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Notices

of the American Mathematical Society

October 2017 Volume 64, Number 9

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San Diego Meeting—JMM 2018

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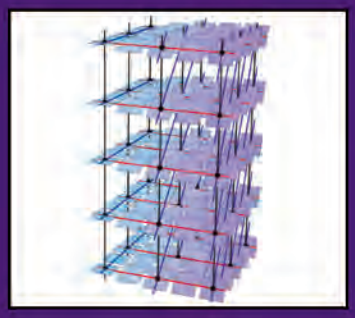
AMS
American Mathematical Society

INSTITUTE FOR PURE AND APPLIED MATHEMATICS



QUANTITATIVE LINEAR ALGEBRA

March 19 - June 15, 2018 | Los Angeles

Organizers: Alice Guionnet (École Normale Supérieure de Lyon), Assaf Naor (Princeton), Gilles Pisier (Texas A&M), Sorin Popa (UCLA), Dimitri Shylakhtenko (UCLA), Nikhil Srivastava (UC Berkeley), and Terence Tao (UCLA).

SCIENTIFIC OVERVIEW

The program lies at the juncture of mathematics and theoretical computer science in a quest for quantitative answers to finite-dimensional questions. The program brings together topics from a number of important directions, including discrepancy theory, spectral graph theory, random matrices, geometric group theory, ergodic theory, von Neumann algebras, as well as specific research directions such as the Kadison-Singer problem, the Connes embedding conjecture and the Grothendieck inequality.

A very important aspect of the program is its aim to deepen the link between research communities working on some infinite-dimensional functional analysis problems that occur in geometric group theory, ergodic theory, von Neumann algebras; and some quantitative finite-dimensional ones that occur in spectral graph theory, random matrices, combinatorial optimization, and the Kadison-Singer problem.

WORKSHOP SCHEDULE

- Opening Day: March 19, 2018.
- Tutorials: March 20 - 23, 2018.
- Workshop I: Expected Characteristic Polynomial Techniques and Applications: April 9 - 13, 2018.
- Workshop II: Approximation Properties in Operator Algebras and Ergodic Theory: April 30 - May 5, 2018.
- Workshop III: Random Matrices and Free Probability Theory: May 14 - 18, 2018.
- Culminating Workshop at Lake Arrowhead: June 10 - 15, 2018.

PARTICIPATION

This long program will involve senior and junior researchers from several communities relevant to this program. You may apply for financial support to participate in the entire fourteen-week program, or a portion of it. We prefer participants who stay for the entire program. Applications will be accepted through **December 4, 2017**, but offers may be made up to one year before the start date. We urge you to apply early. Mathematicians and scientists at all levels who are interested in this area of research are encouraged to apply for funding. Supporting the careers of women and minority researchers is an important component of IPAM's mission, and we welcome their applications.

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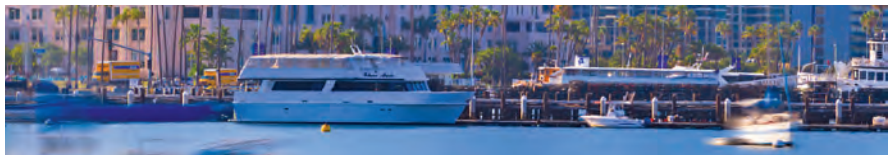

October 2017

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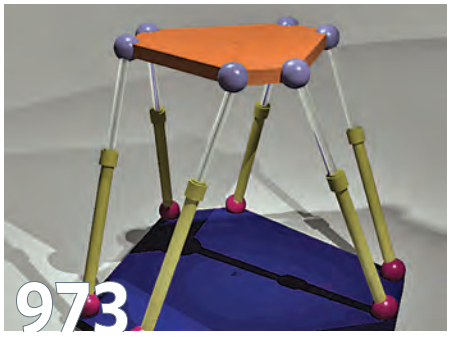

The Rigidity of Frameworks: Theory and Applications

by Jessica Sidman and Audrey St. John

Dido's Problem and Its Impact on Modern Mathematics

by Catherine Bandle

Euphemia Lofton Haynes: Bringing Education Closer to the "Goal of Perfection"

by Susan E. Kelly, Carly Shinners, and Katherine Zoroufy

Inspired by the cover image of San Diego, a favorite and the 2018 site of the Joint Mathematics Meetings, we indulge ourselves in the JMM Program (page 1067), read more about the AMS Short Course lecture topics (page 1016), make plans to attend, and make sure our memberships are up to date. We enjoy articles by Jessica Sidman and Audrey St. John on "The Rigidity of Frameworks" and by Catherine Bandle on "Dido's Problem." We mull over opinion pieces, including a cautionary tale about a proposal to avoid election district gerrymandering, which may come before the Supreme Court this month. We thank Susan Kelly, Carly Shinners, and Katherine Zoroufy for providing the story of Euphemia Lofton Haynes, the first African American woman to receive a PhD in mathematics.

—*Frank Morgan, Editor-in-Chief*

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Cover: "San Diego Harbor on a clear day," by David Toussaint. Courtesy of Getty Images.

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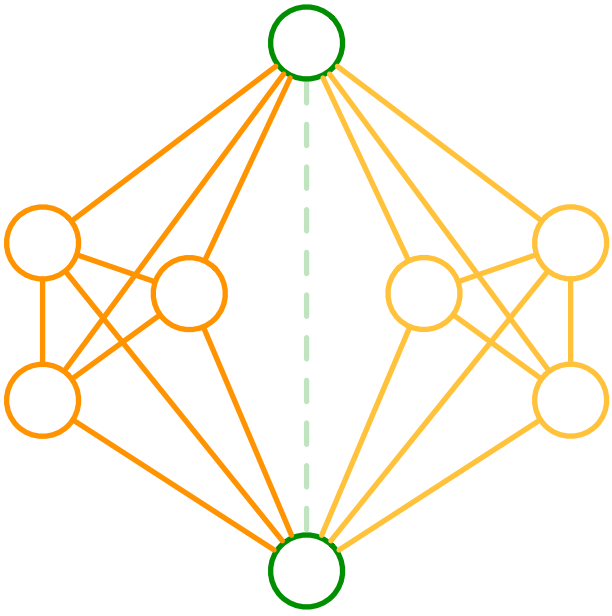
The Rigidity of Frameworks: Theory and Applications

Jessica Sidman and Audrey St. John

Communicated by Benjamin Braun



ABSTRACT. When robots fly to collectively move an object, the algebraic and combinatorial approaches of rigidity theory can provide conditions that determine whether the swarm will maintain formation. We introduce the fundamentals for the analysis of the rigidity of frameworks along with other motivating applications drawn from computer-aided design and computational biology.

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Picture a swarm of robots flying to move a piece of rubble from a disaster site, an engineer designing the roof of a stadium, or a protein docking an inhibiting drug. What these scenarios, pulled from robotics, computer-aided design (CAD), and structural biology, have in common is that each is governed by a finite system of geometric constraints that can be analyzed using ideas from rigidity theory.

The classical structure studied in rigidity theory is the *bar-and-joint* framework, as in Figure 1. It is composed of universal (rotating) joints connected by bars that constrain the distances between pairs of joints. Formally, let $G = (V, E)$ be an undirected graph with n vertices (representing joints) and m edges (representing bars). We define a *bar-and-joint framework* in $\mathbb{R}^d$ to be a pair $(G, \mathbf{p})$, where $\mathbf{p} = (\mathbf{p}_1, \dots, \mathbf{p}_n) \in (\mathbb{R}^d)^n$ is a *realization* of the joints in $\mathbb{R}^d$.

The fundamental question in rigidity theory is:

Question 1. Given a framework $(G, \mathbf{p})$, is it rigid?

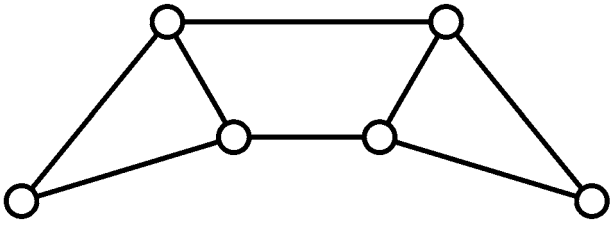


Figure 1. A bar-and-joint framework is composed of universal joints constrained by bars with fixed lengths.

Intuitively this question is asking: if one were to "push" on the framework, would it deform? To formalize this, we define a *length* function $\ell : E \to \mathbb{R}$ specifying the (squared) lengths of the bars from $(G, \mathbf{p})$. Then we are interested in understanding the set of all realizations $\mathbf{q}$ satisfying (1):

$$||\mathbf{q}_i - \mathbf{q}_j||^2 = \ell(ij), \forall ij \in E. \tag{1}$$

These squared distance equations are constraints that form a system of quadratic polynomial equations that must be satisfied by the joint coordinates.

Given a framework $(G, \mathbf{p})$, is it rigid?

It is clear that, given $(G, \mathbf{p})$, there are infinitely many realizations of G satisfying the same length function ℓ, as we can use a Euclidean motion of $\mathbb{R}^d$ to obtain another via translation, reflection, or rotation; such realizations are *congruent*. If there is a unique framework $(G, \mathbf{p})$ in $\mathbb{R}^d$, up to congruence, then we say that $(G, \mathbf{p})$ is *globally rigid*. We will not delve further into the topic of global rigidity, but note that there are many interesting and challenging questions posed around unique realizations. To capture the intuitive notion of rigidity we are interested in the framework's *local* behavior. If $(G, \mathbf{p})$ is the unique realization of (G, ℓ) up to congruence in some neighborhood of $\mathbf{p}$, then we say that $(G, \mathbf{p})$ is *(locally) rigid*; otherwise, it is *flexible*.

We also consider additional structural properties of a framework, as illustrated in Figure 2. If the removal of any edge in a rigid framework causes it to flex, the framework is *minimally rigid*. If, on the other hand, the removal of any edge in a rigid framework does not cause a flex, the framework is *redundantly rigid*. In a flexible framework, there may be rigid *components*: vertex-maximal induced subgraphs that are themselves rigid. These properties are typically studied via the *rigidity matroid*, whose independent sets are the sets of edges of G that impose independent geometric constraints. In general, a matroid is a combinatorial object abstracting the notion of linear independence, appearing in many other guises within mathematics. The rigidity matroid may be defined via the rigidity matrix introduced below or algebraically via the equations defining the Cayley–Menger variety.

Since (squared) distance constraints satisfied by the joint coordinates are given by quadratic polynomials, it is possible to try to analyze the set of all realizations of a given pair (G, ℓ) symbolically using computational algebra. However, a Gröbner basis for an ideal generated by quadratic polynomials in k variables can require generators of degree $O(2^{2^k})$, so computations with the squared distance constraints may quickly become intractable. Moreover, care must be taken in applying results from algebraic geometry in this setting as we are interested in realizations over the real numbers, and many results in algebraic geometry require an algebraically closed ground field.

Therefore, we turn to the study of "infinitesimal rigidity theory" in which we analyze the Jacobian, or *rigidity matrix*, of the quadratic system specified by Equation 1 in order to understand a framework's first-order behavior. As we will see shortly, the dimension of the null space of a framework's rigidity matrix is $\binom{d+1}{2}$ if and only if the framework is infinitesimally rigid. Since infinitesimal rigidity implies rigidity [1], answering the following question gives a sufficient condition for rigidity in the algebraic setting.

Question 2. Is a given framework $(G, \mathbf{p})$ infinitesimally rigid?

The rigidity matrix of a framework with n joints and m bars has dn columns and m rows, and its null space consists of the *infinitesimal motions* permitted by the framework. For example, the rigidity matrix of the 2-dimensional framework depicted in Figure 2(c), without the dashed edge, has joint coordinates $((x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4))$, and its rigidity matrix is the following:

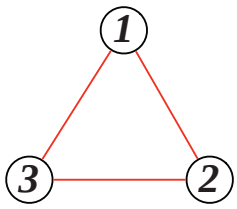
$$\begin{pmatrix} x_1-x_2 & y_1-y_2 & x_2-x_1 & y_2-y_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & x_2-x_3 & y_2-y_3 & x_3-x_2 & y_3-y_2 & 0 & 0 \\ 0 & 0 & 0 & 0 & x_3-x_4 & y_3-y_4 & x_4-x_3 & y_4-y_3 \\ x_1-x_4 & y_1-y_4 & 0 & 0 & 0 & 0 & x_4-x_1 & y_4-y_1 \\ 0 & 0 & x_2-x_4 & y_2-y_4 & 0 & 0 & x_4-x_2 & y_4-y_2 \end{pmatrix}.$$

Every infinitesimal motion consists of a velocity vector assigned to each vertex such that each bar is orthogonal to the relative velocities of its joints. Hence the infinitesimal motion instantaneously preserves the bar lengths. If the only infinitesimal motions permitted are the $\binom{d+1}{2}$ *trivial motions*, then the framework is *infinitesimally rigid*. In the plane, there are three trivial degrees of freedom corresponding to translation of the whole framework in the x- and y-directions and rotation about the origin. Indeed, the dimension of the null space of the example rigidity matrix is generically 3, and the framework is infinitesimally rigid. Note that a rigid framework may not be infinitesimally rigid, as demonstrated by realizing the (rigid) triangle in the plane with its vertices collinear; the null space of its rigidity matrix has dimension 4.

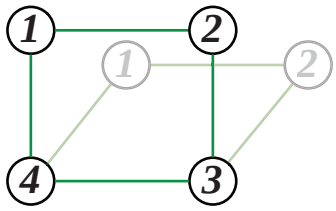
A pivotal theorem of Laman from 1970 [4] states that almost all realizations of a graph will have the same infinitesimal behavior, providing a characterization of "combinatorial rigidity" in the plane.

Theorem (Laman 1970)**.** *A graph $G = (V, E)$ with n vertices is generically minimally rigid if and only if*

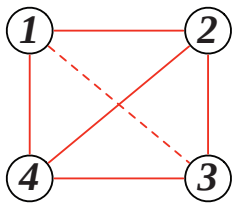
- $m = 2n - 3$, *and*



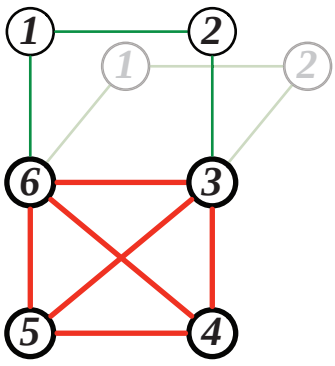
(a) The triangle is (minimally) rigid.



(b) The four-bar framework is flexible.



(c) Adding the solid diagonal to the four-bar framework causes it to be minimally rigid; with the other (dashed) diagonal, the framework is redundantly rigid.



(d) A flexible framework may contain a rigid component; here, red and bolded.

Figure 2. Bar-and-joint frameworks in the plane.

- $m' \leq 2n' - 3$ *for all sets of* $n' \geq 2$ *vertices, where* m' *is the number of induced edges.*

Notice that the framework in Figure 2(d) satisfies the first condition, but fails the second on the subset of vertices $\{3,4,5,6\}$. In an arbitrary dimension d, the first condition generalizes to $m = dn - \binom{d+1}{2}$; assuming this condition holds for a graph, the notion of *genericity*[1] can be captured by a polynomial called the "pure condition" expressing the determinant of the matrix obtained by appending $\binom{d+1}{2}$ rows to the rigidity matrix chosen so that the rows eliminate the trivial motions. In the plane, Laman's theorem holds precisely when this polynomial is not identically zero; in this case, almost all realizations of G are infinitesimally rigid and hence rigid.

Detection of rigid components can vastly reduce the complexity of analyzing large structures, such as proteins.

The counting condition characterizing rigidity in Laman's Theorem is called $(2,3)$-*sparsity*. More generally, (k,ℓ)-sparsity conditions require that the induced subgraph on every subset of n vertices has at most $kn' - \ell$ edges. These conditions arise as necessary (and sometimes also sufficient) conditions for rigidity in other constraint systems. For example, $(2,2)$- and $(2,3)$-sparsity conditions characterize the rigidity of *direction-length* frameworks, composed of points that may be pairwise constrained with a specified direction (the slope of the line joining the points) or length (a bar). To analyze a graph for Laman's counting condition, a quadratic-time algorithm, the *pebble game* of Jacobs and Hendrickson [3], determines if a framework is generically rigid or flexible. If it is flexible, the algorithm detects the rigid components in the structure.

