown University, Providence, RI.*
URL: https://icerm.brown.edu/topical_workshops/tw17-4-psc

12 – 16 **School on Hyperbolic Dynamics**
Location: *Centro di Ricerca Matematica Ennio De Giorgi, Collegio Puteano, Piazza dei Cavalieri 3, 56100 Pisa, Italy.*
URL: crm.sns.it/event/410

12 – 16 **CBMS Conference on Topological Data Analysis: Theory and Applications**
Location: *Macalester College, St. Paul, Minnesota.*
URL: pages.stolaf.edu/tda-conference

19 – 23 **LMS-CMI Research School: New Trends in Representation Theory: The Impact of Cluster Theory in Representation Theory**
Location: *Mathematics Department, University of Leicester, Leicester, UK.*
URL: https://sites.google.com/site/clustertheoryinreptheory

19 – 23 **ICERM Topical Workshop: Robust Methods in Probability and Finance**
Location: *ICERM/Brown University, Providence, RI.*
URL: `https://icerm.brown.edu/topical_workshops/tw17-6-rmpf`

19 – 23 **2017 Innovation Lab on Quantitative Approaches to Biomedical Data Science Challenges in our Understanding of the Microbiome**
Location: *Wylie Inn and Conference Center, Beverly, Massachusetts.*
URL: `www.bigdatau.org/innovationlab2017`

25 – 28 **Conference on Algebraic Informatics**
Location: *Kalamata (Greece).*
URL: `www.cargo.wlu.ca/CAI2017`

26 – 30 **LMS-CMI Research School: Microlocal Analysis and Applications**
Location: *Cardiff University School of Mathematics, Cardiff University, Senghennydd Road, Cardiff, CF24 4AG United Kingdom.*
URL: `https://cardiffmicrolocal.wordpress.com`

26 – 30 **LMS Research School: Orthogonal Polynomials and Special Functions**
Location: *Kent University School of Mathematics, Statistics and Actuarial Science, Cornwallis Building, University of Kent, Canterbury, Kent CT2 7NF United Kingdom.*
URL: `blogs.kent.ac.uk/opsf-summerschool`

26 – 30 **15th School on Interaction between Dynamical Systems, Geometry, and Partial Differential Equations**
Location: *Centre de Recerca Matemàtica, Barcelona, Spain.*
URL: `http://tinyurl.com/kmd6qow`

26 – 30 **Worskhop: Irregular Transport: Analysis and Applications**
Location: *Basel, Switzerland.*
URL: `personal.psu.edu/alm24/TB17`

27 – 30 **32nd Summer Conference on Topology and its Applications**
Location: *University of Dayton, Dayton, Ohio.*
URL: `go.udayton.edu/sumtopo2017`

July 2017

3 – 6 **VIII Jaen Conference on Approximation Theory, Computer Aided Geometric Design, Numerical Methods, and Applications**
Location: *Universidad de Jaén, Ã□beda, Jaén, Spain.*
URL: `www.ujaen.es/revista/jja/jca`

3 – 7 **14th International Symposium on Orthogonal Polynomials, Special Functions and Applications (OPSFA14)**
Location: *University of Kent, Canterbury, United Kingdom.*
URL: `blogs.kent.ac.uk/opsfa`

10 – 13 **International Conference on Operators in Morrey-type Spaces and Applications**
Location: *Ahi Evran University, Kirsehir, Turkey.*
URL: `omtsa.ahievran.edu.tr`

10 – 21 **Summer Graduate School: Positivity Questions in Geometric Combinatorics**
Location: *Mathematical Sciences Research Institute, Berkeley, CA.*
URL: `www.msri.org/summer_schools/823`

24 – 28 **String Math 2017**
Location: *University of Hamburg, Hamburg, Germany.*
URL: `stringmath2017.desy.de`

24 – 28 **CBMS Conference on Tensors and Their Uses in Approximation Theory, Quantum Information Theory and Geometry**
Location: *Auburn University, Auburn, Alabama.*
URL: `www.auburn.edu/~lao0004/cbms.html`

26 – 27 **The 9th Seminar on Geometry and Topology**
Location: *Univercity of Maragheh, Maragheh, Iran.*
URL: `conf.ims.ir/gt9`

27 – 28 **International Conference on Mathematics, Computational Science, and Engineering (ICMCSE 2017)**
Location: *Hotel Celestine, Tokyo, Japan.*
URL: `www.icmcse.openlsociety.org`

30 – 31 **International Conference on Software Engineering, Information System, and Applications (ICSEISA 2017)**
Location: *Hotel Ibis Ambassadar, Seoul, South Korea.*
URL: `www.icseisa.openlsociety.org`

31 – August 4 **CBMS Conference on Topological and Geometric Methods in QFT**
Location: *Montana State University, Bozeman, Montana.*
URL: `www.math.montana.edu/cbms`

August 2017

5 – 17 **First Research School on Commutative Algebra and Algebraic Geometry (RSCAAG)-Algebra, Combinatorics, and Geometry of Monomials**
Location: *Institute for Advanced Studies in Basic Sciences (IASBS), Zanjan, Iran.*
URL: `https://iasbs.ac.ir/seminar/math/school/rscaag1`

7 – 11 **XXII Latin American Algebra Colloquium**
Location: *Pontificia Universidad Católica del Ecuador, Quito, Ecuador.*
URL: `www.puce.edu.ec/claquito2017`

7 – 11 **Local Kernel-Based Meshless Methods for Partial Differential Equations**
Location: *ICERM, Brown University, Providence, RI.*
URL: `icerm.brown.edu/topical_workshops/tw17-5-pde`

14 – 18 **CBMS Conference on Bayesian Modeling for Spatial and Spatio-temporal Data**
Location: *University of California, Santa Cruz, California.*
URL: `https://cbms.soe.ucsc.edu`

14 – 18 **10th Annual Whitney Problems Workshop**
Location: *College of William and Mary, Williamsburg, Virginia.*

14 – 18 **Uppsala Summer School on Legendrian Contact Homology with a Variety of Augmentations**
Location: *Krusenberg Herrgard, near Uppsala, Sweden.*
URL: www2.math.uu.se/~margo137/LCH-school.htm

14 – 19 **Mathematics in the Modern World**
Location: *Sobolev Institute of Mathematics SB RAS, Novosibirsk, Russia.*
URL: math.nsc.ru/conference/mmw/2017/en

17 – 18 **Connections for Women: Geometry and Probability in High Dimensions**
Location: *Mathematical Sciences Research Institute, Berkeley, CA.*
URL: www.msri.org/workshops/808