Detection of rigid components can vastly reduce the complexity of analyzing large structures, such as proteins. These macromolecules are composed of thousands or even hundreds of thousands of atoms whose strongest chemical interactions, such as covalent bonds, can be modeled by distance constraints. Since a protein's function is determined by its 3-dimensional structure, understanding the motion or flexibility near its *native* (folded) state

[1] *A framework is referred to as generic in rigidity theory if it is "general" in the sense of algebraic geometry, meaning that it lies in the complement of the Zariski closed set defined by the vanishing of the pure condition.*

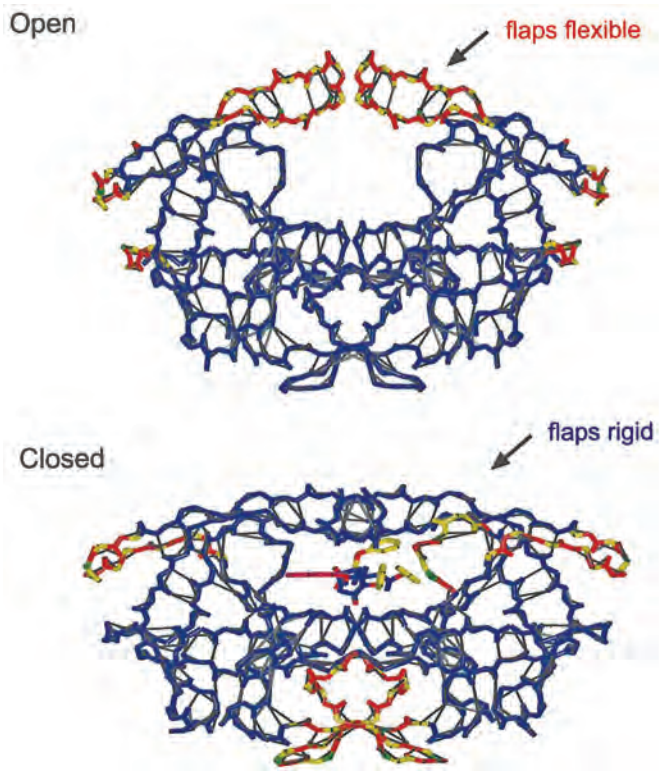


Figure 3. Rigidifying the flaps necessary for the HIV protease to cleave the virus required proteins, as in its closed state, would inhibit the protein's function.

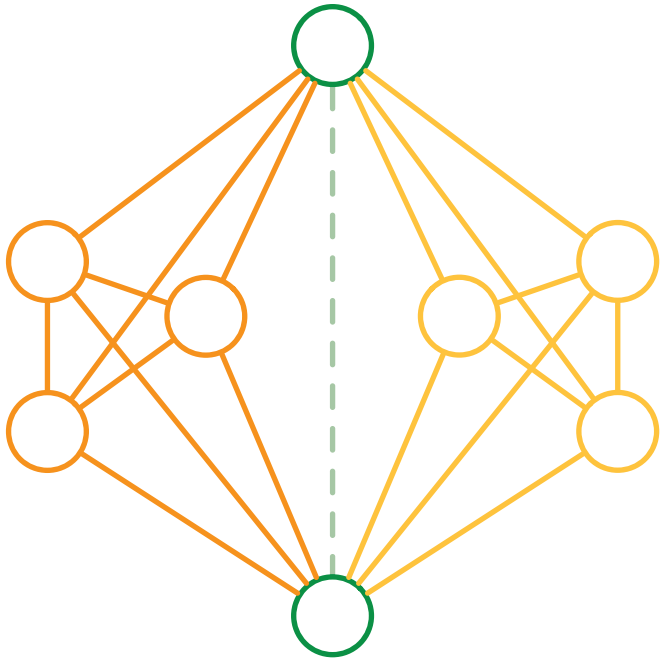


Figure 4. The double banana is a flexible 3D bar-and-joint framework, although it satisfies generalized $(3,6)$-sparsity counts. It is composed of 18 bars (solid) on 8 joints; the "bananas" can rotate about the center axis (green, dashed).

may hold the key for developing a drug that can inhibit or activate its function.

For example, the HIV-protease protein depicted in Figure 3 cleaves additional proteins required by the virus with a hinge-like motion similar to a pair of scissors. Blocking this motion by docking a drug that rigidifies the two flaps would inhibit the protease's function and prevent the virus from replicating.

It is natural to model proteins and other macromolecules as 3-dimensional bar-and-joint structures. However, efficient rigidity analysis is blocked by the following well-known open problem.

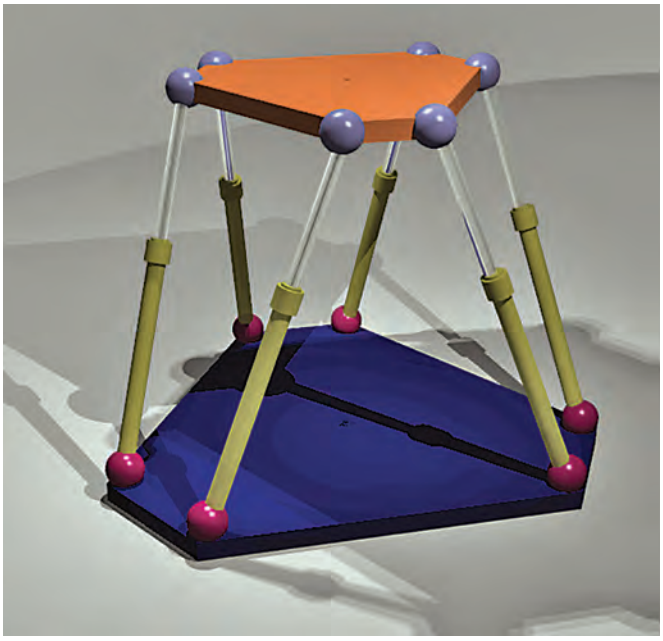
Question 3. Is there a combinatorial characterization for bar-and-joint rigidity in dimension 3 and higher?

The natural generalization of Laman's condition, the $(3,6)$-sparsity counting property, fails to capture rigidity, as demonstrated by the example of Figure 4 known as the "double banana."

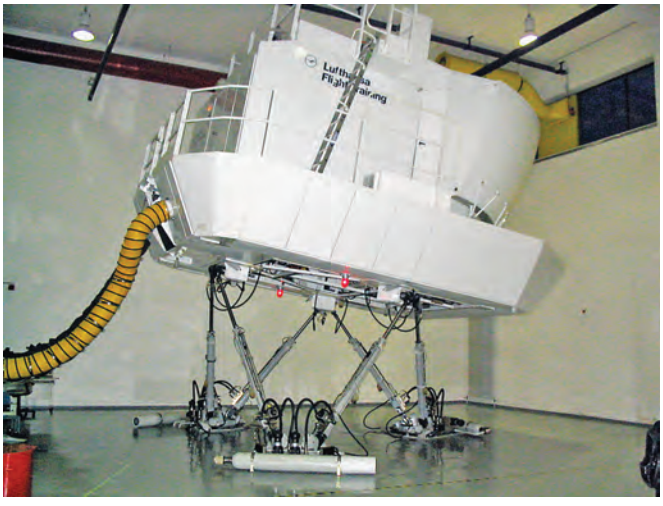
This framework is composed of two "bananas," each of which is made up of two tetrahedra glued along one triangular face. The expected $(3,6)$-sparsity counts hold for the associated graph, but the structure is flexible, as the bananas may rotate relative to one another about the axis defined by their two attachment points. While not sufficient, these counts are necessary, but even they are challenging to verify from an algorithmic perspective. They fall just outside a matroidal range; the efficient pebble game algorithm's approach is greedy and cannot be easily extended to these non-matroidal counts.

Because characterizing 3-dimensional bar-and-joint rigidity remains an open challenge, researchers turn to a different model of rigidity called the *body-and-bar* model. A body-and-bar framework is composed of rigid bodies, constrained by bars placed between pairs of bodies and attached at universal joints. A combinatorial characterization for d-dimensional body-and-bar rigidity proved by Tay in 1984 [5] uses a $(\binom{d+1}{2}, \binom{d+1}{2})$-sparsity condition, and a generalized pebble game has led to efficient analysis tools. Note that, in this model, a pair of bodies may have more than one bar between them. Indeed, a rigid framework in the plane consisting of two rigid bodies must have at least three bars. In 3D, engineers use the famous Stewart-Gough platform depicted in Figure 5 to build hexapods that support a range of positions by changing the lengths of the legs. Once the leg lengths are fixed, the structure becomes (generically) rigid and may be modeled as a body-and-bar framework with each platform a body and each leg a bar; as expected, the 6 bar constraints rigidify the framework.

The motivation to develop other rigidity models does not stem solely from the challenge of 3D bar-and-joint rigidity. For the mechanical engineer using CAD software, geometric constraints provide the language that describes a design. A stadium roof is composed of many parts, each of which is naturally modeled as a rigid body; the engineer



(a) Setting the lengths of the 6 prismatic legs of the platform allows different rigid realizations to be explored.



(b) Engineers use the platform to build hexapods, as seen in this flight simulator.

Figure 5. The Stewart-Gough platform can be modeled as a body-and-bar framework with each platform a rigid body and each leg a bar.

may specify the design by requiring, for example, that "this wooden beam must be at a particular angle to the outer wall." Such a structure may be modeled as a *body-and-cad framework*, composed of rigid bodies with geometric constraints beyond the point-point distance constraints allowed in the body-and-bar model. For example, we can impose constraints that fix the angle between the sides of two bodies or fix the distance between a point on one body and a line on another. The engineer expects that the CAD software will verify that the final design is rigid, both

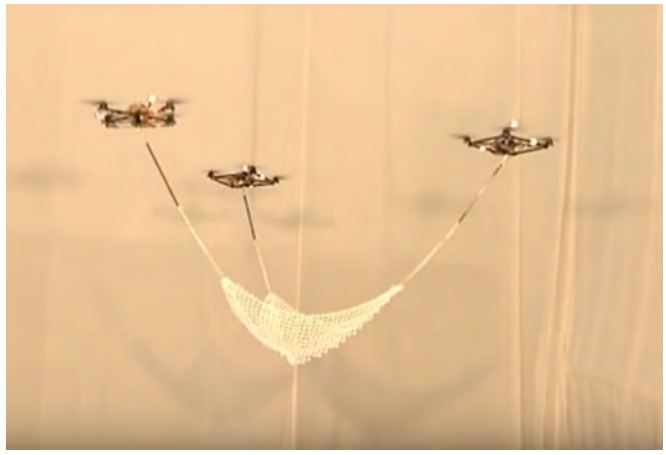


Figure 6. Robots work collaboratively to transport and manipulate objects, as seen in Raffaello D'Andrea's "Flying Machine Arena." Rigidity theory can be used to develop efficient algorithms for controlling a multi-robot formation autonomously.

for structural integrity and for ensuring that its geometry is completely specified.

So, what about when robots fly? If a swarm of robots is tasked with picking up a piece of rubble or something more delicate like a net (as in Figure 6), local communication and sensing can be used to enable autonomous maintenance of the required formation [2]. For example, robots may follow others using specified geometric constraints, such as fixed distance or orientation, resulting in global behavior. Efficient algorithms for analyzing the rigidity of this *multi-robot formation* can minimize communication and sensing costs, allowing the swarm to effectively perform its rescue operation.

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EDITOR'S NOTE. See the related "WHAT IS...a Tensegrity?" by Robert Connelly in the January 2013 issue of *Notices*.

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Jessica Sidman

Audrey St. John

ABOUT THE AUTHORS

Both authors are passionate about supporting women in STEM. They knew each other for years, but it took an undergraduate thesis to jump-start their collaboration. Along with Meera Sitharam, they are co-editors of the forthcoming *Handbook of Geometric Constraint Systems: Principles.*

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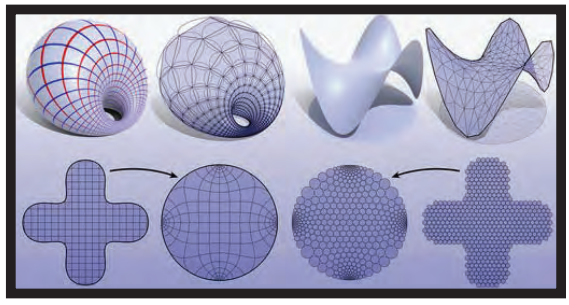

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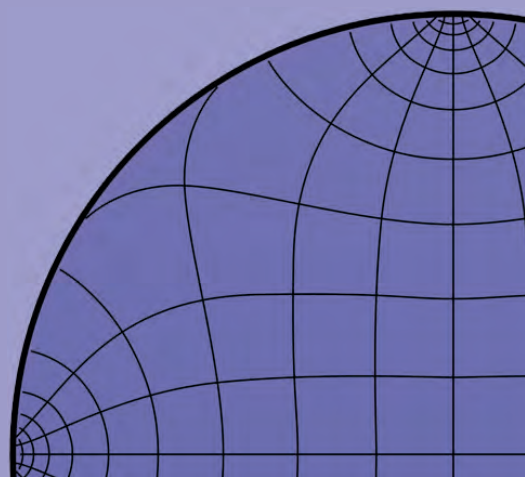

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Dido's Problem and Its Impact on Modern Mathematics

Catherine Bandle

ABSTRACT. We trace the isoperimetric problem from Queen Dido to some recent applications. Emphasis is put on the developments which are significant for the applications in analysis and in partial differential equations.

Ancient Time, Origin of the Problem

Dido Purchases Land for the Foundation of Carthage. Engraving by Matthäus Merian the Elder, in *Historische Chronica*, Frankfurt a.M., 1630. Dido's people cut the hide of an ox into thin strips and try to enclose a maximal domain.

Figure 1. Queen Dido enclosed maximal area with strips of the hide of a bull.

Dido's Problem

The Roman poet Publius Vergilius Maro (70–19 B.C.) tells in his epic *Aeneid* the story of queen Dido, the daughter of the Phoenician king of the 9th century B.C. After the assassination of her husband by her brother she fled to a haven near Tunis. There she asked the local leader, Yarb, for as much land as could be enclosed by the hide of a bull. Since the deal seemed very modest, he agreed. Dido cut the hide into narrow strips, tied them together and encircled a large tract of land which became the city of Carthage. Dido faced the following mathematical problem, which is also known as the *isoperimetric problem*:

Find among all curves of given length the one which encloses maximal area.

Dido found intuitively the right answer.

The Isoperimetric Problem in Antiquity

In those days a formula for the area A of a circle of given length L was known. The Babylonians used around 1800 B.C. the formula $A = \frac{2}{25}L^2$ instead of $A = \frac{1}{4\pi}L^2$. This approximation of π by 3.125 is quite accurate. In his short treatise *On the Measurement of the Circle*, Archimedes (285–212 B.C.) circumscribed and inscribed a 96-gon around and inside the circle and determined that $3.1408 < \pi < 3.14285$.

The Greeks were interested in the isoperimetric problem also for practical reasons. It was useful to have an upper limit for the area in order to prevent the merchants from cheating when they stated the area of an island by its circumference. In those times it was commonly believed that the perimeter of a figure determines its area.

Around 150 B.C. Zenodorus proved rigorously by elementary geometrical arguments:

(i) *if there exists an n-gon having the largest area among all n-gons of given perimeter, it must be regular;*
(ii) *among all regular polygons of equal perimeter the one with more sides has a greater area; and*
(iii) *the circle encloses a greater area than any regular polygon of equal perimeter.*

Does a maximal polygon exist at all? The ancient geometers were not concerned with this question. It was settled many centuries later, for instance by Weierstrass.

No substantial mathematical progress was made for almost 1,900 years on the isoperimetric problem. During all this time it was taken for granted that the circle has the largest area among all plane domains of given perimeter. Similarly, the astronomers believed that an analogous property is also valid for domains in space namely, that the ball has the largest volume of all domains of given surface area. A detailed description of the isoperimetric problem in ancient time is given in [5].

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Towards a Proof

The Eighteenth Century, Calculus of Variations

In 1744 Euler, motivated by the isoperimetric problem, which was suggested to him by the two brothers Johann and Jakob Bernoulli, laid down the foundations of the calculus of variations.

We shall explain his idea for a variant of Dido's problem where Dido wanted to secure access to the sea. Analytically it can be phrased as follows. Look for a graph $y(x), 0 < x < a$ with $y(0) = y(a) = 0$ and such that the area between $y(x)$ and the x-axis, $\int_0^a y(x)\,dx$, is maximal while the length, $L = \int_0^a \sqrt{1 + (y'(x))^2}\,dx$, is kept fixed.

Euler's idea was to reduce it to a finite-dimensional problem that can be handled with the standard method of calculus. He divided the interval $(0, a)$ into n intervals of equal length $x_{k+1} - x_k = h$ and searched for a polygon $\mathcal{P}(h)$ with the corners $C_k = (x_k, y_k)$ of given perimeter L and maximal area below its graph. He first solved this problem within the class of polygons with the corners C_k, $k \neq m, m+1$, $(x_m, y_m + \epsilon)$, and $(x_{m+1}, y_{m+1} + \delta)$, where ϵ, δ are free parameters. Letting $h \to 0$ he was able to show that the optimal graph $y(x)$ satisfies the *Euler-Lagrange differential equation* $\Phi_y - \frac{d}{dx}\Phi_{y'} = 0$, where $\Phi = y + \lambda\sqrt{1 + y'^2}$ and $\lambda \in \mathbb{R}$ is the Lagrange multiplier.

This so-called *Euler's polygon method* is still used for numerical treatment of ODEs.

Eleven years after the appearance of his treatise on the calculus of variations Euler received a letter from the nineteen-year-old Lagrange, who wrote that he had found a more general method. Instead of making pointwise changes, he perturbed the whole curve, the way it is still done today. Euler was very pleased and admitted that much deeper results could be obtained by Lagrange's approach.

Figure 2. Jacob Steiner applied symmetrization to Dido's problem.

The Nineteenth Century, Final Proofs of the Isoperimetric Problem

Many ingenious geometrical arguments were proposed by J. Steiner (1796–1863) to prove the isoperimetric property of the circle and the ball. He always took a figure that is not a circle or a sphere and showed that the area or the volume can be increased by keeping the perimeter fixed. Edler, based on one of Steiner's arguments, showed that any domain in the plane with the same perimeter as the circle has a smaller area. This completed the mathematical proof of the isoperimetric problem in the plane.

Steiner invented the technique of *symmetrization*, which has become a key tool in geometric analysis. The aim is to transform a set $\Omega \subset \mathbb{R}^n$ such that the volume (Lebesgue measure) remains unchanged and the perimeter decreases.

Steiner Symmetrization. Let Ω be a domain in $\mathbb{R}^n$. Denote by x an arbitrary point in $\mathbb{R}^{n-1}$ and by e_n the unit vector perpendicular to $\mathbb{R}^{n-1}$. For each $x \in \mathbb{R}^{n-1}$ consider the line $\ell_x := \{x + x_n e_n : x_n \in \mathbb{R}\}$. The 1-dimensional Lebesgue measure of the slice $\ell_x \cap \Omega$ will be denoted by $\mathcal{L}_1(x)$. ($\mathcal{L}_1(x) = 0$ if $\ell_x \cap \Omega = \emptyset$). The Steiner symmetrization of Ω with respect to the hyperplane $\mathbb{R}^{n-1}$ is the domain $S\Omega$, symmetrically balanced around $\mathbb{R}^{n-1}$ and which has the property that each slice $\ell_x \cap S\Omega$ is an interval of length $\mathcal{L}_1(x)$.

By Cavalieri's principle the volume of Ω is equal to the volume of $S\Omega$. The fact that the perimeter decreases is more subtle.

It is intuitive that after infinitely many symmetrizations with respect to all possible hyperplanes a body is transformed into a ball. Lusternik (1935) showed that there exist countably many symmetrizations S_k such that $\Pi_{k=1}^n S_k(\Omega) \to \Omega^*$ as $n \to \infty$,[1] where Ω^* is the ball with the same volume as Ω. By performing infinitely many symmetrizations with respect to hyperplanes containing the x_n-axis one obtains the

Schwarz Symmetrization. In this case every horizontal slice of Ω at the height $x_n = c$ is replaced by an $(n-1)$-dimensional ball of the same $(n-1)$-dimensional volume, centered at the x_n-axis at height c. A domain $\Omega \subset \mathbb{R}^3$ is

[1] *Here the convergence is with respect to the Blaschke metric* $d(A, C) := \inf h$ *such that* $A \subset C_h$, $C \subset A_h$ *where* A_h *and* C_h *are the exterior parallel sets of* A *and* C *at distance* h.

transformed by Schwarz symmetrization into a surface of revolution with the x_3-axis as axis of revolution.

Again, as for the Steiner symmetrization, the volume does not change and the perimeter does not increase.

This symmetrization together with the calculus of variations enabled H. A. Schwarz to give in 1884 the first rigorous proof of the isoperimetric property of the ball in the class of domains with piecewise analytic boundaries. He was also the first who pointed out the lack of an existence theorem in Steiner's proofs. It turns out—as we will see later—that the symmetrizations play a crucial role in modern analysis and in mathematical physics.

The isoperimetric problem in higher dimensions consists in finding among all domains of given perimeter the one with maximal volume. The solution is the ball. Its proof is much more delicate than in the plane. One reason is that the convex hull has not necessarily a smaller perimeter. It was solved in the most elegant way by means of an inequality derived by H. Brunn (1887) and H. Minkowski (1896) for convex sets and then generalized to nonconvex sets by L. A. Lyusternik (1935).

The Brunn-Minkowski Inequality. Let A and C be two domains in $\mathbb{R}^n$. Then the Lebesgue measure of the *Minkowski sum* $A + C$ is bounded from below by the Lebesgue measures of A and C as follows

$$|A + C|^{\frac{1}{n}} \geq |A|^{\frac{1}{n}} + |C|^{\frac{1}{n}}.$$

If $B(h)$ denotes the ball of radius h, centered at the origin, then $A + B(h) = A_h$ is the exterior parallel set at distance h. The limit inferior of the quotient $(|A_h| - |A|)/h$ as h tends to zero is called *Minkowski content* $\mathcal{M}(A)$ of A. For domains with smooth boundaries the Minkowski content coincides with the classical surface area. From $|A_h|^{\frac{1}{n}} - |A|^{\frac{1}{n}} \geq |B(h)|^{\frac{1}{n}}$ the isoperimetric inequality

$$n|B(1)|^{\frac{1}{n}}|A|^{\frac{n-1}{n}} \leq \mathcal{M}(A)$$

is immediate. Equality holds for the ball A^*.

Modern Times

Further Developments

The power of Steiner's work gave rise to a revival of the isoperimetric problem. A rich collection of geometrical and analytical proofs are now available, in particular for plane domains. It would be beyond the scope of this article to go into details. Interested readers are referred to the many reviews, books, and papers, for instance [2], [4], [7].

An interesting direction is the so-called *Bonnesen-type* inequalities for the *isoperimetric deficit* which measures how much a curve differs from a circle. Steiner made an important discovery that was exploited—at least in the plane and on two-dimensional surfaces—to tackle this problem. He observed that the volume and the perimeter of an exterior parallel set of a convex body at distance h can be expressed as a polynomial in h. For example, in two dimensions the area $A(h)$ and the perimeter $L(h)$ of Ω_h are expressed as follows:

$$A(h) = A(0) + L(0)h + \pi h^2, \text{ and } L(h) = L(0) + 2\pi h.$$

This implies that $L^2(h) - 4\pi A(h)$ is independent of h. If it were possible to show that for a parallel curve it is positive, the isoperimetric inequality would follow. Unfortunately, the exterior parallel curves don't seem suitable for such a conclusion.

A remedy was proposed by Bol. He studied the deficit of the interior parallel sets. Even for a smooth domain, $\Omega_{-h} := \{x \in \Omega : \text{distance}\{x, \partial\Omega\} > h\}$ has more and more corners and spikes as the distance increases. It is not clear at first if their boundary curves $\partial\Omega_{-h}$ are rectifiable. By a clever trick, Sz.-Nagy showed that for a simply connected domain the perimeter $L(-h)$ of Ω_h is usually rectifiable and satisfies for almost all h the inequalities

$$A(0) \leq A(-h) + L(0)h - \pi h^2 \text{ and } L(-h) \leq L(0) - 2\pi h.$$

This implies that $4\pi A(0) - L^2(0) \leq 4\pi A(-h) - L^2(-h)$, and the isoperimetric inequality follows.

The method of interior parallel curves was successfully generalized by Bol and later by Fiala and Hartmann to simply connected domains on two-dimensional surfaces, bounded by a Jordan curve of class C^2. A. D. Alexandrov extended these results by polyhedral approximation and A. Huber proved Fiala's inequality by methods of potential theory. A survey of this topic is found in Osserman's papers [6], [7].

The extension of the Bonnesen-type inequalities—which today are rather known as *quantitative isoperimetric inequalities*—has attracted many mathematicians, for instance Fusco and his collaborators, and has led to extensive and excellent research.

The isoperimetric property of the ball holds also in spaces of constant curvature such as the sphere and the hyperbolic space in general dimensions. The first lengthy proof for arbitrary dimensions is due to Schmidt (1943). Many shorter alternatives are now available.

For application in crystallography anisotropic inequalities are of interest. The anisotropic surface energy is a generalization of the perimeter. The problem is to find the set of given measure for which this energy is minimal. The best known result in this direction is *Wulff's inequality.*

Notions of Perimeter[2]

In the plane the definition of the perimeter is straightforward. If the boundary curve is *rectifiable*, it is the supremum of the perimeters of the polygon approximations. If it is not rectifiable we set $L = \infty$. In higher dimensions the definition for nonsmooth domains causes some problems. Several notions have been proposed that apply to boundaries with all kinds of wiggles. Especially for applications in the calculus of variations it is desirable to have a perimeter that is lower semicontinuous with respect to domain convergence. This is not the case for the $(n-1)$-dimensional Hausdorff measure $\mathcal{H}^{n-1}$ nor for the Minkowski content $\mathcal{M}$.

The definition that is now standard in analysis is the perimeter of Caccioppoli and De Giorgi. In geometric terms it is described as follows. If Ω is measurable and

[2] *See "WHAT IS... Perimeter" in this issue of Notices, page 1009.*

$\mathcal{P} = \{P_i\}_1^\infty$ is a series of polyhedra converging to Ω, then the *perimeter of Caccioppoli and De Giorgi* is defined by

$$P(\Omega) = \inf_{\mathcal{P}}(\liminf \mathcal{H}^{n-1}(\partial P_i)).$$

Analytically it is given by

$$P(\Omega)=\sup\left\{\int_\Omega \operatorname{div}\phi\, dx : \phi\in C_0^\infty(\Omega,\mathbb{R}^n), \max\sum_{k=1}^n \phi_k^2(x)\le 1\right\}.$$

De Giorgi has shown that it is lower semicontinuous and satisfies the isoperimetric inequality. Moreover $P(\Omega) \le \mathcal{H}^{n-1}(\Omega)$.

Analytic Tools

In analysis the method of symmetrization leads to a useful transformation of measurable functions $u : \Omega \to \mathbb{R}^+$. Denote by $\mu(t)$ its distribution function $|\{x \in \Omega : u(x) > t\}|$. As before we write A^* for the ball of the same volume as $A \subset \mathbb{R}^n$, centered at the origin. The *Schwarz symmetrized (rearranged)* function $u^* : \Omega^* \to \mathbb{R}^+$ has the same distribution function as u and its level surfaces are balls. Its main properties are:

1. $\int_\Omega g(u)\, dx = \int_{\Omega^*} g(u^*)\, dx$ for any continuous function $g : \mathbb{R} \to \mathbb{R}$;
2. if u vanishes on the boundary and if $p > 1$, then $\int_\Omega |\nabla u|^p\, dx \ge \int_{\Omega^*} |\nabla u^*|^p\, dx$.

These properties are valid for large classes of functions. Talenti (1976) was the first who extended them to functions belonging to Sobolev spaces. For additional properties of the symmetrization of functions and further references see Brock's survey article [3].

An opposite transformation of the symmetrization is the *harmonic transplantation*. It arose from the conformal transplantation in complex function theory and was introduced by Hersch (1969). In this case a radial function $u : B(R) \to \mathbb{R}^+$ is transformed into a function $U : \Omega \to \mathbb{R}^+$ by means of the Green's function. If Ω has the *harmonic (conformal) radius* R, then $\int_\Omega |\nabla U|^p\, dx = \int_{B(R)} |\nabla u|^p\, dx$ and for any continuous, positive function g there holds $\int_\Omega g(U)\, dx \ge \int_{B(R)} g(u)\, dx$.

A further link between analysis and geometry is the *co-area formula* relating an integral to integrals over slices by level sets of a function u. Let $u : \Omega \to \mathbb{R}$ be Lipschitz, hence almost everywhere differentiable. Then for any measurable $g : \Omega \to \mathbb{R}$

$$\int_\Omega g(x)|\nabla u(x)|\, dx = \int_{\mathbb{R}} \left(\int_{u^{-1}(t)} g(x) d\mathcal{H}^{n-1}(x)\right) dt.$$

Fleming and Rishel have extended this formula to functions whose distributional gradient is of bounded variation. One has

$$\int_\Omega |\nabla f|\, dx = \int_{\mathbb{R}} P_\Omega\{x \in \Omega : f(x) > t\}\, dt, \qquad (P_\Omega(A) = P(A \cap \Omega)).$$

This relation applies also to functions in Sobolev spaces.

Applications

Mathematical Physics

There are several physical quantities that depend on the shape of the domain and for which the ball is optimal. Pólya and Szegö have made extensive use of symmetrizations to treat such problems.

It is now customary to call an inequality *isoperimetric* if it relates quantities associated with the same domain and if the equality sign is attained for some domain. The history of isoperimetric inequalities in mathematical physics began with the conjectures of St. Venant (1856) for the torsional rigidity and of Rayleigh (1877) for the principal eigenvalue of a membrane. For more information on this topic see for instance [8], [1], [3]. The strength of symmetrization shall be illustrated by

The Rayleigh-Faber-Krahn Inequality. Let Δ be the Laplace operator and consider the eigenvalue problem $\Delta\phi + \lambda\phi = 0$ in the domain Ω and $\phi = 0$ on the boundary $\partial\Omega$. The lowest eigenvalue is characterized by the Rayleigh principle

$$\lambda_1(\Omega) = \inf_{C_0^\infty(\Omega)} \frac{\int_\Omega |\nabla v|^2\, dx}{\int_\Omega v^2\, dx}.$$

By symmetrizing the trial functions and using the properties of the symmetrized functions mentioned above we conclude that $\lambda_1(\Omega) \ge \lambda_1(\Omega^*)$. In the same way Talenti (1976) computed the best Sobolev constants.

Symmetrizations and PDEs

Symmetrizations can be used not only to estimate energies related to elliptic and parabolic problems, but also to derive information on the distribution function of the solutions [1], [3]. This topic has attracted many mathematicians and has been exploited in all possible directions.

We describe this idea with the simple problem $\Delta u + 1 = 0$ in $\Omega \subset \mathbb{R}^2$ with $u = 1$ on $\partial\Omega$. Denote by $\mu(t)$ the area of $\Omega_t := \{x : u(x) > t\}$ and by $L(t)$ its perimeter. Then integration over Ω_t implies that $\oint_{\partial\Omega_t} |\nabla u|\, ds = \mu(t)$, where s denotes the arclength. The co-area formula together with Sard's lemma yields for almost every $t > 0$

$$-\mu'(t) = \oint_{\partial\Omega_t} \frac{ds}{|\nabla u|}.$$

By the isoperimetric and the Schwarz inequalities we get for almost every t

$$4\pi\mu(t) \le L^2(t) \le \oint_{\partial\Omega_t} |\nabla u| ds \oint_{\partial\Omega_t} \frac{ds}{|\nabla u|} d\mathcal{H}^1 = \mu(t)(-\mu'(t)).$$

Consequently $4\pi t \le -\mu(t) + |\Omega|$ and thus $u^* \le U$, where U is the solution in Ω^*.

Shape Derivatives and Optimization

A direct approach to characterize the optimal domain is the variation of domains. In the spirit of calculus this can be done by studying the volume and the perimeter of infinitesimal changes of the domain. Suppose that $\Omega \subset \mathbb{R}^{n-1}$ is a smooth domain and let ν be its outer normal. If we displace each point on $\partial\Omega$ by the vector $t\eta\nu$,

where η is a smooth function on $\partial\Omega$, we obtain for small $t \in (-\epsilon, \epsilon)$ a family of domains Ω^t. Their perimeter is $P(t)$ and their volume $V(t)$. The first variations (shape derivatives) at $t = 0$ are

$$\frac{dV}{dt}(0) = \oint_{\partial\Omega} \eta d\mathcal{H}^{n-1} \text{ and } \frac{dP}{dt}(0) = -\oint_{\partial\Omega} H\eta d\mathcal{H}^{n-1},$$

where H is mean curvature of $\partial\Omega$. From here it is not difficult to infer that the solution of the isoperimetric problem must be a surface of constant mean curvature. This type of argument is now widely used to treat problems in shape optimization.

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Catherine Bandle

ABOUT THE AUTHOR

Catherine Bandle's areas of expertise include elliptic and parabolic partial differential equations, the calculus of variations, and shape optimization.

Associate Editor, Mathematical Reviews
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OPINION

Ensuring That Mathematics is Relevant in a World of Data Science

Johanna S. Hardin and Nicholas J. Horton

Communicated by Benjamin Braun

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

ABSTRACT. We propose two new courses in continuous and discrete mathematics to provide essential mathematical underpinnings of the rapidly growing new field of data science.

The recent growth of data science has been remarkable. Analysts now have rich data and powerful computational tools to help answer important questions. Examples of ways that insights can be wrangled from this information abound in diverse areas. This has led some to dub computational thinking (or fluency) as the "new literacy" on par with writing and quantitative skills. A major unanswered question relates to the role of mathematics in the training of future data scientists. How can we be sure that data science is on a firm mathematical and statistical foundation? In this article, we will consider what courses in mathematics would best prepare future data scientists.

Background and Brief History

Some institutions have responded to the development of data science by creating innovative new programs. At the University of California, Berkeley, the Data 8 introductory course (`data8.org`) is now offered to a large proportion of incoming students, with connector courses on topics such as genomics, neuroscience, cultural data, social data, demography, smart cities, ethics, and social networks (as well as courses in statistics and mathematics). Many (most?) other four-year colleges and universities are responding with their own initiatives.

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While data science is often described as a new discipline, those in the mathematical sciences have been engaged with data science for decades. In a widely referenced call to action, Donoho [4] quotes noted statistician John Tukey from 1962 who presaged "an as-yet unrecognized science, whose subject of interest was learning from data, or 'data analysis.'" Donoho describes the history of data science as a new field and speculates about a future that brings together statistics and machine learning by marrying computational and inferential methods. His proposed "Greater Data Science" includes six main divisions (see sidebar, next page).

David Donoho's Six Main Divisions for a "Greater Data Science" (Donoho, 2017) [4]

- Data exploration and preparation: addresses the 80% (or more) of data wrangling needed prior to analysis.
- Data representation and transformation: including modern databases and special types of data.
- Computing with data: multiple environments, high-performance computing, and workflow.
- Data visualization and presentation: as a way to explore and present results in static or dynamic form.
- Data modeling: including both generative (stochastic model) and predictive (modern machine learning).
- Science of data analysis: described as one of the most complicated of all sciences.