17 – 19 **Nonlocal School on Fractional Equations - NSFE 2017**
Location: *Department of Mathematics, Iowa State University, Ames, Iowa.*
URL: www.public.iastate.edu/%7Estinga/NSFE2017

20 – September 1 **Frontiers of Selection Principles, Celebrating the Sixtieth Birthday of Marion Scheepers**
Location: *Bielanski forest, Warsaw.*
URL: selectionprinciples.com

21 – 25 **The Last Sixty Years of Mathematical Fluid Mechanics: Longstanding Problems and New Perspectives In Honor of Professors Robert Finn and Vsevolod Solonnikov**
Location: *Vilnius University, Faculty of Mathematics and Informatics Address, Naugarduko str. 24, Vilnius, Lithuania.*
URL: mfm2017.com

21 – 25 **ICERM Topical Workshop: Pedestrian Dynamics: Modeling, Validation, and Calibration**
Location: *ICERM/Brown University, Providence, RI.*
URL: https://icerm.brown.edu/topical_workshops/tw17-1-pd

September 2017

4 – 15 **CIMPA Research School - Group Actions on Algebraic Varieties.**
Location: *Pontificia Universidad Catolica del Peru, Lima, Peru.*
URL: sites.google.com/site/cimpaperu2017

13 – 15 **Mathematical Modelling in Life Sciences. A Probability Summer School.**
Location: *Centro di Ricerca Matematica Ennio De Giorgi, Piazza dei Cavalieri 3, 56100 Pisa, Italy.*
URL: crm.sns.it/event/409/index.html#title

25 – 29 **ICERM Semester Program Workshop: Waves and Imaging in Random Media**
Location: *ICERM, Brown University, Providence RI.*
URL: icerm.brown.edu/programs/sp-f17/w1

October 2017

9 – October 12, 2019 **The First International Conference on the Evolution of Contemporary Mathematics and Their Impact in Sciences and Technology (ECMI-SciTech 2017)**
Location: *Department of Mathematics, Faculty of Exact Sciences, Freres Mentouri Constantine University, Constantine 25017, Algeria.*
URL: ecmi2017.labomam.net/call_for_papers.html

11 – 12 **International Conference on Advances in Computational Mathematics and Mathematical Physics (ICACMMP 2017)**
Location: *Moscow, Russia.*
URL: www.icacmmp.openlsociety.org

16 – 20 **ICERM Semester Program Workshop: Mathematical and Computational Aspects of Radar Imaging**
Location: *ICERM, Brown University, Providence, RI.*
URL: icerm.brown.edu/programs/sp-f17/w2

23 – 27 **AIM Workshop: Constructing Cryptographic Multilinear Maps**
Location: *American Institute of Mathematics, San Jose, CA.*
URL: aimath.org/workshops/upcoming/cryptomultilin

23 – 27 **International Conference on Analytical and Computational Methods in Probability Theory and its Applications - ACMPT-2017**
Location: *Lomonosov Moscow State University and in RUDN University, Moscow, Russia.*
URL: acmpt.ru

November 2017

6 – 10 **ICERM Semester Program Workshop: Recent Advances in Seismic Modeling and Inversion: From Analysis to Applications**
Location: *ICERM, Brown University, Providence, RI.*
URL: icerm.brown.edu/programs/sp-f17/w3

26 – December 1 **III International Conference on Applied Mathematics and Informatics - ICAMI 2017**
Location: *San Andres Island, Colombia.*
URL: www.icami2017.org

December 2017

4 – 8 **AIM Workshop: Functoriality and the Trace Formula**
Location: *American Institute of Mathematics, San Jose, CA.*
URL: aimath.org/workshops/upcoming/functorialtrace

February 2018

5 – 9 **Introductory Workshop: Group Representation Theory and Applications**
Location: *Mathematical Sciences Research Institute, Berkeley, California.*
URL: www.msri.org/workshops/818

March 2018

12 – 16 **The Homological Conjectures: Resolved!**
Location: *Mathematical Sciences Research Institute, Berkeley, California.*
URL: www.msri.org/workshops/842

MEETINGS & CONFERENCES OF THE AMS

MAY TABLE OF CONTENTS

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 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.

The most up-to-date meeting and conference information can be found online at: **www.ams.org/meetings/**.

Important Information About AMS Meetings: Potential organizers, speakers, and hosts should refer to page 75 in the January 2017 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 similarily 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.

MEETINGS IN THIS ISSUE

See **www.ams.org/meetings/** *for the most up-to-date information on these conferences.*

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 18015-3174; 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.

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See www.ams.org/meetings/.

Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL .

Pullman, Washington

Washington State University

April 22–23, 2017

Saturday – Sunday

Meeting #1128

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: February 2017
Program first available on AMS website: March 9, 2017
Issue of *Abstracts*: Volume 38, Issue 2

Deadlines

For organizers: Expired
For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Michael Hitrik, Department of Mathematics, UCLA, *Spectra for non-self-adjoint operators and integrable dynamics*.

Andrew S Raich, University of Arkansas, *Closed range of the Cauchy-Riemann operator on domains in* $\mathbb{C}^n$.

Daniel Rogalski, University of California, San Diego, *Noncommutative Projective Surfaces*.

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.

Analysis on the Navier-Stokes equations and related PDEs, **Kazuo Yamazaki**, University of Rochester, and **Litzheng Tao**, University of California, Riverside.

Analytic Number Theory and Automorphic Forms, **Steven J. Miller**, Williams College, and **Sheng-Chi Liu**, Washington State University.

Clustering of Graphs: Theory and Practice, **Stephen J. Young** and **Jennifer Webster**, Pacific Northwest National Laboratory.

Combinatorial and Algebraic Structures in Knot Theory, **Sam Nelson**, Claremont McKenna College, and **Allison Henrich**, Seattle University.

Combinatorial and Computational Commutative Algebra and Algebraic Geometry, **Hirotachi Abo**, **Stefan Tohaneanu**, and **Alexander Woo**, University of Idaho.

Commutative Algebra, **Jason Lutz** and **Katharine Shultis**, Gonzaga University.

Early Career Research and Exposition: Posters and Discussions, **Enrique Alvarado** and **Yunfeng Hu**, Washington State University, and **Kevin R Vixie**, Washington State University and Sailfan Research.

Fixed Point Methods in Differential and Integral Equations, **Theodore A. Burton**, Southern Illinois University in Carbondale.

Geometric Measure Theory and it's Applications, **Kevin R. Vixie**, Washington State University.