What Mathematical Preparation Do Future Data Scientists Need?

What training is needed for data scientists to be able to extract meaning from data? This question was the topic for discussion by several working groups of the National Academy of Sciences as well as a working group from the 2016 Park City Mathematics Institute. The potential for missteps, overgeneralization, and inferential errors abounds. One of the challenges in training the next generation of students to think with data is to ensure that they have sufficient background in the mathematical sciences to provide a firm foundation for their future work in data science.

Unfortunately, many new data science programs have arisen that provide little or no formal preparation in the theoretical (mathematical, statistical, and computational) underpinnings of this new field. While data science programs should appropriately focus on applications and practice, underlying many approaches is the use of modeling, a topic very familiar to the mathematical sciences, and abstraction, which underlies modern mathematics, statistics, and computational science. Practitioners need to understand when methods are applicable, where they are robust to underlying assumptions, and the potential for misbehavior. The danger is that students who skip out on math completely run the peril of black box thinking, with no understanding of the *uncertainties* and *limitations* of models and algorithms. We argue that key concepts in statistics and mathematics undergird data science and that these essential aspects are needed as a foundation for data science. Additionally, we believe that mathematicians should become directly involved in curricular decisions with respect to new data science programs.

What kind of training in mathematics would be ideal for a future data scientist? It is not, we argue, the same training as would be ideal for a future mathematician. The proposal we outline below (two new courses on mathematics for data scientists) creates a path for integration of mathematics into data science. These new courses would not replace existing paths, since different preparation is needed for students who will be pursuing graduate degrees in mathematics.

Computer scientists, statisticians, and mathematicians assembled at Park City Mathematics Institute during the summer of 2016 to propose guidelines for the discipline of data science (De Veaux et al. 2017[3]). The group suggested that data science majors would indeed be well prepared by three semesters of calculus (including single and multivariable), linear algebra, discrete math, and probability (in addition to several courses in statistics). They also noted, however, that such a course progression is not feasible for all students: it is not realistic for students to build a mathematical foundation that consists of such a long string of prerequisite courses before starting courses within their own data science curriculum. (Even if space could be made, the leakiness of lower-division pathways is a continuing problem; see the TPSE Math website `www.tpsemath.org`.)

Project INGenIOuS (Investing in the Next Generation through Innovative and Outstanding Strategies)[1] focused on ways that the mathematical sciences could help prepare the next generation of STEM students. The joint report by the AMS, MAA, SIAM, and ASA highlighted the importance of alternative curricular pathways and new approaches to teaching to ensure that the mathematical sciences are not left out of the growth of data science and other innovative interdisciplinary programs: "Curricula in the mathematical sciences traditionally aim toward upper-level majors' courses focused on theory. Shorter shrift is usually given to applications that reflect the complexity of problems typically faced in BIG (Business/Industry/Government) environments, and to appropriate uses of standard BIG technology tools."

Students who skip out on math completely run the peril of black box thinking.

How can the mathematics community respond to the challenge being posed by the growth of data science? We don't have all the answers, but we see the mathematical sciences as a key component of a vibrant and useful data science curriculum that provides students with a solid theoretical foundation. We suggest that the solution is to make changes to the mathematics and data science curricula to give future data scientists a glimpse into the power of mathematics and statistics for modeling and understanding a larger quantitative framework. Our fear is that the important mathematical foundational ideas will get lost if alternate pathways are not developed.

Mathematics Preparation

What then is needed in terms of mathematical preparation? In order for students to be able to function effectively in the world of data science, we believe that mathematics

[1] `www.maa.org/programs/faculty-and-departments/ingenious`

departments need to consider developing additional entry points as service courses.

We propose two new courses, one discrete and one continuous, which intertwine abstraction, modeling, and problem solving. The idea of two new courses comes directly from the PCMI report:

> Mathematically speaking, the emphasis of an undergraduate data science degree should be on choosing, fitting, and using mathematical models. Because data-driven problems are often messy and imprecise, students should be able to impose mathematical [ideas] on [data science] problems by developing structured mathematical problem-solving skills. Students should have enough mathematics to understand the underlying structure of common models used in statistical and machine learning as well as the issues of optimization and convergence of the associated algorithms. Although the tools needed for these include calculus, linear algebra, probability theory, and discrete mathematics, we envision a substantial realignment of the topics within these courses and a corresponding reduction in the time students will spend to acquire them.

Proposed New Course 1—Mathematical Foundations I: Discrete Mathematics

The first proposed mathematics course formalizes the connections between mathematics and discrete model building and thus leads naturally to more sophisticated topics and extensions in terms of continuous distributions, multivariate relationships, and causal inference. Combinatorial techniques can provide concrete pathways for explicitly conceptualizing models and their limitations. Linear algebra allows ideas of multivariate relationships, including independence. Many computer science departments teach a discrete course in their own departments. We suggest that unfortunately those courses often focus more on algorithms than on more desirable discrete models, to be used to conceptualize and model actual data and real-world scenarios and further develop the ability to problem solve using mathematics. Key discrete mathematical topics that would help a data scientist to model and describe data effectively include:

- Linear algebra: ideas of independence/invertibility, Markov models and eigenvalues;
- Counting principles: understanding of first principles related to randomness;
- Computational (discrete) simulations associated with continuous models;
- Graph theory: understanding confounding, causal inference and analysis of network data.

Proposed New Course 2—Mathematical Foundations II: Continuous Mathematics

A key aspect to modeling in data science is optimization. Part of what makes a model appropriate has to do with its boundaries, maximal values, and sensitivity to parameter choices—all features that use mathematical optimization. In statistics, one foundational method is to find parameter estimates by maximizing the relevant likelihood. Alternatively, in other mathematical models, the goal might be nonlinear state-space system identification. In both cases, a solid foundation of calculus, differential equations, and numerical methods techniques will allow the data scientist to solve the problem at hand. However, we argue that understanding how to find simple minima and maxima acts as a vehicle for understanding what optimization means at a fundamentally intuitive level. We recognize that the ideas below are typically taught across many semesters. We are suggesting that much of the content will be removed or taught differently so as to emphasize the critical mathematical components necessary for data science. (For a model of such a course, see MATH 135, Applied Calculus, taught at Macalester College to a large fraction of the undergraduate population.)

To this end, the continuous mathematics course we suggest focuses on understanding the continuous mathematical ideas necessary for problem solving. Some key topics to be incorporated into such a course might include:

- Functions and basic mathematical logic;
- Enough calculus to understand the ideas of partial derivatives (interactions in a model);
- Taylor expansion method of approximating functions;
- Probability as area/integration;
- Multivariate thinking (functions, optimization, integration).

The Importance of Computing

To be relevant to the broader data science curriculum, the proposed mathematics courses need to be heavily infused with computing. As the MAA CUPM guidelines[2] recommend, mathematics students should not only learn to use technological tools (Cognitive Recommendation 3), but the mathematics programs should include methods which promote data analysis, computing, simulation, and mathematical modeling (Content Recommendation 3). We believe that these recommendations are even more important for future data scientists.

One aspect of integrating computing into the mathematics curriculum is a plea for mathematicians to connect more with computer scientists. If the computer scientists believe that mathematicians care only about theory, without understanding the challenges in the real world, it will be difficult to have a two-way exchange of information across the fields. Indeed, we believe that the computing world would do well to embrace theoretical constructs; but this will only come when the mathematical world is willing to embrace computation.

Integrating computing into the mathematics curriculum not only gives students computational skills, but additionally allows students to understand the mathematical theory more completely. As the CUPM guidelines state:

> In courses at all levels, substantial and realistic applications involve "messy" mathematics that makes calculation by hand onerous or infeasible. Using

[2] www.maa.org/programs/faculty-and-departments/curriculum-department-guidelines-recommendations/cupm

technology opens the door for students to set up solution strategies, justify their analyses, and interpret the results.

Using computational skills to simulate produces a deeper understanding of the model and complements analytic solutions. Additional computing will help develop better problem solvers and may yield additional mathematics majors drawn to the power and beauty of what they see in these courses.

While this article focuses on mathematical preparation, we believe that statistical preparation is also critically important. In recent years, the statistics community has taken on the challenge to improve their existing curriculum in order to ensure that statistical courses incorporate theoretical concepts, computation, and statistical practice. See for example the revised *Guidelines for Assessment and Instruction in Statistics Education* (GAISE) college report [1] and the ASA revised *Guidelines for Undergraduate Programs in Statistics* [2]. The latter report recommends that introductory and intermediate statistics courses:

- Be an integral part of a data science curriculum;
- Incorporate reproducible research using statistical software, such as R Studio, Python notebooks, or GitHub, and
- Use modern and relevant real data, possibly obtained through data scraping.

Closing Thoughts

We see the world of data and modeling changing quickly. As mathematicians and statisticians we need to be proactive about what our disciplines have to offer. Mathematics will be better off if it is part of the solution. Data science will be on a better foundational footing if it starts with mathematical first principles: abstraction and modeling. From teaching students for many years, we understand at a visceral level how difficult it is for undergrads to grasp the benefits of generality and abstraction. Ensuring that they see the mathematical conceptual framework early and often will help make for better data scientists. In addition, abstraction is a key component of computer science.

Mathematics will be better off if it is part of the solution.

We argue that mathematics needs to meet the growing data science community halfway so that the analysis and models leverage vital foundational mathematical concepts. If not, we run the risk that math will be left out. We have proposed one pathway to provide mathematical sophistication for beginning data scientists.

Our deliberately provocative suggestions, which build on the PCMI guidelines and the supplementary material therein, will not necessarily be easy to implement for many mathematics departments, given multiple competing interests and limited resources. However, we implore the community of mathematicians to take our suggestions seriously and engage in curricular discussions at their institutions so as to provide a strong theoretical framework to the world of data science and ensure that mathematics is not left behind. We look forward to working with our colleagues to develop multiple alternative approaches along the lines of those outlined by the Park City group in 2016.

EDITOR'S NOTE. You can read about MAA's StatPREP.org, helping instructors teach with data, in the April/May 2017 *MAA FOCUS*: bit.ly/2rm77Za

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Jo Hardin

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OPINION

Flexibility in the Mathematics Major Would Benefit Students and Society

by William Yslas Vélez

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

Mathematics and engineering have been undergraduate majors at US universities since the early 1900s. To meet the technological changes that occurred in the last hundred years, the career paths of engineers and mathematicians changed, and engineering has expanded by adding several specialties. In 1950 the College of Engineering at the University of Arizona (UA) had three degree programs: mechanical, civil, and electrical. Now at the UA there are 14 different engineering programs, including Engineering Management, which prepares engineers to run a business, become entrepreneurs, and launch their own high-tech firms. Why aren't we all providing mathematics majors the option for exactly this kind of training?

We should be providing math majors with a flexible program for a variety of careers.

What happened to the mathematics major over this same time period? In 1950, at the UA (similarly at San Diego State (SDSU) and the University of California, Los Angeles (UCLA)) the mathematics major consisted of 24 units, with 12 of those having to be upper division. Neither abstract algebra nor linear algebra was offered at the undergraduate level at the UA or SDSU. By 1965 the programs of study had morphed into programs we would all recognize. The number of required units went to the mid 30s and the core program of study required analysis (convergence and continuity using ε–δ), abstract algebra, linear algebra, complex variables, and perhaps topology.

Vélez with four math majors: Craig Gross, Philippa Pinnington, Alexis Jane Torre, and Axel Gomez Casarez.

What changed in the mathematics program of study in the 50 years since 1965? For many departments, the requirement for the mathematics degree is the same core that was in place 50 years ago. Are we preparing undergraduate mathematics majors as classicists or as mathematical scientists, prepared to address today's

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problems with analytical thinking applied with modern technological tools?

A common view among mathematicians is that there are two standard paths for mathematics majors, becoming a high school mathematics teacher or pursuing graduate studies in mathematics. A recent *Notices* report [1] provides an estimate of 15 percent for the percentage of mathematics majors who pursue graduate studies in the mathematical sciences (mathematics, applied mathematics, statistics, and biostatistics). It would be difficult to call undergraduate programs successful if their vision is for their graduates to pursue graduate training in the mathematical sciences and this percentage is around 15 percent. Given that statistics and biostatistics and many graduate programs in applied mathematics do not require abstract algebra, it is possible that the percentage of mathematics majors who pursue graduate programs in pure mathematics is less than five percent. How can we offer a program of study for five percent of our undergraduate majors and make all the other mathematics majors go through this program? Worse, this view of mathematical training completely dominates our upper-division courses, which other majors may not find germane.

Perhaps it is the name of the major that is the problem.

We should be preparing students to use their mathematical training to pursue challenges in business, science, and industry. Instead of abstract algebra and analysis, these students would benefit from differential equations, probability and statistics, data analysis, and computational mathematics. Fortunately, we do have evidence of change. The departments that I mentioned above have created options that are more flexible, that allow students to graduate as mathematics majors without courses in abstract algebra and analysis. The University of California, Merced has gone even further. Its department is called Applied Mathematics, not Mathematics. They do not offer year-long courses in abstract algebra or analysis.

Here might be the crux of the matter. Should students who do not study abstract algebra and analysis be called mathematics majors? Perhaps it is the name of the major that is the problem! The name conjures up the training that faculty had for graduate school. If we renamed the undergraduate major or accepted that the undergraduate major would not lead necessarily to graduate school in the mathematical sciences, then a department might be more willing to accept that mathematical training should be different from what it was 50 years ago. There are a growing number of departments that are doing just this.

Mathematics departments with a small number of faculty may not have the resources to offer different options to students, so they select the standard path, abstract algebra and analysis. For those programs I would ask: How many of your students pursue graduate programs in pure mathematics? How many non-majors take your upper-division mathematics courses? Might your students be better served by offering a program of study that prepares them for a broader array of careers?

Of course, a non-traditional program of study does have a drawback: mathematical talent or interest can appear late in a student's undergraduate career making it impossible to take those courses preparatory for graduate studies in the mathematical sciences. We need to address this. There are currently a few post-bac programs whose function is exactly this: to help students transition from a BS degree that did not provide them with the material necessary to pursue graduate programs in the mathematical sciences. In fact, these post-bac programs are models of what could be a much more effective program for the mathematical sciences. Undergraduate programs could provide a different and broader undergraduate curriculum, thereby increasing the mathematical preparation of more students, and for those students who find an increased interest in mathematics, a one-year post-bac program could then provide preparation for graduate school.

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The photo of Velez and the math majors is courtesy of the University of Arizona Math Department.
The author headshot is courtesy of William Yslas Vélez.

ABOUT THE AUTHOR

Even when building walls, **William Yslas Vélez** wears a hat and tie.

William Yslas Vélez

Statistics on Women Mathematicians

Compiled by the AMS

At its August 1985 meeting the Council of the AMS approved a motion to regularly assemble and report in the *Notices* information on the relative numbers of men versus women in at least the following categories: membership in the AMS, invited hour addresses at AMS meetings, speakers at Special Sessions at AMS meetings, percentage of women speakers in AMS Special Sessions by gender of organizers, and members of editorial boards of AMS journals.

It was subsequently decided that this information would be gathered by determining the gender of the individuals in the above categories based on name identification if no other means was available and that additional information on the number of PhDs granted to women would also be collected using the AMS-ASA-IMS-MAA-SIAM Annual Survey. Since name identification was used, the information for some categories necessitated the use of three classifications:

Male: names that were obviously male

Female: names that were obviously female

Unknown: names that could not be identified as clearly male or female (e.g., only initials given, non-gender-specific names, etc.)

The following is the thirty-first reporting of this information. Updated reports will appear annually in the *Notices*.

Invited Hour Address Speakers at AMS Meetings (2007–2016)

Male:	333	80%
Female:	82	20%
Unknown:	0	0%
Total:	415	

Speakers at Special Sessions at AMS Meetings (2012–2016)

Male:	13,267	75%
Female:	3,774	21%
Unknown:	677	4%
Total:	17,718	

Percentage of Women Speakers in AMS Special Sessions by Gender of Organizers (2016)

Special Sessions with at Least One Woman Organizer

Male:	1,034	63%
Female:	407	25%
Unknown:	190	12%
Total:	1,631	

Special Sessions with No Women Organizers

Male:	1,354	69%
Female:	347	18%
Unknown:	249	13%
Total:	1,950	

Trustees and Council Members

	2016		2015		2014		2013	
Male:	26	62%	23	55%	23	56%	23	62%
Female:	16	38%	19	45%	18	44%	14	38%
Total:	42		42		41		37	

2016 Members of the AMS Residing in the US

Male:	8,966	40%
Female:	1,699	8%
Unknown:	11,848	53%
Total:	22,513	

Members of AMS Editorial Committees

	2016		2015		2014		2013		2012		2011		2010		2009		2008		2007	
Male:	161	80%	173	80%	179	81%	182	82%	178	83%	176	83%	176	82%	178	84%	168	83%	194	84%
Female:	41	20%	73	20%	43	19%	40	18%	37	17%	37	17%	39	18%	34	16%	35	17%	36	16%
Total:	202		216		222		222		215		213		215		212		203		230	

PhDs Granted to US Citizens

	2016		2015		2014		2013		2012		2011		2010		2009		2008		2007	
Male:	683	73%	636	72%	664	72%	627	73%	621	72%	574	72%	564	71%	515	69%	431	69%	396	69%
Female:	249	27%	244	28%	256	28%	230	27%	242	28%	228	28%	225	28%	227	31%	191	31%	180	31%
Total:	934		880		920		857		863		802		790		742		622		576	

Euphemia Lofton Haynes: Bringing Education Closer to the "Goal of Perfection"

Susan E. Kelly, Carly Shinners, Katherine Zoroufy

Figure 1: Haynes was named Lady of the Year by the DC "Oldest Inhabitants" in 1967.