Geometry and Optimization in Computer Vision, **Bala Krishnamoorthy**, Washington State University, and **Sudipta Sinha**, Microsoft Research, Redmond, WA.

Inverse Problems, **Hanna Makaruk**, Los Alamos National Laboratory (LANL), and **Robert Owczarek**, University of New Mexico, Albuquerque & Los Alamos.

Mathematical Modeling of Forest and Landscape Change, **Demetrios Gatziolis**, US Forest Service, and **Nikolay Strigul**, Washington State University Vancouver.

Mathematical and Computational Neuroscience, **Alexander Dimitrov**, Washington State University Vancouver, **Andrew Oster**, Eastern Washington University, and **Predrag Tosic**, Washington State University.

Microlocal Analysis and Spectral Theory, **Michael Hitrik**, University of California, Los Angeles, and **Semyon Dyatlov**, Masssachusetts Institute of Technology.

Noncommutative Algebraic Geometry and Related Topics, **Daniel Rogalski**, University of California, San Diego, and **James Zhang**, University of Washington.

Partial Differential Equations and Applications, **V. S. Manoranjan**, **C. Moore**, **Lynn Schreyer**, and **Hong-Ming Yin**, Washington State University.

Recent Advances in Applied Algebraic Topology, **Henry Adams**, Colorado State University, and **Bala Krishnamoorthy**, Washington State University.

Recent Advances in Optimization and Statistical Learning, **Hongbo Dong**, **Bala Krishnamoorthy**, **Haijun Li**, and **Robert Mifflin**, Washington State University.

Recent Advances on Mathematical Biology and Their Applications, **Robert Dillon** and **Xueying Wang**, Washington State University.

Several Complex Variables and PDEs, **Andrew Raich** and **Phillip Harrington**, University of Arkansas.

Theory and Applications of Linear Algebra, **Judi McDonald** and **Michael Tsatsomeros**, Washington State University.

Undergraduate Research Experiences in the Classroom, **Heather Moon**, Lewis-Clark State College.

New York, New York

Hunter College, City University of New York

May 6–7, 2017
Saturday – Sunday

Meeting #1129

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: March 2017
Program first available on AMS website: March 29, 2017
Issue of *Abstracts*: Volume 38, Issue 2

Deadlines

For organizers: Expired
For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Jeremy Kahn, City University of New York, *Applications and frontiers in surface subgroups*.

Fernando Coda Marques, Princeton University, *The space of cycles, a Weyl's law and Morse index estimates*.

James Maynard, Magdalen College, Oxford and Clay Mathematics Institute, *Large gaps between prime numbers* (Erdős Memorial Lecture).

Kavita Ramanan, Brown University, *Tales of random projections: where geometry meets probability theory*.

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.

Analysis and Numerics on Liquid Crystals and Soft Matter, **Xiang Xu**, Old Dominion University, and **Wujun Zhang**, Rutgers University.

Applications of Modular Forms, **Cormac O'Sullivan** and **Karen Taylor**, Bronx Community College, City University of New York.

Applications of Network Analysis, in Honor of Charlie Suffel's 75th Birthday, **Michael Yatauro**, Pennsylvania State University-Brandywine.

Asymptotic Properties of Discrete Dynamical Systems, **Ann Brett**, Johnson and Wales University, and **M. R. S. Kulenović** and **O. Merino**, University of Rhode Island.

Automorphic Forms and Arithmetic, **Jim Brown**, Clemson University, and **Krzysztof Klosin**, Queens College, City University of New York.

Banach Space Theory and Metric Embeddings, **Mikhail Ostrovskii**, St John's University, and **Beata Randrianantoanina**, Miami University of Ohio.

Bases in Hilbert Function Spaces, **Azita Mayeli**, City University of New York, and **Shahaf Nitzan**, Georgia Institute of Technology.

Cluster Algebras in Representation Theory and Combinatorics, **Alexander Garver**, Université du Quebéc à Montréal and Sherbrooke, and **Khrystyna Serhiyenko**, University of California at Berkeley.

Cohomologies and Combinatorics, **Rebecca Patrias**, Université du Québec à Montréal, and **Oliver Pechenik**, Rutgers University.

Common Threads to Nonlinear Elliptic Equations and Systems, **Florin Catrina**, St. John's University, and **Wenxiong Chen**, Yeshiva University.

Commutative Algebra, **Laura Ghezzi**, New York City College of Technology-CUNY, and **Jooyoun Hong**, Southern Connecticut State University.

Computability Theory: Pushing the Boundaries, **Johanna Franklin**, Hofstra University, and **Russell Miller**, Queens College and Graduate Center, City University of New York.

Computational and Algorithmic Group Theory, **Denis Serbin** and **Alexander Ushakov**, Stevens Institute of Technology.

Cryptography, **Xiaowen Zhang**, College of Staten Island and Graduate Center-CUNY.

Current Trends in Function Spaces and Nonlinear Analysis, **David Cruz-Uribe**, University of Alabama, **Jan Lang**, The Ohio State University, and **Osvaldo Mendez**, University of Texas at El Paso.

Differential and Difference Algebra: Recent Developments, Applications, and Interactions, **Omár León-Sanchez**, McMaster University, and **Alexander Levin**, The Catholic University of America.

Dynamical Systems, **Marian Gidea**, Yeshiva University, **W. Patrick Hooper**, City College of New York and the City University of New York, and **Anatole Katok**, Pennsylvania State University.

Ehrhart Theory and its Applications, **Dan Cristofaro-Gardiner**, Harvard University, **Quang-Nhat Le**, Brown University, and **Sinai Robins**, University of São Paulo.

Euler and Related PDEs: Geometric and Harmonic Methods, **Stephen C. Preston**, Brooklyn College, City University of New York, and **Kazuo Yamazaki**, Kazuo Yamazaki, University of Rochester.

Finite Fields and their Applications, **Ricardo Conceicao** and **Darren Glass**, Gettysburg College, and **Ariane Ma-**

suda, New York City College of Technology, City University of New York.

Geometric Function Theory and Related Topics, **Sudeb Mitra**, Queens College and Graduate Center-CUNY, and **Zhe Wang**, Bronx Community College-CUNY.

Geometry and Topology of Ball Quotients and Related Topics, **Luca F. Di Cerbo**, Max Planck Institute, Bonn, and **Matthew Stover**, Temple University.

Hydrodynamic and Wave Turbulence, **Tristan Buckmaster**, Courant Institute of Mathematical Sciences, New York University, and **Vlad Vicol**, Princeton University.