Martha Euphemia Lofton Haynes was the first African American woman to receive a PhD in mathematics. She grew up in Washington, DC, earned a bachelor's degree in mathematics from Smith College in 1914, a master's in education from University of Chicago in 1930, and a doctorate in mathematics from The Catholic University of America in 1943. Haynes spent over forty-five years teaching in Washington, DC, from elementary and secondary level to university level. She was active in many community service organizations where she served in leadership roles and received numerous honors, including being named a Fellow of the American Association for the Advancement of Science and being awarded a Papal Medal. She was a member of the Washington, DC, school board from 1960 to 1968, serving as president from June 1966 through July 1967. She played a leadership role in ending the tracking system, which she argued discriminated against African American students by assigning them to education tracks that did not prepare them for college. This fight culminated in the 1967 Hobson v. Hansen court case, in which the judge ruled that tracking was discriminatory towards poor and minority students.

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Carly Shinners and Katherine Zoroufy began their work on this project as an undergraduate research project directed by Kelly.

*The phrase "Goal of Perfection" is from Haynes's "*Mathematics–Symbolic Logic" *1945 address* [3].

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Setting the Stage

Seldom does the story of one's life begin at birth. In documenting the life and accomplishments of Haynes, it is important to also look at some of the history that sets the stage for her life. Haynes was born on September 11, 1890, in Washington, DC [2], just twenty-five years after the end of the United States Civil War. This location, the time period, and her race played major roles in shaping her life.

Washington, DC, by its very nature has always been unique. This is illustrated in its history related to race. The Declaration of Independence calls it "self-evident" that "all men are created equal," yet slavery was allowed to continue. George Washington was a slave owner. The White House and Capitol Building were built by slaves. Philip Reid, a slave, worked on the *Statue of Freedom,* which sits atop the Capital dome. Slaves, some likely owned by Martha Washington, excavated the sandstone used to build the Smithsonian Castle on the National Mall. In 1800 one fourth of DC's population was African American, and most of them were slaves. By 1830 the majority of African Americans in the capital were free. While free African Americans had access to education in Washington, DC, in neighboring states such as Virginia such education was against the law. Also at this time, public auctions of slaves continued in the nation's capital. In April 1862, nine months prior to the general Emancipation Proclamation, President Lincoln signed the DC Compensation Emancipation Act, which began the process of freeing

slaves in DC while compensating their owners for their deemed value [2].

Haynes's mother, (Anne) Lavinia Day Lofton, was a native of Washington, DC, and taught kindergarten in the public schools. She was active in her Catholic church as an organist, children's choir director, and Sunday school teacher [3]. Haynes's mother's side of the family can be traced back to Haynes's great-great-grandmother, Agnes Day, who was born in Maryland about 1790. In the 1850s and 1860s, the Day family members were listed as "Free Inhabitants" of Washington, DC, (see Figure 2). Census data from 1850–1870 list no adult males living in the household. Adult females were listed with occupations of domestic servant, housekeeper, and washing [5].

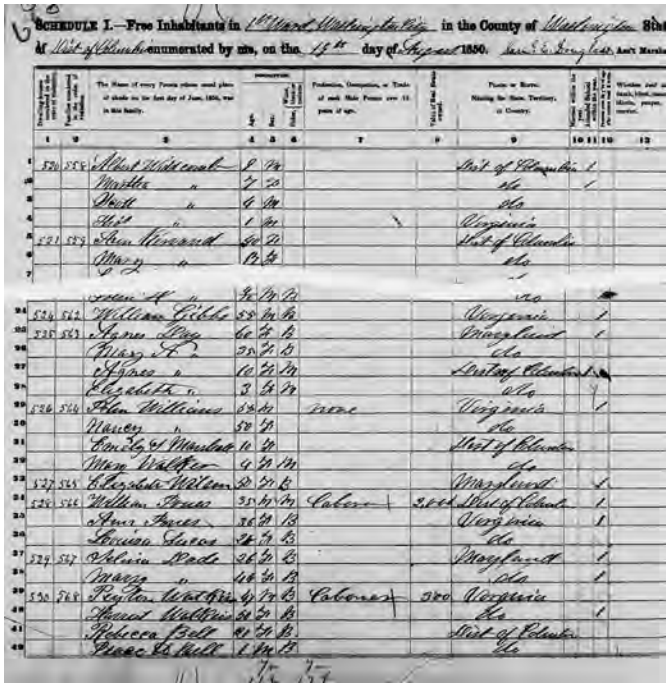


Figure 2: Euphemia's great-great-grandmother, Agnes Day, line 25; great-grandmother Mary; and grandmother Agnes are listed as Free Inhabitants of Washington DC in the 1850 census.

Haynes's father, William S. Lofton, was born in the 1860s in Batesville, Arkansas, and moved with his parents to Washington, DC, prior to the 1870 census [5]. William was a graduate of Howard University and became a successful dentist and a member of the board of directors of the Capital Savings Bank. He was a Catholic lay leader on the national level who pressed the Church to establish schools for African American children and worked to help create Catholic organizations for African Americans in the 1890s, when racial prejudices were increasing [2], [3]. In the 1870 census, William's father, also named William, was listed as a laborer born in Kentucky who could not read or write. William's mother, Martha, was a housekeeper who was born in Maryland or Missouri and who could not write. By the 1900 census, Martha was listed as a housekeeper with the skills to both read and write. Haynes's father was listed as being mixed race according to the 1910 census [5].

By the time Haynes was born, slavery had been abolished; however, opportunities and rights of black Americans were not equal to those of whites. In the United States in 1890, at the time of Haynes's birth, 45 percent of blacks fourteen years old or above were illiterate, while only 6 percent of whites of that age were [2]. Haynes's parents could read and write, but some of her grandparents could not [5]. Schools in DC were segregated along with many other aspects of society. Haynes lived through the Civil Rights years, including the 1954 Brown v. Board of Education decision, which ruled that segregation of public schools was illegal. Her background and location set the stage for her fight for equal education opportunities in the nation's capital.

Early Life and Family

Martha Euphemia Lofton Haynes preferred being called Euphemia rather than Martha. Her father, William Lofton, was a member of the Washington "black 400," a small group of fewer than one hundred families in Washington, DC, who were considered aristocrats of color, a distinction often based on family background, occupation, color, and generations removed from slavery [2]. Because Haynes's father was a member of this elite group and her mother was a school teacher, Haynes had opportunities that most African Americans in DC would not have at this time. However, her family situation began to generate turmoil early in her life.

Haynes's family began to break up during her early youth. Her brother, Joseph, was born in 1893, but by 1895 her parents had separated. In a letter William sent to Lavinia in December of 1895, William stated that he had not seen their children except by accident since September of that year and accused his wife of intentionally keeping the children from him. He told her that he had prepared a comfortable home for her and their children and also asked if the children were in need of shoes. In 1900 the divorce was finalized, and custody was given to Haynes's mother, while Haynes's father was given weekly visitation rights. The relationship between Haynes and her father appeared to be strained throughout the rest of William's life, based on letters William wrote to his daughter. William included both of his children in his final will [3].

Figure 3: Euphemia Lofton before marrying Harold Haynes in 1917.

By the time of the 1900 census, nine-year-old Haynes was living with her family in the home of her uncle and aunt, Benjamin and Anna Swann. Benjamin was a butler and Anna, Lavinia's sister, was a dressmaker. Other adults in the home were Haynes's mother, Lavinia Lofton, who worked as a school teacher; Haynes's grandmother, Agnes Day; and Haynes's great-grandmother, Grace Delany. Children in the home were Haynes; her seven-year-old brother, Joseph; and her two-year-old cousin, Daniel Swann [5]. Archive records indicate family struggles at times, but also showed a family that stayed close. Later in life Haynes traveled to Chicago frequently when her brother was dying, and in a 1972 interview Haynes spoke of her mother, saying, "My mother was so successful as a mother because she believed in me" [4].

Euphemia Lofton married Harold Haynes in 1917. They had known each other as teenagers growing up in the same neighborhood. In 1908 Harold wrote to Euphemia telling her not to worry about her mom wishing to separate them. He said it made him "more determined to stick" and that he had learned "that it pays to wait for some things." Harold graduated from M Street High School in 1906, a year earlier than Euphemia. He earned an electrical engineering degree from the University of Pennsylvania in 1910, a master's in education from the University of Chicago in 1930, and a doctorate in education from New York University in 1946. His teaching career included time at Howard University before moving to teach in DC public schools. He became the superintendent of Black Schools in DC's segregated schools in 1951 and moved to the role of deputy superintendent when schools were desegregated [3].

Figure 4: Euphemia and Harold Haynes.

Education

Haynes graduated as valedictorian from the M Street High School in 1907 [3]. The school's origins can be traced to 1870, when a school for blacks was established in a church basement after the United States Congress defeated a bill for an integrated public school system in the nation's capital. A compromise was a promise of equal quality segregated education. A school building was first constructed in 1890–91 and was one of the nation's first high schools for African American students. Because there were few opportunities for black professionals, the school was able to obtain teachers whose educational backgrounds surpassed those of most teachers at high schools for white students. Many of the graduates of M Street High School went on to college or university and became black leaders in DC and beyond [2]. In Haynes' valedictorian speech, her words reflect her actions throughout her life: "For a person of intelligence is well equipped to solve the problems of life… We must have some defined aim in life and be able to fill competently that position in which we may find ourselves… Let each defeat be a source of a new endeavor and each victory the strengthening of our spirit of gratitude and charity towards the unsuccessful" [3]. As will be addressed later, lack of funding directed to black schools in DC allowed the schools' quality to greatly diminish, and Haynes would become a voice challenging the unequal education offered in public schools based on race.

Haynes next attended Miner Normal School and graduated in 1909. She began teaching elementary school and enrolled in Smith College. She earned a bachelor of arts with a major in mathematics and a minor in psychology in 1914. Letters written to her mother expose vivid images of this time period in her life. In one such letter, she writes about her determination and perseverance: "In haste to give you the news that I passed the exam…I suffered everything from 2–5:30. When I came out I could hardly walk home… When I sat down to take it, he did not want to give it to me and said he knew I would not pass it and it would be fatal for me if I did not. Now that is what I had to brave. I knew if I did not give an excellent paper he would never let me through." In that same letter, she describes a more pleasant experience: "Did I tell you too that last week we had to write an original composition in music. Mine was the best in the class and Mr. Moog played it before the class" [3].

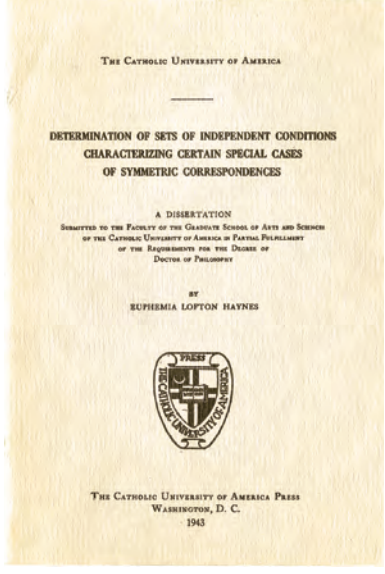
Her letters also express her excitement in learning and soaking up ideas. In one example, she describes an occasion when she heard Dr. Lyman Abbott, a nationally known Congregationalist pastor and editor of several magazines and periodicals, speak on campus: "He spoke on the commerce of ideas, the commerce of thought… He just filled us with it. He started in a way that seemed to shock everyone by saying that we were not going out into the world to serve as it was so often put. Then he went on to explain that it was our business to take as well as give. He said, 'There is no living being in the world who does not know more about something than anyone of you. From every person, even a beggar we can learn something.' Then he said we must remember that what we got in college it was our duty to give to our friends who did not have that opportunity…" [3].

Haynes's graduate work took her to the University of Chicago. The university was a leader in admitting women and students of color for advanced degrees, with forty-five African Americans earning PhDs between 1870 and 1940, the highest number for any institution in the country. Reasons cited for this leadership role include the university being more open than more established institutions in experimenting to establish its identity, its proximity to an established black community, and the "courage and conviction of a few faculty and administrators, combined

with a handful of African American students determined to pursue their education" [2].

Haynes earned a master's degree in education from Chicago in 1930 with her thesis "The Historical Development of Tests in Elementary and Secondary Mathematics." In this work, she traced the development of standardized testing tools from 1900 to 1930. In her conclusions she noted the difficulty of early tests in determining both the nature and causes of variations in scores. She also discussed later tendencies to use tests to measure progress in learning rather than to classify pupils [2]. These observations would serve her well later in her career as she challenged the tracking system of DC public schools. Euphemia then began taking graduate-level mathematics classes from the University of Chicago [3].

Figure 5: Haynes' doctoral thesis advisor, Aubrey E. Landry, was a leading advisor for women.


THE CATHOLIC UNIVERSITY OF AMERICA

DETERMINATION OF SETS OF INDEPENDENT CONDITIONS CHARACTERIZING CERTAIN SPECIAL CASES OF SYMMETRIC CORRESPONDENCES

A DISSERTATION

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL OF ARTS AND SCIENCES OF THE CATHOLIC UNIVERSITY OF AMERICA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

BY

EUPHEMIA LOFTON HAYNES

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WASHINGTON, D. C.
1943

Figure 6: Haynes's doctoral thesis studied rational plane curves.

Later, Haynes returned to school to pursue a doctoral degree in mathematics from The Catholic University of America in Washington, DC. The university, which attracted many nuns, had produced the fourth highest number of female doctoral students prior to 1940 in the country. Euphemia's thesis advisor, Aubrey Landry (see Figure 5), was responsible for directing the mathematical dissertations for all the nuns at the time. He had earned a PhD from Johns Hopkins in 1907 under the direction of Frank Morley, who also was a leading advisor for women in mathematics. Landry's research area was algebraic geometry, and he typically chose thesis topics outside mainstream research for students looking to gain credentials for teaching rather than research [1], [3].

Haynes's dissertation, "Determination of Sets of Independent Conditions Characterizing Certain Special Cases of Symmetric Correspondences," examined two ways geometric representations were defined on parametric rational plane curves and investigated their differences [2]. Like many of Landry's students, Euphemia did not continue to work in this area after graduating, and much of the vocabulary of the thesis is not commonly used today.

Haynes completed her doctoral degree in 1943 (see Figure 7). She applied her educational experiences to both her teaching career and to the many service activities that she pursued throughout her life.

Figure 7: Haynes received her doctoral degree from The Catholic University of America in 1943.

Teaching

In a 1945 address, "Mathematics–Symbolic Logic," given to junior high and high school mathematics teachers, Haynes eloquently described the full beauty of mathematics framed with logic and the need for teachers to convey this understanding. She stressed the need to devote significant time for observation and reflection to estab-

"Mathematics is no more the art of reckoning…than architecture is the art of making bricks."

lish truth rather than repetition to cement in facts. She stated that if mathematics was not taught correctly, its true nature would not be seen: "Mathematics is no more the art of reckoning and computation than architecture is the art of making bricks, no more than painting is the art of mixing colors." She went further in saying, "…what is the mathematician doing? He is building notions or ideas, he is constructing, inventing, adding to his body of science. With what is he working? Ideas, relationships, implications, etc. What are his methods? Observations, experimentation, incomplete induction. He is deliberately providing time for reflection and contemplation" [3].

Haynes began her teaching career as an elementary teacher in 1909 after graduating from Miner Normal School. She later taught mathematics at various DC public high schools, including becoming the head of the mathematics department at Dunbar High School. She served as professor of mathematics at Miner Teaching College, organizing the department in 1930 and also chairing the department. With the merger of schools after desegregation, she continued as professor and chair of the DC Teacher College until her retirement in 1959. During part of that time period, she also was a part-time instructor at Howard University [3].

In a 1960 address on international communication, Haynes described the quality teacher: "We remember that professor who was really able to communicate his point of view. Why will we remember him? His vitality, his zeal for truth, the apparent joy and satisfaction he experienced from his endeavors—all these evidences of enthusiasm stimulated us. His enthusiasm was contagious. This great teacher was a great person operating thru the medium of subject matter" [3].

It seems fitting to close this section on teaching with words she gave at a 1960 high school commencement address: "I believe there are two requisites for success in life: (1) that one be always a student and (2) that he dedicate himself to the service of others" [3].

Service and Honors

Haynes lived according to her message of service. A complete list of her activities is likely not possible, but a sample gives a picture of her tireless dedication towards causes she valued.

She started service early in her life by following in her mother's footsteps as organist and choir member in her church. She continued church-related work with service on the board of Catholic Charities. She was also on the executive committee of the National Conference of Christians and Jews and was one of the founders of the Catholic Interracial Council. As a member of the Washington Archdiocesan Council of Catholic Women, her service included time as a vice president and as president. On the national level, she served as president of the New Federated Colored Catholics of America for fourteen years. In 1959 she was awarded the Pro Ecclesia et Pontifice, the highest medal that the Pope can award to laity [3].

In an address she delivered in the 1960s entitled "What Faith Means to Me," Haynes stated, "My faith also teaches me that every human being is created in the image and likeness of God…As one moves about his daily work he influences the lives of his brothers. It is his obligation to be certain therefore that his influence contributes always to the salvation of these souls. An outstanding example of this responsibility in action is the 'living wage' for workers…it is a concrete and material expression of man's consciousness of his responsibility to his fellow man in the field of labor relations." She went further to speak of the National Labor Relations Act, which guarantees employees in the private sector the right to collective bargaining, and the Social Security Act as additional examples of policies that modeled these principles in practice [3].

Figure 8: Haynes was a member of the USO from 1943 to 1965.

Her application of her faith to serving others and to social justice issues is reflected in many areas of service. She was a member of the United Service Organization (USO) from 1943 to 1965 (see Figure 8), including twelve years on the national board of directors and service on

the National Committee on Service to Negroes and on the National Committee on Service to Women and Girls. In a letter from 1946 she wrote, "Like many of the volunteer workers with the USO I am deeply appreciative of the opportunity afforded me because I realize that I have gained far more than I have given." She also served on the National Committee of the Girl Scouts and on the local level was chairman of the advisory board of the Fides Neighborhood House, which provided activities for children and distributed food, clothing, and other necessities to families. She also accepted an invitation to serve as a delegate to the 1960 White House Conference on Children and Youth [3].

Haynes was a member of the American Mathematical Society, a Fellow of the American Association for the Advancement of Science, president of the National Association of College Women–DC Branch, and chairman of the Committee on Education for Sigma Delta Epsilon, a graduate fraternity of women scientists [3].

DC School Board and Battle for Improved Integration

In 1960, shortly after retiring from a 47-year teaching career, Haynes was an invited panelist discussing how retirement could be viewed as a new career. Haynes's personal notes for her discussion state, "Concept of retirement—Not as a termination, but as a new challenge or opportunity. Confidence of Self: In life one has accumulated valuable experiences and new talents. Retirement offers opportunities to use these in new and different areas." After only eight months of retirement, Haynes was selected to serve on the DC school board [3]. Thus, Haynes began a new career and used it to achieve possibly her greatest impact on education.

To understand Haynes's role in DC public education, it is important to understand some of the history of the DC public school system. As stated earlier, when M Street school was established in the 1800s as the first black high school in the nation, the quality of education at M Street equaled or surpassed the quality at white schools. However, as the black population of DC grew, new schools were not built, and overcrowding became an issue in black schools.

In 1954, after the Supreme Court's Brown v. Board of Education decision, DC schools were desegregated. Afterwards, a four-track curriculum was introduced in 1959 for students at all levels. Based on IQ test scores or opinion of a principal or teacher, students were tracked into Honors or Regular College Preparatory, which prepared students for college; General Curriculum, which educated students for blue-collar type work; or Basic Curriculum for students deemed to be academically delayed [2], [3]. It was in this setting that Haynes joined the school board.

In November 1963 Haynes spoke of the lack of validity of IQ tests and the question of whether they measured cause or effect, an area related to her master's research. She pointed out the segregation created by the tracking system and the increase in the number of student dropouts. She stated how "man made predictions determine the future of the child" and removed "freedom of choice." She stated that the tracking system was in "direct opposition to the American ideal…a free society capable of self-direction and appreciative of the dignity and potential worth of all members." She pointed out how it gave those placed in the highest tracks a "better than thou attitude" and gave those placed in the lower tracks a "feeling of inadequacy" [3].

In the December 1963 meeting of the school board, Haynes stated, "Where in our track system do we find any self-participation in the determination of the kind of educational experience one may have? The importance of the opportunity to succeed has been recognized. But equally important is the opportunity to fail. Only here does one meet the challenge to modify his chosen path. Never on the basis of dictation but only thru his right to try and his right to fail can any student accept an evaluation of self so essential to an attitude of self respect, so necessary to the very fundamental appreciation that for every human being there are areas in which he will succeed and there are areas in which he will fail." She requested that the superintendent and staff study the issue and replace the track system with a system that meets the needs of all students [3].

In 1964 Haynes spoke again before the school board, claiming that the tracking system "attempts in apartheid-like fashion to separate the underprivileged." She said there was little opportunity for students to move between tracks, some tracks did not prepare students for further

THE WASHINGTON AFRO-AMERICAN, AUGUST 27, 1966 YOU KNOW BECAUSE YO

'Back To School' Message From School Board President

By DR. EUPHEMIA HAYNES

This summer has shown an interested, alert, and active Board of Education. It has shown also, an interested and expressive community seeking an opportunity for meaningful communication in an attempt to resolve its problems. With continued cooperation of the administrative staff we expect marked improvement in our public schools. We are interested in changes today, not promises for tomorrow.

I think of the public schools as a resource center, a kind of laboratory, for students and parents as they plan their way of life. Here they readily accept the program designed for, and so essential to, living in the democratic social order.

In this laboratory, they are free to try and fail, and then to try again. Nor is there any limit to the number of available trials. Success and failure are both essential to a realistic self-image and this, in turn, is essential to successful living. Self evaluation is the goal.

* * *

I SEE the individual development of each child as the objective of every teacher. I see the individual development of each teacher, encouraged to experiment with new techniques, as the objective of each administrator.

No longer shall we speak merely of the equality of opportunity in education for each child, but rather, of the equality of the means of implementing this opportunity. To deny textbooks, competent teachers, adequate classroom space, pupil personnel services, academic freedom modern teaching equipment in curriculum offerings, or modern teaching equipment and the like, is to deny equality of opportunity in education.

I am concerned that in the distribution of funds priority be strictly observed.

* * *

THE NOTION that students in any group are equal in their abilities is obviously untrue. There are areas in which each one will succeed and areas in which each one will fail.

It is the business of the school to help the student distinguish these areas. Under our American creed, that "every man has a chance," all avenues for effort and development must be open equally to all. Hence the public school must offer each child equal freedom to grasp his opportunity.

Under the broad cultural experiences offered by the classroom teachers, the analytic study and guidance of counselors, each child will be able to see the area in which he finds joy and satisfaction. He will acquire an appreciation of self as well as an appreciation of all his associates.

He will grow in dignity of self as well as in the respect for the dignity of all others. For him society will no longer be "me" and "they" but rather "we." Let us guard against any tendency toward disintegration. Let the public schools meet their challenge to build a social order firm in its respect for the dignity of all men.

Figure 9: As the new school board president, Haynes wrote that students "are free to try and fail, and then try again."

education, and diplomas from the various tracks carried different values. She added that "a school experience which insures no contact of 'my' group with 'that' group and preserves the attitude of 'we' and 'they' cannot lead to a unified citizenry, working towards the same goals" [3].

In early 1965, letters from parents, administrators, and education experts were collected both supporting and denouncing tracking. In the summer of 1966 Haynes was elected president of the school board, and the board ordered the school administration to dismantle the track system and replace it with new classroom methods [3].

The years of debate culminated in the Hobson v. Hansen district court case that was filed by civil rights activist Julius Hobson in 1966, with the decision handed down on June 21, 1967. Circuit Judge J. Skelly Wright concluded that the superintendent and school board of DC unconstitutionally deprived black students and poor students of their right to an equal education. Among its findings, the court found many examples of discrimination: the school's racial and socially homogeneous make-up was damaging to students, a quota system of four blacks on the nine-member school board kept blacks in the minority even with a public school population made up of 90 percent blacks, schools that were predominantly black were overcrowded and underfunded, allowances were given for affluent white students to leave neighborhood schools that were predominantly black, and the track system was based on aptitude tests that were standardized towards middle class white students. Among the remedies cited, the school district was to abolish the track system and the optimal zones that placed students in neighborhood schools. Busing was to be offered to students wishing to leave overcrowded schools [2], [3].

After the court decision, many community members supported the work of Haynes. However, the changes called for also caused infighting among school board members, and, in an unprecedented move, a seated board president was not nominated for a second term. On July 1, 1967, Haynes was deposed as president, and another board member was named in her place. Haynes remained on the board until 1968, when she chose to retire. For Haynes's service as board president, she was recognized for bringing the DC school system forward further in one year than what had been done in the previous four. Relations were improved between the board and teachers by permitting teachers to select their representative through collective bargaining, and parent and community involvement had been increased with the board's greater transparency on issues [3].

Thoughts on Gender and Race

Haynes, with hard work and determination, excelled despite many obstacles for both women and African Americans. She encouraged more women to seek new opportunities: "The increasing demands by industry for workers together with the change in the nature of household tasks has resulted in a great change in the status of the woman in the home… household tasks… far simpler and less time consuming than they were a generation ago… If the home

Figure 10: Haynes was appointed to the DC school board in 1960.

of today is to retrieve the blessings and the joys of the traditional home and yet profit by the advantages of the time and labor saving devices of the modern age, it must expand its horizon far beyond the four walls of the family dwelling…her spiritual leadership is not confined to her immediate family, but is felt in her community. Only by influencing the community can she successfully mould her family." After advances made by women during WWII, Haynes also encouraged more women to answer callings to mathematics and science: "After this war the results of the researches in physics will transform our world. Whole new industries present a vision of future accomplishment that promises almost miraculous changes in our way of living. This introduction of more physical techniques into industry means a greater demand for physicists. The industries of tomorrow demand a higher level of mathematical training than those of today. Before the close of this war, women will have established themselves in the technical world. Tests have shown that women have mechanical ability but have lacked the opportunity to learn about machines…Thousands of women have demonstrated their ability. They have proved that it is worthwhile to get ready for work in science and in industry" [3].

Still a greater devotion of Haynes's was to address discrimination based on race. In looking at the world history of slavery, she noted that prior to slavery in America, most masters and slaves were of the same race. The change to different races in America caused an association of inferior

status based on the race of a person. Haynes experienced personal discrimination due to race early in life as a student of a segregated school system. Later in life she also faced discrimination from the shade of her skin. In a letter of resignation from the Catholic Interracial Council, she explained her reason: During a meeting of the council, they chose representatives to meet with the archbishop during an upcoming reception. They desired the chairman, the secretary, and one "noticeably colored person." She stated, "I am the only colored person on the steering committee of the council, but I do not qualify as 'noticeably colored.' A young woman, a former student of mine was selected…I trust that serious consideration will be given by the group to the matter of their own prejudices and that there may soon be a flowering of true Catholic charity which embraces even those Negroes who are not wholly black" [3].

"The scientific exploration of the universe is the right of all men."

Haynes noted that children were not born with prejudices and that parents needed to help by (1) making sure children understand that with current science, people of every country are also our neighbors; (2) helping children to appreciate others with interactions; and (3) getting children to work in groups within their community. Citing her faith, she noted "…race prejudice is not found among children; that among artists, scholars, among those who have achieved something which they have no fear of losing, there seems to be a tendency to lay it aside completely. Because of race prejudice the Negro must endure many forms of social disadvantage… According to the Catholic Doctrine all men are members of one family…created by God in His own image and likeness… my conviction that a living faith in these fundamental teachings of the Catholic Church and racial friction are incongruous..." [3].

Finally, Hayes tied these thoughts to mathematics and to science: "…mathematics is an essential factor in cultural integration…In whatever corner of the world they may find themselves, mathematicians, like all scientists, are bonded together by a universal desire to understand life. Cooperation is natural, it is easy, it is necessary in the all-out effort of science to establish truth. As has frequently been pointed out science is international rather than national. The scientific exploration of the universe is the right of all men" [3].

Conclusion

Haynes died on July 25, 1980, two years after her husband's passing. The couple had no children, and upon her death $700,000 was willed to The Catholic University of America, where a chair in the Department of Education was named in her honor [3]. It was not until 2001 that Haynes was recognized by the mathematics community as the first African American woman to earn a doctorate in mathematics. Patricia Kenschaft, who conducted early research on black women in mathematics, believed this was due in part to racial segregation both in the education system and in the professional mathematical community during Haynes's life [4].

Haynes lived life based on her ideals. She saw the need to always take time to fill oneself with knowledge and to then give of oneself in service to others. Haynes spoke of her faith, which taught her that everyone "has a dignity that must be preserved." She spoke of the difficulty of achieving goals, but also spoke of the inner strength that her faith gave her: "…consolation in sorrow…darkness into light…replace disappointment and affliction by peace; fear and hysteria by courage and hope" [3].

The battles Haynes so gallantly fought are still with us today. Unequal public education related to prosperous and poorer neighborhoods is still present today. State funding for public education does not ensure equal access to quality education for all. Today we see additional funding needs addressed with local school referenda, and thus wealthier regions can afford to vote to give more to schools while other regions may not have such resources. In addition, tracking, ability grouping, and gifted and talented programs still face similar issues. While schools look for ways to best teach diverse groups of students, such systems of separation still often occur along racial lines and income levels. While advanced classes are found to academically benefit the students who take them, students in lower-level classes are found to suffer. Current suggestions for improvement include requiring all students to take tests to qualify for advanced tracks, thus eliminating the common practice of such tests being taken predominantly by students whose parents push for such options. Another suggestion, similar to Haynes's ideas, is to remove all barriers to enter advanced classes and let students self-select instead of basing entry on exams [2].

Haynes devoted much of her life to her own education and to the education of public school students of Washington, DC. In examining the battles she fought to improve educational opportunities and in reflecting on the progress that still must be made, we consider her words in an address delivered to educators in 1945: "The concept of limit is merely an expression (in) mathematical form of an ever receding goal of perfection for which man yearns and for which he strives, yet never attains. With each new approximation, he is merely closer" [3]. Haynes knew that some goals are difficult to achieve and sometimes are not reached. That did not mean they should not be attempted. As we continue to face the challenges of equal opportunities for all, we are wise to remember that we may not reach the goal, but we can each work to move the world closer to the "goal of perfection."

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The authors dedicate this paper to public school teachers across the country who continue to work towards Euphemia's goals of quality and equal educational opportunities for all students.

For a longer version of this paper with fuller references, see referenced article on `arXiv.org` [2].

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Evelyn Lamb Interview

Conducted by Alexander Diaz-Lopez

Evelyn J. Lamb is a full-time freelance math and science writer. She has a *Scientific American* blog "Roots of Unity" and writes for the AMS "Blog on Math Blogs." Lamb obtained her PhD in Teichmüller theory from Rice University. To subscribe to her writings, you can visit `tinyletter.com/evelynjlamb`.

Diaz-Lopez: *When did you know you wanted to be a mathematician?*

Lamb: I did well in math classes going through school, and I even did (and enjoyed) MathCounts in middle school, but math never really grabbed me. I thought of math as rote and computational. You memorize a formula, plug in the numbers, and chug through to get the right answer. MathCounts wasn't really like that, but I didn't see a connection between the fun puzzles we did there and the math from my math classes.

I had the advantage of going to the Texas Academy of Math and Science (TAMS) for my last two years of high school. It's a residential program on the University of North Texas campus, so I graduated from high school with about seventy hours of college credit. That gave me the flexibility to meander in college and still be able to graduate in four years.

I went to Baylor University wanting a career as a researcher in nutrition or pharmacology, and I also loved music and had a viola performance scholarship. I technically entered college as a biochemistry and church music double major, although I pretty quickly decided the church music program there wasn't a good fit for me. After a couple years of slogging through organic chemistry and biochemistry classes, I realized that wasn't right for me either. Thanks to my TAMS credits, I was only a few classes away from a math minor. I figured that wouldn't be a bad thing to complete no matter what my major ended up being. I liked my linear algebra class, but what really converted me was an introduction to proofs class I took in the fall of my junior year. It completely changed the way I thought about math. Looking back, I'm tempted to say that two weeks into this one math class, my future was decided, but in reality, there was a lot more back and forth about what I wanted to do because I was also so involved in music. At that point, I played viola and carillon (the giant clock tower bell instrument), I was a soprano section leader in a local church choir, and I absolutely loved my music theory classes. But I was concerned that I didn't really want to practice enough to make it as a professional performer, wasn't interested in teaching private lessons, and didn't have much faith in my employability as a music theorist. I had a lot more confidence in my employability with a math degree, so that's what I did.

Diaz-Lopez: *Who encouraged or inspired you?*

Lamb: My family has always been very encouraging of all my endeavors, whether it was science (my first career goal was to be a herpetologist because I loved snakes), music, sewing, or anything else that caught my fancy. I was lucky to be born into a geeky family, and even though I had those teenage years of feeling like nobody understood me, in reality I've been fortunate at every stage in my life to have wonderful friends who love me for, not in spite of, my geekiness. I'm not going to name individual friends or family members because there are too many to mention!

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I had a lot of good teachers in pretty much every subject who encouraged me throughout my schooling. Mathematically, three of my Baylor professors really went out of their way to support me once I decided to do math. Brian Raines, David Ryden, and Paul Hagelstein wrote my graduate school recommendation letters and spent a lot of time listening to me think out loud about what direction I wanted to go in my career, how I should prepare for graduate school, and where I should apply. I didn't always take their advice, but it was important that they were so encouraging of me.

For writing, my mentor at *Scientific American,* Robin Lloyd, was just the person I needed to start my career. She helped and continues to help me be a better science writer. Julie Rehmeyer is another science writer with a math background who has been both an inspiration and an encourager. You should get her to do one of these interviews!

My spouse Jon Chaika is now my biggest fan and supporter. I bounce a lot of ideas off of him, and when I'm nervous about something I'm trying, he's great at listening to my concerns, talking through problems with me, and encouraging me to try new things.