Infinite Permutation Groups, Totally Disconnected Locally Compact Groups, and Geometric Group Theory, **Delaram Kahrobaei**, New York City College of Technology and Graduate Center-CUNY, and **Simon Smith**, University of Lincoln, U.K..

Invariants in Low-dimensional Topology, **Abhijit Champanerkar**, College of Staten Island and The Graduate Center, City University of New York, and **Anastasiia Tsvietkova**, Rutgers University, Newark.

Invariants of Knots, Links and 3-manifolds, **Moshe Cohen**, Vassar College, **Ilya Kofman Kofman**, College of Staten Island and The Graduate Center, City University of New York, and **Adam Lowrance**, Vassar College.

Mathematical Phylogenetics, **Megan Owen**, City University of New York, and **Katherine St. John**, Lehman College, City University of New York, and American Museum of Natural History.

Model Theory: Algebraic Structures in "Tame" Model Theoretic Contexts, **Alfred Dolich**, Kingsborough Community College and The Graduate Center, City University of New York, **Michael Laskowski**, University of Maryland, and **Mahmood Sohrabi**, Stevens Institute of Technology.

Nonlinear and Stochastic Partial Differential Equations: Theory and Applications in Turbulence and Geophysical Flows, **Nathan Glatt-Holtz**, Tulane University, **Geordie Richards**, Utah State University, and **Xiaoming Wang**, Florida State University.

Numerical Analysis and Mathematical Modeling, **Vera Babenko**, Ithaca College.

Operator Algebras and Ergodic Theory, **Genady Grabarnik** and **Alexander Katz**, St John's University.

Qualitative and Quantitative Properties of Solutions to Partial Differential Equations, **Blair Davey**, The City College of New York-CUNY, and **Nguyen Cong Phuc** and **Jiuyi Zhu**, Louisiana State University.

Recent Developments in Automorphic Forms and Representation Theory, **Moshe Adrian**, Queens College-CUNY, and **Shuichiro Takeda**, University of Missouri.

Representation Spaces and Toric Topology, **Anthony Bahri**, Rider University, and **Daniel Ramras** and **Mentor Stafa**, Indiana University-Purdue University Indianapolis.

Topological Dynamics, **Alica Miller**, University of Louisville.

Montréal, Quebec Canada

McGill University

July 24–28, 2017

Monday – Friday

Meeting #1130

The second Mathematical Congress of the Americas (MCA 2017) is being hosted by the Canadian Mathematical Society (CMS) in collaboration with the Pacific Institute for the Mathematical Sciences (PIMS), the Fields Institute (FIELDS), Le Centre de Recherches Mathématiques (CRM), and the Atlantic Association for Research in the Mathematical Sciences (AARMS).

Associate secretary: Brian D. Boe

Program first available on AMS website: January 23, 2017

Deadlines

For organizers: Expired

For abstracts: Expired

Denton, Texas

University of North Texas

September 9–10, 2017

Saturday – Sunday

Meeting #1131

Central Section

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: June 2017

Program first available on AMS website: July 27, 2017

Issue of *Abstracts*: Volume 38, Issue 3

Deadlines

For organizers: Expired

For abstracts: July 18, 2017

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Mirela Çiperiani, University of Texas at Austin, *Title to be announced.*

Adrianna Gillman, Rice University, *Title to be announced.*

Kevin Pilgrim, Indiana 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 Combinatorics of Flag Varieties (Code: SS 11A), **Martha Precup**, Northwestern University, and **Edward Richmond**, Oklahoma State University.

Analysis and PDEs in Geometry (Code: SS 20A), **Stephen McKeown**, Princeton University.

Applicable and Computational Algebraic Geometry (Code: SS 17A), **Eric Hanson**, Texas Christian University, and **Frank Sottile**, Texas A&M University.

Banach Spaces and Applications (Code: SS 9A), **Pavlos Motakis**, Texas A&M University, and **Bönyamin Sari**, University of North Texas.

Combinatorial/Geometric/Probabilistic Methods in Group Theory (Code: SS 19A), **Rostislav Grigorchuk** and **Volodymyr Nekrashevych**, Texas A&M University, **Dmytro Savchuk**, University of South Florida, and **Zoran Sunic**, Texas A&M University.

Combinatorics and Representation Theory of Reflection Groups: Real and Complex (Code: SS 14A), **Elizabeth Drellich**, Swarthmore College, and **Drew Tomlin**, Hendrix College.

Commutative Algebra (Code: SS 10A), **Jonathan Montano**, University of Kansas, and **Alessio Sammartano**, Purdue University.

Differential Equation Modeling and Analysis for Complex Bio-systems (Code: SS 8A), **Pengcheng Xiao**, University of Evansville, and **Honghui Zhang**, Northwestern Polytechnical University.

Differential Geometry of Smooth and Discrete Surfaces in Euclidean and Lorentz Spaces (Code: SS 18A), **Barbara Shipman**, University of Texas at Arlington, and **Patrick Shipman**, Colorado State University.

Dynamics, Geometry and Number Theory (Code: SS 1A), **Lior Fishman** and **Mariusz Urbanski**, University of North Texas.

Fractal Geometry and Ergodic Theory (Code: SS 5A), **Mrinal Kanti Roychowdhury**, University of Texas Rio Grande Valley.

Generalizations of Graph Theory (Code: SS 22A), **Nathan Reff**, SUNY Brockport, and **Lucas Rusnak** and **Piyush Shroff**, Texas State University.

Geometric Combinatorics and Combinatorial Commutative Algebra (Code: SS 16A), **Anton Dochtermann** and **Suho Oh**, Texas State University.

Homological Methods in Commutative Algebra (Code: SS 15A), **Peder Thompson**, Texas Tech University, and **Ashley Wheeler**, University of Arkansas.

Integrable Systems and Applications (Code: SS 24A), **Baofeng Feng**, The University of Texas Rio Grande Valley, and **Akif Ibragimov** and **Magdalena Toda**, Texas Tech University.

Invariants of Links and 3-Manifolds (Code: SS 7A), **Mieczyslaw K. Dabkowski** and **Anh T. Tran**, The University of Texas at Dallas.

Lie algebras, Superalgebras, and Applications (Code: SS 3A), **Charles H. Conley**, University of North Texas, **Dimitar Grantcharov**, University of Texas at Arlington, and **Natalia Rozhkovskaya**, Kansas State University.