Diaz-Lopez: *You finished your PhD, then worked in academia, and now you are a full-time freelance writer. What motivated you to make these career choices?*

Lamb: In 2012, right after I got my PhD, I had the opportunity to work for *Scientific American* through an AMS-AAAS Mass Media Fellowship. The AAAS [American Association for the Advancement of Science] runs this program, in which graduate students in the sciences work at various media outlets for the summer, and the AMS sponsors one of the fellowships every year. I had heard about the program for a few years and always thought it would be fun to see how people wrote about math and science for a general audience.

The [AMS-AAAS Mass Media] fellowship was a revelation. Graduate school had really been tough for me, and I kind of felt like I was the person in the world who was the absolute worst at math. I was the infimum! Working at *Scientific American* helped me gain confidence, not because I figured out that there were people in the world worse than I was at math, but because I realized I had something to offer with my mathematical background, creativity, and communication skills. During the fellowship, I wrote about math in addition to physics, biology, chemistry, engineering, materials science, and health. Lloyd and the other editors I worked with were incredibly generous with their time, feedback, and encouragement. At the end of the summer I really felt like I could do this as a career. Before the fellowship, I had no idea how big the science writing world was and that there was room in it for someone like me.

But I had a job lined up already. My spouse got a tenure-track job at the University of Utah, and they had thrown a postdoc for me into the deal. (That's selling myself a bit short. I had been on their short list for a postdoc a year or two prior, and it was a good fit for my research area.) We got the job offers in the spring of 2012, before I did the fellowship at *Scientific American,* but we wouldn't be starting until fall 2013 so he could finish his postdoc. In the intervening year, I did some freelance math writing for *Scientific American* and a few other places and started my *Scientific American* blog "Roots of Unity." I decided that I wanted to give the postdoc a try and do some blogging and writing on the side.

I loved my students and colleagues at the U, but in the end I felt like I wasn't able to do what I wanted to with my writing because of the energy I was spending on teaching and research. I was having some success and getting positive feedback about my writing, and it was more fun and fulfilling for me than my other work, so I made the emotionally fraught decision to leave academia and do freelance writing full-time. I felt awful and like a failure for a long time while I was making the decision, but the relief I felt when I finally decided and told my chair about it made me pretty confident that it was the right call. So far, I'd say it was. I'm still at the beginning of this career, though. Ask me again in five to ten years.

Diaz-Lopez: *How would you describe your current work?*

Lamb: I'm a freelance math and science writer, which means I'm both self-employed and work for many employers. Currently my ongoing gigs are my *Scientific American* blog "Roots of Unity" and the "Blog on Math Blogs" for the AMS, which I co-write with Duquesne University mathematician Anna Haensch. I've also written for other media outlets, including *Slate, Nautilus, Smithsonian Magazine, Nature News, New Scientist, Undark,* and the *Association for Women in Mathematics Newsletter.* This year I've been experimenting with an email newsletter for people who want to keep up with my writing.[1]

[My *Scientific American* blog] "Roots of Unity" is kind of my playground. I can write about whatever I want in whatever way I want. That's where I can experiment with what topics and type of writing work well and make me feel satisfied. I can make goofy math quizzes or write

Figure 1. An interesting octagonal tiling in Sankt Goar, Germany, that inspired a stream-of-consciousness post on my *Scientific American* blog, "Roots of Unity."[2]

[1] tinyletter.com/evelynjlamb

[2] blogs.scientificamerican.com/roots-of-unity/math-under-my-feet/

about the intersection of politics and mathematicians or share my stream of consciousness thoughts about an interesting tiling I saw on the ground [see accompanying sidewalk tiling image]. The [AMS] "Blog on Math Blogs" is about sharing good blog and online math content that will be of interest to AMS members. In other publications, I tend to write more journalistically, though sometimes I write opinion pieces for them as well. Each outlet has a little bit of a different voice and focus, and it's fun (though also time-consuming and sometimes frustrating) to try to figure out the best places for different story ideas. Recently, I've written some articles for middle- and high-school students in *Science News for Students* and *Muse Magazine.* Writing for that age is a fun new challenge, and I'm excited to think that my stories might connect kids with parts of math they don't always see in the classroom.

University of Florida math professor Kevin Knudson and I recently launched a math podcast called "My Favorite Theorem." As the name implies, in each episode we talk to a mathematician about their favorite theorem. You should be able to subscribe on your favorite podcast delivery service.

I have some ideas for larger projects and books. I'm currently trying to figure out how to bring those into the world. Stay tuned!

In all of my work, I want to help people have positive experiences with math. That takes a lot of forms for me. Yes, it's about new research and fun ideas in math, Pi Day, and weird applications of math, but it's also about mathematicians. I want people to see that lots of kinds of people become mathematicians. That includes diversity in gender, race, and national origin, as well as a broad range of mathematical histories. Some people knew they loved math from a young age, but I think more mathematicians than most people realize came to math a little later, like I did. If people can see that there's more than one way to be a mathematician, maybe more of them will feel they can understand and appreciate mathematical concepts.

That's the big pie-in-the-sky idea of my work. On the ground level, I've learned a lot in the past few years about the nuts and bolts of freelancing and being self-employed. I'm getting better at keeping records for taxes. I'm getting better at invoicing on time and asking for more money or a better contract with a new publication. I'm getting better — a little, maybe — at accepting criticism and rejection.

It's hard to make a living as a freelance writer. It takes time to figure out what you're doing, build a client base, and get enough well-paying work to make ends meet. Even if you're doing enough work, the paychecks can come sporadically, and you're an independent contractor, so you don't get benefits. I'm fortunate that I can get health insurance through my spouse's employer. I probably couldn't have taken the chance on freelancing if that hadn't been the case.

Diaz-Lopez: *What message would you give to those doctoral students and professional mathematicians thinking about a career outside academia?*

Lamb: Having a career outside of academia is not failing or wasting your degree. It took me longer than it should have to decide to leave academia because I felt like I was throwing my PhD away (even though my job is directly related to my PhD!) or disappointing…my advisor? my parents? my spouse? They don't seem too disappointed.

For me, I think another aspect was that I felt pressure as a Woman in Math to have some fancy R1 tenure-track job or else I would be Letting All Women Down. That's not a recipe for a successful career or a satisfying life. I think there is a stigma still about leaving academia, but sometimes a lot of it can come from within. "My advisor will be so disappointed in me." No. Your advisor should be a human who cares about you as a human. They should want you to have a post-PhD life that satisfies you. If they don't, that means they're messing up this part of being an advisor not that you are doing something wrong by leaving academia.

With the academic job market as it is right now, mathematicians should be actively combatting the non-academic employment stigma because we do produce more PhDs than we have room for in academic jobs. We need to be setting students up to be successful in a variety of careers.

One of the most important things Robin Lloyd said to me was during a conversation maybe a month into my fellowship about my future career plans. I mentioned that I had a postdoc lined up but didn't know if I had what it takes to be a researcher and an academic but felt like science writing would be a good fallback. She told me that I shouldn't pursue this career because I was feeling unsuccessful in math. I should pursue this career because I would find it fulfilling and could be successful at it. In retrospect, my comment was both absurd and offensive. Science writing is a competitive field, not a backup option if you don't get a teaching job. Believing that an academic career was the only way to be a successful mathematician was a big part of the reason I thought that way. Non-academic jobs are not consolation prizes.

Diaz-Lopez: *What advice do you have for graduate students?*

Lamb: I should have gotten more help earlier than I did in graduate school. I needed mental health help and help learning how to learn mathematics. I was a pretty cocky student up through college. Math, and most subjects, came easily to me, and when I got to grad school I thought the fact that I was suddenly struggling meant I was a fraud. I was afraid of looking like I didn't know something, so I faked my way through things, nodded without understanding things, and spun my wheels a lot more than I needed to. There are mental health resources on campus, and your professors and fellow graduate students want to help you understand things. Tell them when you don't understand.

As for getting jobs outside of academia, don't waste too much time asking your advisor about this. Your advisor stayed in academia and might only have a vague idea of what other jobs are out there. But there are ways to learn about what's available and how to get those jobs. Reach out to former students from your school or other mathematicians who have gone into those jobs. I wrote a blog post recently for the AMS called "What are you going

to do with that?"[3] about resources for non-academic job searches.

Diaz-Lopez: *All mathematicians feel discouraged occasionally. How do you deal with discouragement?*

Lamb: When I can afford the time, I will step away for a while from projects that are discouraging or frustrating me. Sometimes I'll work on something else for my job, and sometimes I'll take a break from work altogether. For me, I think a lot of work gets done subconsciously, or when I'm taking a walk, cooking dinner, playing music, or pulling some weeds. Rolling ideas around in my head for a while can help me with writer's block or dissatisfaction with what I'm working on. It's really helpful to come back to something with a fresh eye. The article that's been bugging me is often better than I remembered it, and my time away can be especially helpful for solving organizational problems in my writing. A break is also a good way to remember I am a complex, multifaceted human who eats and reads and sings and enjoys nature. We are more than our work, and I think that's an important thing to remember.

Diaz-Lopez: *If you were not a mathematician, what would you be?*

Lamb: Who knows?! I have a lot of different interests, and I can imagine myself in a lot of different careers. In addition to music, I was very close to going into ordained ministry when I was in college, but I no longer feel pulled in that direction.

One of my hobbies is sewing, and sometimes I imagine quitting my job and going to school to become a fashion designer. Sewing and design are mathematically satisfying activities. You get to think about orientation, curvature, and singularities, but in the end, instead of a bunch of theorems written on paper, you might have a dress! So yeah, let's go with fashion designer.

Diaz-Lopez: *If you could recommend one lecture or paper to graduate students, what would it be?*

Lamb: The lectures and papers that come to mind as formative for me seem a little too specific to my former field of research, Teichmüller theory, to recommend them to graduate students in general. Instead, they (and other mathematicians) should read Erica Walker's book *Beyond Banneker: Black Mathematicians and the Paths to Excellence.* All mathematicians should know more about the history of African Americans in math. White mathematicians in particular should know about past and present examples of Black mathematical excellence and understand some of the obstacles their Black classmates, colleagues, and students may be facing and what we can do to make the mathematical community better for them.

Diaz-Lopez: *Any final comment or advice?*

Lamb: Mathematicians and math enthusiasts are understandably eager to promote math. But sometimes we alienate people rather than welcome them. We can sometimes create an exclusive, in-crowd atmosphere when we throw around jargon and assume everyone is going to know what we're talking about. Not knowing something about math is not an indication that someone isn't smart or couldn't do math. We need to do a better job inviting more people in when we're expressing our excitement rather than making people feel like they're on the outside and will never understand it. Math anxiety and trauma from past math classes are unfortunately quite common. People don't need much of an excuse to tune out when you start talking about math. Don't give them one by being condescending or exclusionary.

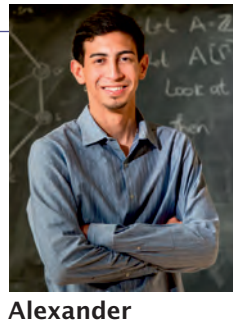
Figure 2. Everything looks better in the hyperbolic plane! I used this picture from a trip to the Firth of Forth in Scotland to tile the hyperbolic plane using Malin Christersson's hyperbolic tiling tool.[4] If you look closely, you can figure out what kind of polygons I used and how many meet around each vertex.

Image Credits

Photo of Evelyn Lamb by Jon Chaika.
Figure 1 by Evelyn Lamb.
Figure 2 by Jon Chaika and Evelyn Lamb, created with Malin Christersson's hyperbolic tiling tool.

ABOUT THE INTERVIEWER

Alexander Diaz-Lopez, having earned his PhD at the University of Notre Dame, is now assistant professor at Villanova University. Diaz-Lopez was the first graduate student member of the *Notices* Editorial Board.



Alexander Diaz-Lopez

[3] blogs.ams.org/blogonmathblogs/2017/05/15/what-are-you-going-to-do-with-that/

[4] www.malinc.se/m/ImageTiling.php

WHAT IS...

Perimeter

Editors

The standard notion of the area of the boundary of a region in $\mathbf{R}^3$ is too big for complicated sets. Figure 1 suggests a countable dense union R of disjoint open balls in a region of volume 100 whose surface areas sum to 1 and volumes sum to some $\epsilon < 1$. The standard topological boundary is the entire complement of R, a solid region of volume $100 - \epsilon$ and infinite two-dimensional "area." On the other hand, the boundary measure we want is just the sum of the areas of the spheres, which we've taken to be 1. This desirable answer is provided by the *perimeter* of Caccioppoli and De Giorgi.

In her article on the isoperimetric problem in this issue (see p. 980), Bandle defines this perimeter first via approximations by (finitely many) polyhedra. For large N, a good approximation in our example would be N nearly round polyhedra of N faces approximating the N largest balls. As N approaches infinity, the approximate areas would converge to the sum of the areas of the spheres, which we chose to be 1.

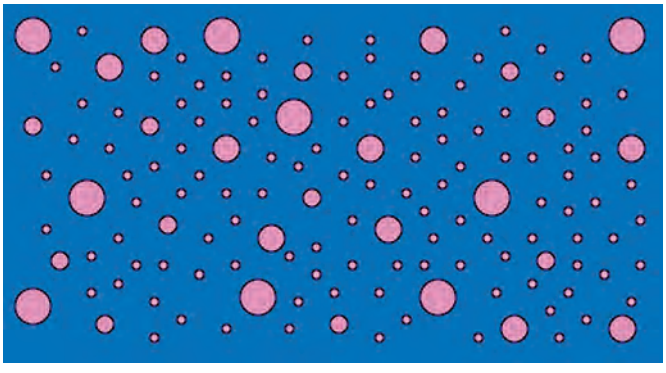


Figure 1. An infinite collection of dense disjoint balls should have finite "perimeter" even though the topological boundary can be almost the whole space.

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Then Bandle provides the more standard, technical definition of the perimeter $P(R)$ of a region R as a supremum over smooth vectorfields $\mathbf{v}$:

$$P(R) = \sup_{|\mathbf{v}|\le 1} \int_R \operatorname{div} \mathbf{v}.$$

Note that on a smooth region, by the divergence theorem,

$$\int_R \operatorname{div} \mathbf{v} = \int_{\partial R} \mathbf{v}\cdot\mathbf{n} \le \text{area } \partial R,$$

because $|\mathbf{v}| \le 1$. The supremum actually equals the area of ∂R (by taking the vectorfield $\mathbf{v}$ to be the unit normal $\mathbf{n}$ on the boundary).

As Bandle remarks, this perimeter is lower-semicontinuous: the perimeter of a limit is at most the limit of the perimeters. Note that this property fails for the area of the topological boundary. The infinite collection of balls suggested by Figure 1 has huge topological boundary, even though it is the limit of finite subcollections, all of which have topological boundary of area less than 1.

Such lower-semicontinuity is a key fact in general proofs of the existence of solutions to isoperimetric problems, which typically seek to minimize area among regions of prescribed volume. Such proofs begin with a sequence of regions of the prescribed volume with perimeters approaching the infimum. Certain deep compactness theorems yield a convergent subsequence. Now *by lower-semicontinuity of perimeter,* the limit has the infimum perimeter and hence solves the isoperimetric problem.

You might worry that a solution so obtained might be a strange one for which the specially defined perimeter is artificially small. The next and harder part of the theory is to prove that the resulting solution actually is nice, ideally smooth, so that perimeter means what it should.

Finally, knowing that nice solutions to the isoperimetric problem exist makes it easier to find them.

Further Reading

FRANCESCO MAGGI, *Sets of Finite Perimeter and Geometric Variational Problems: An Introduction to Geometric Measure Theory,* Cambridge University Press, 2012.

Image Credit

Figure 1 © Frank Morgan.

Gerrymandering, Sandwiches, and Topology

Pablo Soberón

Communicated by Cesar E. Silva

ABSTRACT. We describe some applications of measure partitioning theorems, which extend the ham sandwich theorem, to draw biased political maps. The results we use are at the crossroads of metric geometry and algebraic topology.

In May, I gave a talk about fair division problems in a seminar. These are the kind of mathematical results that you would use if, for example, you wanted to divide rent fairly with your roommates, split a cake so that no one is envious of another person's piece, or distribute a stolen necklace among your fellow thieves. I was asked if those results could be used to "solve gerrymandering." I was surprised that a direct application would not help fix this problem, but rather make it worse. In particular, one would be able to draw extremely gerrymandered maps without using strange shapes for the districts, which goes against the intuition in this subject.

Gerrymandering is the practice of drawing political maps to gain an advantage. There is evidence of gerrymandered maps all over the world, and it has been a reason for heated debate in the United States for over 200 years. Suppose that you, a cartographer consulting for the government, are tasked with dividing the country into districts. Each district will have a representative. Every person will choose a color, blue or red, and the color of the representative of each district will be determined by the majority of the votes there.

If 57 percent of the population voted blue and 43 percent voted red, it would seem fair that roughly 57 percent of the representatives are blue, and 43 percent are red. However, a well-drawn map can drastically change this, as in Figure 1. The person drawing the map has much more power on the distribution of representatives than it may seem at first sight.