Mathematical and Computational Biology (Code: SS 21A), **Rajeev K. Azad**, University of North Texas, and **Brandilyn Stigler**, Southern Methodist University.

Noncommutative and Homological Algebra (Code: SS 4A), **Anne Shepler**, University of North Texas, and **Sarah Witherspoon**, Texas A&M University.

Nonlocal PDEs in Fluid Dynamics (Code: SS 12A), **Changhui Tan**, Rice University, and **Xiaoqian Xu**, Carnegie Mellon University.

Numbers, Functions, Transcendence, and Geometry (Code: SS 6A), **William Cherry**, University of North Texas, **Mirela Çiperiani**, University of Texas Austin, **Matt Papanikolas**, Texas A&M University, and **Min Ru**, University of Houston.

Real-Analytic Automorphic Forms (Code: SS 2A), **Olav K. Richter**, University of North Texas, and **Martin Westerholt-Raum**, Chalmers University of Technology.

Recent Progress on Hyperbolic Conservation Laws (Code: SS 23A), **Ilija Jegdic**, Texas Southern University, and **Katarina Jegdic**, University of Houston, Downtown.

Topics Related to the Interplay of Noncommutative Algebra and Geometry (Code: SS 13A), **Richard Chandler**, University of North Texas at Dallas, **Michaela Vancliff**, University of Texas at Arlington, and **Padmini Veerapen**, Tennessee Technological University.

Buffalo, New York

State University of New York at Buffalo

September 16–17, 2017
Saturday – Sunday

Meeting #1132

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: June 2017
Program first available on AMS website: August 3, 2017
Issue of *Abstracts*: Volume 38, Issue 3

Deadlines

For organizers: Expired
For abstracts: July 25, 2017
Program issue of electronic *Notices*: To be announced
The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Inwon Kim, University of California at Los Angeles, *Capillary drops on rough surfaces.*

Govind Menon, Brown University, *Building polyhedra by self-assembly.*

Bruce E Sagan, Michigan State University, *The protean chromatic polynomial.*

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.

Advanced Techniques in Graph Theory (Code: SS 9A), **Sogol Jahanbekam** and **Paul Wenger**, Rochester Institute of Technology.

Algebraic Topology (Code: SS 17A), **Claudia Miller**, Syracuse University, and **Inna Zakharevich**, Cornell University.

Automorphic Forms and L-functions (Code: SS 14A), **Mahdi Asgari**, Oklahoma State University, and **Joseph Hundley**, University at Buffalo-SUNY.

CR Geometry and Partial Differential Equations in Complex Analysis (Code: SS 5A), **Ming Xiao**, University of Illinois at Urbana-Champaign, and **Yuan Yuan**, Syracuse University.

Cohomology, Deformations, and Quantum Groups: A Session Dedicated to the Memory of Samuel D. Schack (Code: SS 6A), **Miodrag Iovanov**, University of Iowa, **Mihai D. Staic**, Bowling Green State University, and **Alin Stancu**, Columbus State University.

Geometric Group Theory (Code: SS 4A), **Joel Louwsma**, Niagara University, and **Johanna Mangahas**, University at Buffalo-SUNY.

High Order Numerical Methods for Hyperbolic PDEs and Applications (Code: SS 2A), **Jae-Hun Jung**, University at Buffalo-SUNY, **Fengyan Li**, Rensselaer Polytechnic Institute, and **Li Wang**, University at Buffalo-SUNY.

Infinite Groups and Geometric Structures: A Session in Honor of the Sixtieth Birthday of Andrew Nicas (Code: SS 7A), **Hans Boden**, McMaster University, and **David Rosenthal**, St. John's University.

Knots, 3-manifolds and their Invariants (Code: SS 15A), **William Menasco** and **Adam Sikora**, University at Buffalo-SUNY, and **Stephan Wehrli**, Syracuse University.

Nonlinear Dispersive Partial Differential Equations (Code: SS 18A), **Santosh Bhattrai**, Trocaire College, and **Sharad Silwal**, Jefferson College of Health Sciences.

Nonlinear Evolution Equations (Code: SS 16A), **Marius Beceanu**, SUNY Albany, and **Dan-Andrei Geba**, University of Rochester.

Nonlinear Partial Differential Equations Arising from Life Science (Code: SS 8A), **Junping Shi**, College of William and Mary, and **Xingfu Zou**, University of Western Ontario.

Nonlinear Wave Equations, Inverse Scattering and Applications. (Code: SS 1A), **Gino Biondini**, University at Buffalo-SUNY.

Polynomials in Enumerative, Algebraic, and Geometric Combinatorics (Code: SS 13A), **Robert Davis** and **Bruce Sagan**, Michigan State University.

Recent Advancements in Representation Theory (Code: SS 12A), **Yiqiang Li**, University at Buffalo-SUNY, and **Gufang Zhao**, University of Massachusetts.

Recent Progress in Geometric Analysis (Code: SS 11A), **Ovidiu Munteanu**, University of Connecticut, **Terrence Napier**, Lehigh University, and **Mohan Ramachandran**, University at Buffalo.

Structural and Chromatic Graph Theory (Code: SS 10A), **Hong-Jian Lai**, **Rong Luo**, and **Cun-Quan Zhang**, West Virginia University, and **Yue Zhao**, University of Central Florida.

p-adic Aspects of Arithmetic Geometry (Code: SS 3A), **Liang Xiao**, University of Connecticut, and **Hui June Zhu**, University at Buffalo-SUNY.

Orlando, Florida

University of Central Florida, Orlando

September 23–24, 2017
Saturday – Sunday

Meeting #1133
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: June 2017
Program first available on AMS website: August 10, 2017
Issue of *Abstracts*: Volume 38, Issue 4

Deadlines

For organizers: Expired
For abstracts: August 1, 2017

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Christine Heitsch, Georgia Institute of Technology, *Title to be announced.*

Jonathan Kujawa, University of Oklahoma, *Title to be announced.*

Christopher D Sogge, Johns Hopkins 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 Dirac Equations, Variational Inequalities, Sequence Spaces and Optimization (Code: SS 21A), **Ram N. Mohapatra**, University of Central Florida, and **Turhan Koprubasi**, Kastamonu University (Turkey).

Algebraic Curves and their Applications (Code: SS 3A), **Lubjana Beshaj**, The University of Texas at Austin.

Applied Harmonic Analysis: Frames, Samplings and Applications (Code: SS 6A), **Dorin Dutkay**, **Deguang Han**, and **Qiyu Sun**, University of Central Florida.

Categorical Methods in Representation Theory (Code: SS 11A), **Brian Boe**, University of Georgia, **Jonathan Kujawa**, University of Oklahoma, and **Daniel K. Nakano**, University of Georgia.

Commutative Algebra: Interactions with Algebraic Geometry and Algebraic Topology (Code: SS 1A), **Joseph Brennan**, University of Central Florida, and **Alina Iacob** and **Saeed Nasseh**, Georgia Southern University.

Complex Analysis, Harmonic Analysis, and Approximation Theory (Code: SS 15A), **Alexander V Tovstolis**, University of Central Florida, and **John Paul Ward**, North Carolina A&T State University.

Differential Equations in Mathematical Biology (Code: SS 12A), **Andrew Nevai**, **Yuanwei Qi**, and **Zhisheng Shuai**, University of Central Florida.

Fractal Geometry, Dynamical Systems, and Their Applications (Code: SS 4A), **Mrinal Kanti Roychowdhury**, University of Texas Rio Grande Valley.

Global Harmonic Analysis and its Applications (Code: SS 10A), **Christopher Sogge** and **Yakun Xi**, Johns Hopkins University, and **Steve Zelditch**, Northwestern University.

Graph Connectivity and Edge Coloring (Code: SS 5A), **Colton Magnant**, Georgia Southern University.

Mathematics of Biomolecules: Discrete, Algebraic, and Topological (Code: SS 20A), **Natasha Jonoska**, University of South Florida, and **Christine Heitsch**, Georgia Institute of Technology.

Modern Statistical Methods for Structured Data (Code: SS 17A), **Marianna Pensky**, University of Central Florida.

Nonlinear Dispersive Equations (Code: SS 7A), **Benjamin Harrop-Griffiths**, New York University, **Jonas Lührmann**, Johns Hopkins University, and **Dana Mendelson**, University of Chicago.

Nonlinear Elliptic Partial Differential Equations (Code: SS 16A), **Luis E. Silvestre**, University of Chicago, and **Eduardo V. Teixeira**, University of Central Florida.

Operator Algebras and Related Topics (Code: SS 8A), **Zhe Liu**, University of Central Florida.

Progress in Fixed Point Theory and Its Applications (Code: SS 9A), **Clement Boateng Ampadu**, Boston, MA, and **Buthinah A. Bin Rehash** and **Afrah A. N. Abdou**, King Abdulaziz University, Saudi Arabia.

Recent Developments in Integral Geometry and Tomography (Code: SS 14A), **Alexander Katsevich**, **Alexander Tovbis**, and **Alexandru Tamasan**, University of Central Florida.

Stochastic Analysis and Applications (Code: SS 19A), **Hongwei Long**, Florida Atlantic University, and **Jiongmin Yong**, University of Central Florida.

Structural Graph Theory (Code: SS 2A), **Martin Rolek**, **Zixia Song**, and **Yue Zhao**, University of Central Florida.

Symplectic and Contact Topology and Dynamics (Code: SS 13A), **Basak Gurel**, University of Central Florida, and **Viktor Ginzburg**, University of California, Santa Cruz.

Trends in Applications of Functional Analysis in Computational and Applied Mathematics (Code: SS 18A), **M Zuhair Nashed**, University of Central Florida.

Riverside, California

University of California, Riverside

November 4–5, 2017

Saturday – Sunday

Meeting #1134

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: September 2017
Program first available on AMS website: September 21, 2017
Issue of *Abstracts*: Volume 38, Issue 4

Deadlines

For organizers: Expired
For abstracts: September 12, 2017

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Paul Balmer, University of California, Los Angeles, *An invitation to tensor-triangular geometry.*

Pavel Etingof, Massachusetts Institute of Technology, *Double affine hecke algebras and their applications.*

Monica Vazirani, University of California, Davi, *Combinatorics, categorification, and crystals.*

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 Algebras (Code: SS 13A), **Michael Hartglass**, UC Riverside, Santa Clara University, and **Chenxu Wen** and **Feng Xu**, University of California, Riverside.

Algebraic Geometry (Code: SS 9A), **Humberto Diaz**, **Jose Gonzalez**, and **Ziv Ran**, University of California, Riverside.

Algebraic and Combinatorial Structures in Knot Theory (Code: SS 3A), **Patricia Cahn**, Smith College, and **Sam Nelson**, Claremont McKenna College.

Analysis and Geometry of Fractals (Code: SS 6A), **Erin Pearse**, California Polytechnic State University, and **Goran Radunovic**, University of California, Riverside.

Applied Category Theory (Code: SS 4A), **John Baez**, University of California, Riverside.

Characteristics of a Successful Mathematics Gateway Program (Code: SS 12A), **Sara Lapan**, University of California, Riverside, **Jeff Meyer**, California State University, San Bernardino, and **David Weisbart**, University of California, Riverside.

Combinatorial Aspects of the Polynomial Ring (Code: SS 1A), **Sami Assaf** and **Dominic Searles**, University of Southern California.

Combinatorial Representation Theory (Code: SS 5A), **Vyjayanthi Chari**, University of California, Riverside, and **Maria Monks Gillespie** and **Monica Vazirani**, University of California, Davis.

Conservation Laws, Nonlinear Waves and Applications (Code: SS 18A), **Geng Chen**, University of Kansas, **Tien Khai Nguyen**, North Carolina State University, and **Qingtian Zhang**, University of California, Davis.

Generalized Geometry (Code: SS 16A), **Daniele Grandini**, Virginia State University, and **Yat-Sun Poon**, University of California, Riverside.

Model Theory (Code: SS 14A), **Artem Chernikov**, University of California, Los Angeles, and **Isaac Goldbring**, University of California, Irvine.

Non-Commutative Birational Geometry, Cluster Structures and Canonical Bases (Code: SS 19A), **Arkady Berenstein**, University of Oregon, Eugene, **Jacob Greenstein**, University of California, Riverside, and **Vladimir Retakh**, Rutgers University.

Preparing Students for American Mathematical Competitions (Code: SS 7A), **Adam Glesser**, **Phillip Ramirez**, and **Bogdan D. Suceava**, California State University, Fullerton.

Random and Deterministic Dynamical Systems (Code: SS 15A), **Nicolai Haydn**, University of Southern California, Los Angeles.

Rational Cherednik Algebras and Categorification (Code: SS 8A), **Pavel Etingof**, Massachusetts Institute of Technology, and **Ivan Losev**, Northeastern University.

Ring Theory and Related Topics (Celebrating the 75th Birthday of Lance W. Small) (Code: SS 2A), **Jason Bell**, University of Waterloo, **Ellen Kirkman**, Wake Forest University, and **Susan Montgomery**, University of Southern California.

Several Complex Variables (Code: SS 10A), **Bingyuan Liu** and **Bun Wong**, University of California, Riverside.

Stochastic and Multi-scale Models in Mathematical Biology, Analysis and Simulations (Code: SS 17A), **Mark Alber**, University of California, Riverside, and **Bjorn Birnir**, University of California, Santa Barbara.

Tensor Categories: Bridging Algebra, Topology, and Physics (Code: SS 11A), **Paul Bruillard**, Pacific Northwest National Laboratory, **Julia Plavnik**, Texas A&M University, and **Henry Tucker**, University of California, San Diego.

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 10–13, 2018

Wednesday – Saturday

Meeting #1135

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*: Volume 39, Issue 1

Deadlines

For organizers: Expired
For abstracts: Septeber 26, 2017

Columbus, Ohio

Ohio State University

March 17–18, 2018

Saturday – Sunday

Meeting #1136

Central Section
Associate secretary: Georgia Benkart
Program first available on AMS website: January 31, 2018
Issue of *Abstracts*: Volume 39, Issue 2

Deadlines

For organizers: August 15, 2017
For abstracts: January 22, 2018

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`.

Homological Algebra (Code: SS 4A), **Ela Celikbas** and **Olgur Celikbas**, West Virginia University.

Probability in Convexity and Convexity in Probability (Code: SS 2A), **Elizabeth Meckes**, **Mark Meckes**, and **Elisabeth Werner**, Case Western Reserve University.

Quantum Symmetries (Code: SS 3A), **David Penneys**, The Ohio State University, and **Julia Plavnik**, Texas A & M University.

Recent Advances in Approximation Theory and Operator Theory (Code: SS 1A), **Jan Lang** and **Paul Nevai**, The Ohio State University.

Nashville, Tennessee

Vanderbilt University

April 14–15, 2018

Saturday – Sunday

Meeting #1138

Southeastern Section
Associate secretary: Brian D. Boe
Program first available on AMS website: February 22, 2018
Issue of *Abstracts*: Volume 39, Issue 2

Deadlines

For organizers: September 14, 2017
For abstracts: February 13, 2018

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Andrea Bertozzi, University of California Los Angeles, *To be announced* (Erdős Memorial Lecture).

Portland, Oregon

Portland State University

April 14–15, 2018

Saturday – Sunday

Meeting #1137

Western Section
Associate secretary: Michel L. Lapidus

Announcement issue of *Notices*: To be announced
Program first available on AMS website: February 15, 2018
Issue of *Abstracts*: Volume 39, Issue 2

Deadlines

For organizers: September 14, 2017
For abstracts: February 6, 2018

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Sándor Kovács, University of Washington, Seattle, *Title to be announced*.

Elena Mantovan, California Institute of Technology, *Title to be announced*.

Dimitri Shlyakhtenko, University of California, Los Angeles, *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`.

Inverse Problems (Code: SS 2A), **Hanna Makaruk**, Los Alamos National Laboratory (LANL), and **Robert Owczarek**, University of New Mexico, Albuquerque & Los Alamos.

Pattern Formation in Crowds, Flocks, and Traffic (Code: SS 1A), **J. J. P. Veerman**, Portland State University, **Alethea Barbaro**, Case Western Reserve University, and **Bassam Bamieh**, UC Santa Barbara.

Boston, Massachusetts

Northeastern University

April 21–22, 2018

Saturday – Sunday

Meeting #1139

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: March 1, 2018
Issue of *Abstracts*: Volume 39, Issue 2

Deadlines

For organizers: September 21, 2017
For abstracts: February 20, 2018

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`.

Analysis and Geometry in Non-smooth Spaces (Code: SS 5A), **Nageswari Shanmugalingam** and **Gareth Speight**, University of Cincinnati.

Arithmetic Dynamics (Code: SS 1A), **Jacqueline M. Anderson**, Bridgewater State University, **Robert Benedetto**, Amherst College, and **Josheph H. Silverman**, Brown University.

Arrangements of Hypersurfaces (Code: SS 2A), **Graham Denham**, University of Western Ontario, and **Alexander I. Denham**, Northwestern University.

Ergodic Theory and Dynamics in Combinatorial Number Theory (Code: SS 7A), **Stanley Eigen**, Northeastern University, **Daniel Glasscock**, Ohio State University, and **Vidhu Prasad**, University of Massachusetts, Lowell.

Facets of Symplectic Geometry and Topology (Code: SS 3A), **Tara Holm**, Cornell University, **Jo Nelson**, Columbia University, and **Jonathan Weitsman**, Northeastern University.

Hopf Algebras, Tensor Categories, and Homological Algebra (Code: SS 8A), **Cris Negron**, Massachusetts Institute of Technology, and **Julia Plavnik**, Texas A&M University, and **Sarah Witherspoon**, Texas A&M University.

Prototypes and Discrete Geometry (Code: SS 6A), **Gabriel Cunningham**, University of Massachusetts, Boston, **Mark Mixer**, Wentworth Institute of Technology, and **Egon Schulte**, Northeastern University.

Singularities of Spaces and Maps (Code: SS 4A), **Terence Gaffney** and **David Massey**, Northeastern University.

Shanghai, People's Republic of China

Fudan University

June 11–14, 2018

Monday – Thursday

Meeting #1140

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: To be announced

Newark, Delaware

University of Delaware

September 29–30, 2018

Saturday – Sunday

Meeting #1141
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: August 9, 2018
Issue of *Abstracts*: Volume 39, Issue 3

Deadlines
For organizers: February 28, 2018
For abstracts: July 31, 2018

Fayetteville, Arkansas

University of Arkansas

October 6–7, 2018
Saturday – Sunday

Meeting #1142
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: August 16, 2018
Issue of *Abstracts*: Volume 39, Issue 3

Deadlines
For organizers: March 6, 2018
For abstracts: August 7, 2018

Ann Arbor, Michigan

University of Michigan, Ann Arbor

October 20–21, 2018
Saturday – Sunday

Meeting #1143
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: August 30, 2018
Issue of *Abstracts*: Volume 39, Issue 4

Deadlines
For organizers: March 20, 2018
For abstracts: August 21, 2018

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.

Geometry of Submanifolds, in Honor of Bang-Yen Chens 75th Birthday (Code: SS 1A), **Alfonso Carriazo**, University of Sevilla, **Ivko Dimitric**, Penn State Fayette, **Yun Myung Oh**, Andrews University, **Bogdan D. Suceava**, California State University, Fullerton, **Joeri Van der Veken**, University of Leuven, and **Luc Vrancken**, Universite de Valenciennes.

San Francisco, California

San Francisco State University

October 27–28, 2018
Saturday – Sunday

Meeting #1144
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2018
Program first available on AMS website: September 6, 2018
Issue of *Abstracts*: Volume 39, Issue 4

Deadlines
For organizers: March 27, 2018
For abstracts: August 28, 2018

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

Auburn, Alabama

Auburn University

March 15–17, 2019
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: To be announced
For abstracts: To be announced

Honolulu, Hawaii

University of Hawaii at Manoa

March 22–24, 2019
Friday – Sunday
Central Section
Associate secretaries: Georgia Benkart and 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

Denver, Colorado

Colorado Convention Center

January 15–18, 2020
Wednesday – Saturday
Joint Mathematics Meetings, including the 126th Annual Meeting of the AMS, 103rd 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*: To be announced
Program first available on AMS website: November 1, 2019
Issue of *Abstracts*: To be announced

Deadlines
For organizers: April 1, 2019
For abstracts: To be announced

Washington, District of Columbia

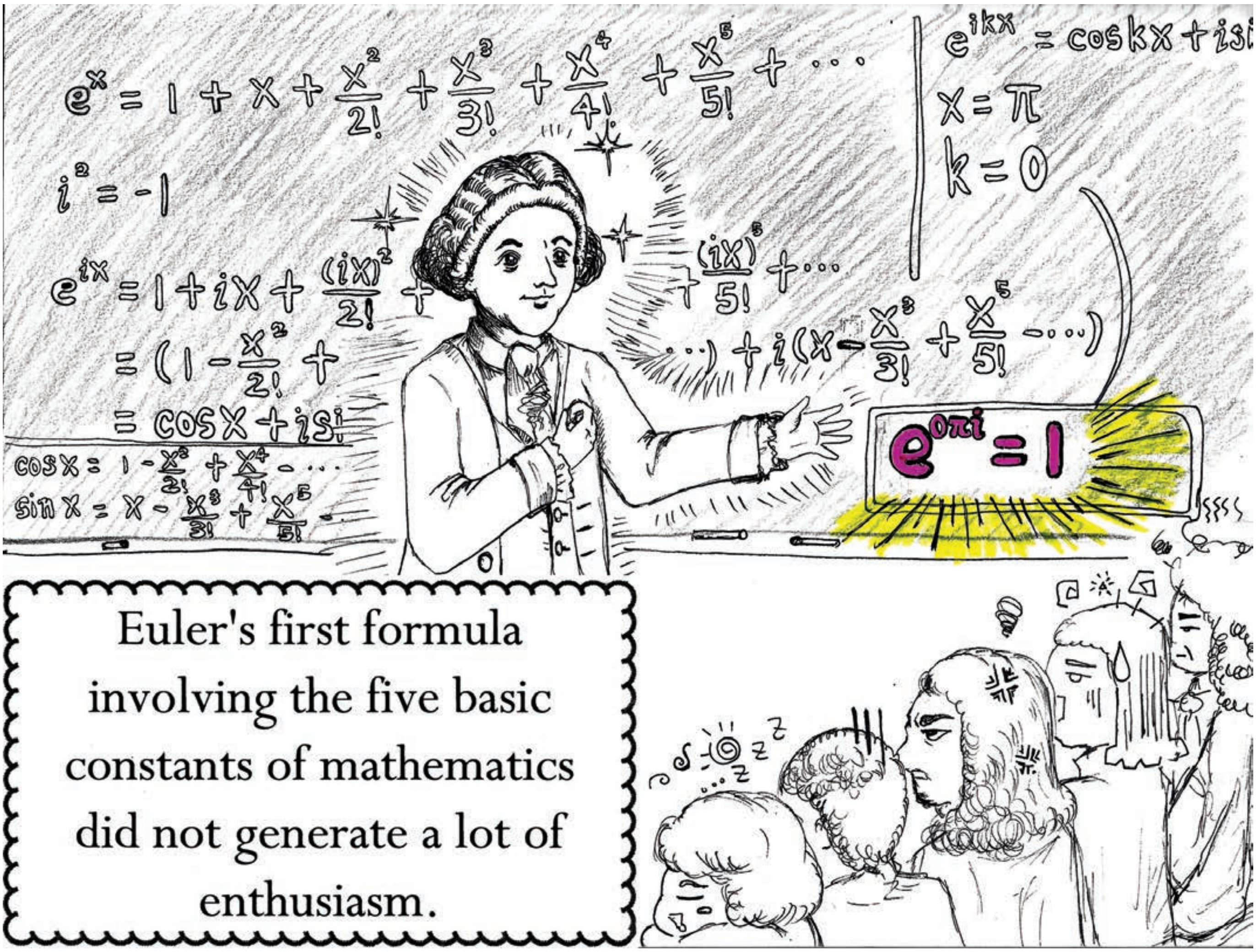
Walter E. Washington Convention Center

January 6–9, 2021
Wednesday – Saturday
Joint Mathematics Meetings, including the 127th Annual Meeting of the AMS, 104th 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: Brian D. Boe
Announcement issue of *Notices*: October 2020
Program first available on AMS website: November 1, 2020
Issue of *Abstracts*: To be announced

Deadlines
For organizers: April 1, 2020
For abstracts: To be announced

THE BACK PAGE

"I must study politics and war that my sons [and daughters!—Ed.] may have liberty to study mathematics and philosophy." —*John Adams*



Concept and artwork by Anna Pun and Richard Stanley.

The Mathematics Genealogy Project listed over 200,000 mathematicians as of July 2016. C.-C. Luo (MIT, 1987) has the most students, 137. Shams ad-Din Al-Bukhari has the most descendants at 137,029; his dissertation was well before 1315, the year of the dissertation of his mathematical grandson, Theodore Metochites.

From the Extrema page at the Mathematics Genealogy Project (see the article on page 466).

What crazy things happen to you? Readers are invited to submit original short amusing stories, math jokes, cartoons, and other material to: **noti-backpage@ams.org**.

IN THE NEXT ISSUE OF NOTICES

JUNE/JULY 2017…

Fern Y. Hunt of the Mathematical and Computational Sciences Division of the National Institute of Standards and Technology reviews the film *Hidden Figures*.

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Distribution Center

35 Monticello Place,
Pawtucket, RI 02861 USA