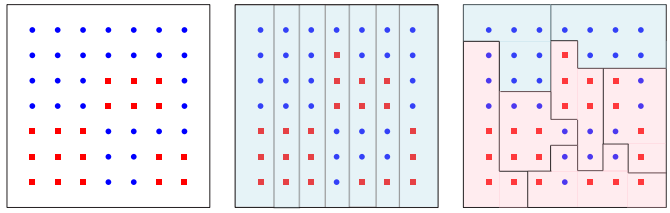

Figure 1. Two different divisions of the same electoral map, where 57 percent of the votes are blue and 43 percent are red, into seven districts. In the first division blue wins 100 percent of the districts. In the second division blue wins 28 percent of the districts and red wins 72 percent.

An ill-intentioned cartographer has two tools at his disposal: packing and cracking. Packing refers to concentrating a group in a single district where they win by a large margin, thereby minimizing the impact of their votes. Cracking refers to dispersing a group across many districts, thereby diluting the impact of their votes. As you may imagine, very biased maps often end up having districts with unusual shapes to make the most of these tools. Indeed, this is where the name gerrymandering comes from, as one of the districts drawn in the redistricting map of Massachusetts signed by Elbridge Gerry in 1812 was said to resemble a salamander. Figure 2 shows an example of a district with an odd shape.

There has been a lot of effort to use mathematics to understand and detect gerrymandering. One instance is the group led by Moon Duchin at Tufts University [3]. Many approaches rely on finding oddly shaped districts or counting voting efficiency. It is not an easy task, especially since it is sometimes difficult to tell apart intentional partisan gerrymandering and accidental gerrymandering.

Let's see what we could do if we took the job of the biased cartographer and decided to use mathematics to gerrymander on purpose. What is the worst we could do

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See Opinion piece "A Formula Goes to Court: Artisan Gerrymandering and the Efficiency Gap" (page 1020).

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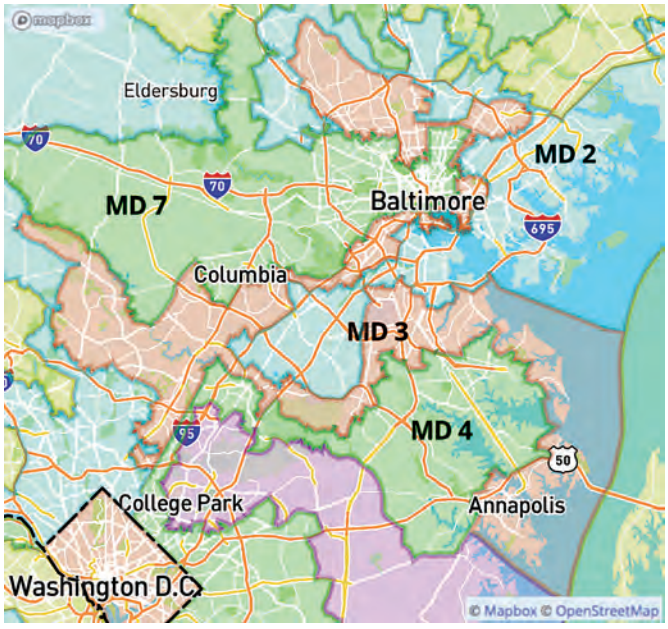


Figure 2. Maryland's third congressional district (in brown) has an odd shape.

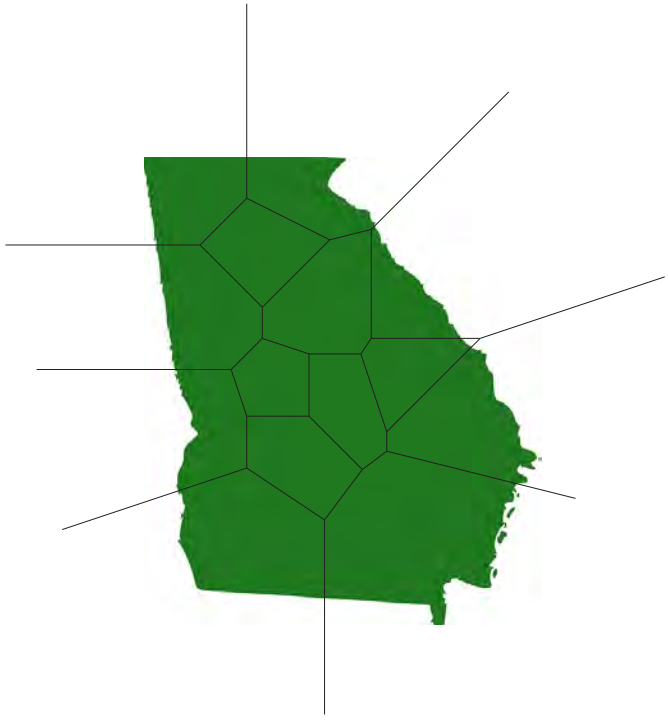


Figure 3. A map of the state of Georgia divided using fourteen convex sets.

without using strange shapes for the districts? We will ask the following of our map:

- The districts will have *convex* shapes, up to the boundary of the map. In other words, if two points are inside a district, the straight segment between them is also there. This prevents any dents or holes in the districts. Figure 3 shows an example with the state of Georgia.
- Each district will hold the same number of voters, in an effort to promote "equal representation."

With these conditions, what is the worst we could do? If we are inclined to benefit the party that already has the majority of the total votes, I claim that we can always get them to win *every single district*.

The tool we will use for this is a generalization of a particularly beautiful theorem in discrete geometry, called the *ham sandwich theorem*. The ham sandwich theorem was conjectured by Steinhaus and subsequently proved by Banach in 1938. This result is one of the first applications of equivariant algebraic topology to metric geometry. In formal terms, equivariant topology is the branch of mathematics that studies continuous functions between topological spaces that preserve some kind of symmetry; certainly something that seems far detached from our map-drawing goals. For two dimensions, it says the following.

Theorem 1. *Given two finite sets of points in the plane, blue and red, both with an even number of points and such that no three colored points are collinear, there is a line that splits simultaneously both colors in half.*

The reason for the name is the interpretation where each color represents an ingredient on a table. Then,

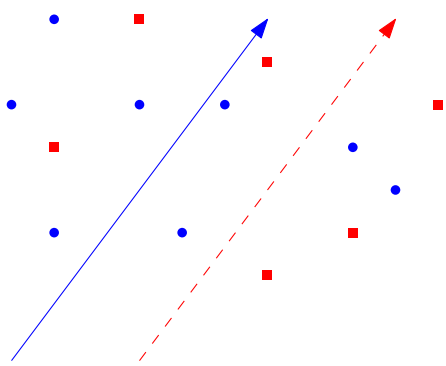


Figure 4. Two parallel lines with the same direction splitting their colored point sets.

for our two ingredients (say, ham and cheese) we can always find a straight line that leaves exactly half of each ingredient on each side.

To prove this result, draw two parallel lines. One will be red, splitting the red points in half, and one will be blue, splitting the blue points in half, as in Figure 4. If we are lucky, they are the same line and we are done. If not, assign a direction to them so that they are pointing to the same side, and start rotating them clockwise, always keeping them parallel. It turns out that we can move them as we rotate in order for each line to split its corresponding color in half all the time. Moreover, the movement can be continuous. Once you've given a half-turn, you will end up with the same two lines that you started with, but

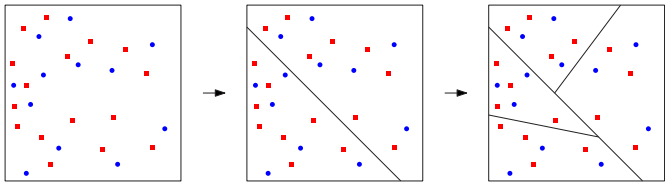


Figure 5. After two steps, we have a division into four convex districts where the same party wins all.

pointing in the opposite direction. If at the beginning a person walking along the red line had the blue line on his left, at the end he has the blue line on his right. Thus, at some point the two lines had to coincide, giving us the desired line. If the resulting line is a degenerate case that goes through a point, it has to go through two points of the same color. A small perturbation fixes this problem.

Let's see how we can use the ham sandwich theorem to draw our map. We start with a particular case, and suppose that the number of districts we want to produce is a power of two. Then, we can find a straight line that splits both colors in half. We can repeat the argument for each new region. We can continue this way, and in each new region we can split both colors in half simultaneously. After doing this k times, we will have 2^k districts, all convex and all with the same portion of the blue voters and the same portion of the red voters, as in Figure 5. Whichever color had the majority of the votes will have the majority in each district, as we wanted.

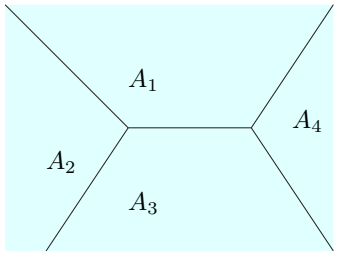
Unfortunately, since the number of districts in most states is not a power of two, this method of repeatedly halving the population will not work. Fortunately, we can find similar biased maps, regardless of the number of congressional districts we want.

Theorem 2 (Bespamyatnikh, Kirkpatrick, Snoeyink 2000; Sakai 2002 [1], [4])**.** *Suppose we are given positive integers g, h, n, a set of gn red points in the plane, and a set of hn blue points in the plane, so that no three colored points lie in a line. Then, we can split the plane into n convex sets, each with exactly g red points and h blue points.*

The result above with $n = 14$ would give us a congressional map for Georgia, perhaps as in Figure 3, using simple shapes that greatly benefit whichever party has won the total vote. Let us describe the general framework to prove a result such as Theorem 2. This is a standard approach often called the *test map scheme*. One of the best introductions to this technique remains the book by Jiří Matoušek [2].

First, we assume that instead of red and blue points, we are given two smooth probability measures μ_1, μ_2. The result with point sets can be recovered via approximation results (this is not always trivial). Once we are set with a family of partitions of the plane into 14 parts that we want to use, we can parametrize it with a space X. Now we can form a function $f_1 : X \to \mathbb{R}^{13}$, that depends on μ_1, as follows. Given a partition $P = (A_1, \dots, A_{14}) \in X$, we define

$$f_1(P) = \left(\mu_1(A_1) - \frac{1}{14}, \dots, \mu_1(A_{14}) - \frac{1}{14}\right).$$



$$f_1(P) = \left(\mu_1(A_1) - \tfrac{1}{4}, \mu_1(A_2) - \tfrac{1}{4}, \mu_1(A_3) - \tfrac{1}{4}, \mu_1(A_4) - \tfrac{1}{4}\right)$$

Figure 6. We can repeat the argument with $n = 4$. Notice that if $\mu_1(\mathbb{R}^2) = 1$, then $\text{image}(f_1) \cong \mathbb{R}^3 = \{(x_1, x_2, x_3, x_4) \in \mathbb{R}^4 : x_1 + x_2 + x_3 + x_4 = 0\}$.

Notice that the image is contained in a 13-dimensional subspace of $\mathbb{R}^{14}$ because the sum of the coordinates is always zero. A similar example is shown in Figure 6. We repeat the construction with μ_2, and consider $f = (f_1, f_2) : X \to \mathbb{R}^{2\cdot 13}$. The conditions on the measures make f continuous. We are looking for an partition P such that $f(P) = \bar{0}$. If it does not exist, we can reduce the dimension of the image and construct a function to a $(2 \cdot 13 - 1)$-dimensional sphere $\tilde{f} : X \to S^{2\cdot 13-1}$ such that $\tilde{f}(P) = \frac{f(P)}{||f(P)||}$.

Moreover, there is a natural action of the symmetric group S_{14} in both spaces, which only permutes the names of the districts. With this action, we have that $\tilde{f}$ is equivariant; i.e. $\tilde{f}(gP) = g\tilde{f}(P)$ for all $g \in S_{14}$. The question now becomes one of equivariant topology: *Prove that there is no S_{14}-equivariant continuous map*

$$\tilde{f} : X \to_{S_{14}} S^{2\cdot 13-1}.$$

Sometimes factoring arguments and other tricks reduce the amount of algebraic topology needed. The proof becomes a tug of war where one side consists of the construction and paramentrization of X and factorization tricks, and in the other side you have the topological machinery needed to solve the resulting problem. For instance, Theorem 2 and the ham-sandwich theorem can be proven by clever applications of the mean value theorem. They both have generalizations in higher dimensions, where we have points of as many colors as the dimension, whose proofs rely on stronger results from algebraic topology, such as the Borsuk-Ulam theorem and Dold's theorem.

Theorem 3 (Dold 1983)**.** *Given a finite group G with $|G| > 1$, if X and Y are two paracompact spaces with free actions of G, X is n-connected and Y is at most n-dimensional, there is no G-equivariant map $f : X \to_G Y$.*

Other extensions exist if you want to divide the plane (or a convex object) into convex pieces that are equal in a different light. For example, let us consider partitions of an equilateral triangle into five convex pieces. However, instead of requiring that each set has the same number

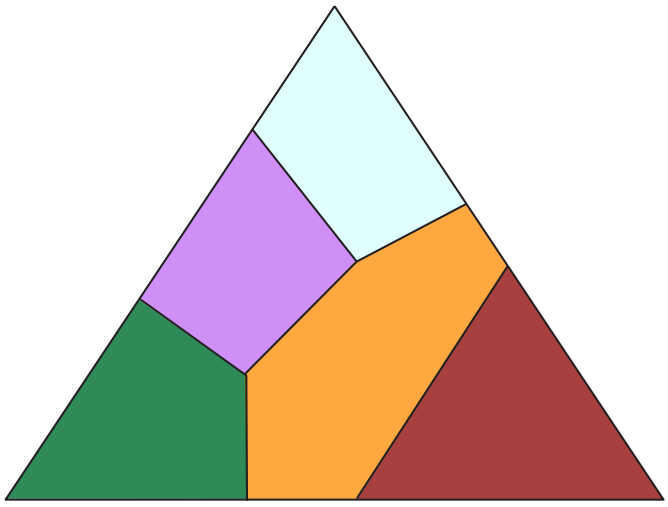


Figure 7. Trying to find partitions with parts of equal area and equal perimeter breaks most factorization tricks.

of blue and red points, is it possible for the five pieces to have equal area and equal perimeter? An attempt is shown in Figure 7, but it is no easy task.

This seemingly innocent question was first asked by Nandakumar and Rao. Direct applications of Dold's theorem fail, so one has to dive deeper into topological methods. The answer to this problem is positive, and has far-reaching generalizations, best explained in an expository article by Günter M. Ziegler [5]. Those results point out the fact that if there is an accepted formula to measure gerrymandering, it might still be possible to subdivide a map into convex pieces where each part has the same proportion of each colored set and all yield the same result under the formula (we are no longer requiring all districts to hold the same population).

In other words, even with strong conditions on the shape of the districts, gerrymandering can be done. An analysis of an electoral map should not be based solely on the geometry of the districts. In particular, you should be wary if the person drawing congressional maps knows his share of algebraic topology.

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EDITOR'S NOTE. Applications of similar techniques to problems of optimization and mathematical economics is one area of focus for the current MSRI program "Geometric and Topological Combinatorics" www.msri.org/programs/309 .

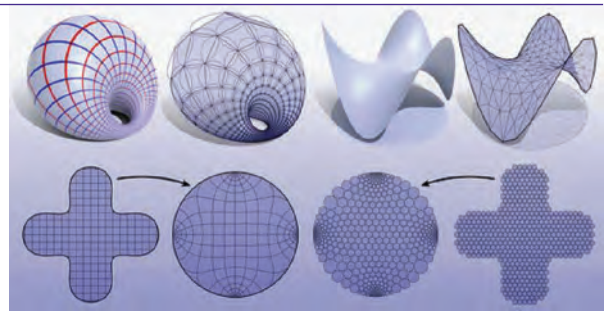
Image Credits

Figures 1, 3–7, and author photo courtesy of Pablo Soberón. Figure 2 ©MapBox. Taken from GovTrack.us Congressional District Maps.

ABOUT THE AUTHOR

Pablo Soberón's research lies in the connection of topology, linear algebra, and combinatorics. In particular, he is interested in discrete geometry and combinatorial topology.

Pablo Soberón



AMS Short Course

Discrete Differential Geometry (DDG)

San Diego Convention Center, San Diego, CA

January 8–9, 2018

AMS Short Course on Discrete Differential Geometry

This two-day course is organized by **Keenan Crane,** Carnegie Mellon University. The speakers include **Yaron Lipman**, Weizmann Institute; **Justin Solomon,** Massachusetts Institute of Technology; **Johannes Wallner**, TU Graz; and **Max Wardetzky,** University of Göttingen.

The emerging field of *discrete differential geometry (DDG)* studies discrete analogs of smooth geometric objects, providing an essential link between analytical descriptions and computation. In recent years it has unearthed a rich variety of new perspectives on applied problems in computational anatomy/biology, computational mechanics, industrial design, computational architecture, and digital geometry processing at large. The basic idea behind discrete differential geometry (DDG) is that a discrete object like a polyhedron is not merely an approximation of a smooth one, but rather a differential-geometric object in its own right. In contrast to traditional discretization which focuses on eliminating approximation error only in the limit of refinement (e.g., by taking smaller and smaller *finite differences*), DDG places an emphasis on so-called "mimetic" discretization where key properties of a system are guaranteed to be exactly preserved, no matter how fine or coarse the discretization. For instance, just as algorithms for simulating mechanical systems might seek to exactly preserve energy or momentum, structure-preserving discretizations of geometry might seek to exactly preserve quantities like total curvature. More broadly, DDG focuses on the discretization of differential geometric objects that do not naturally fall under the umbrella of traditional numerical analysis. This course provides an overview of recent themes in DDG, including both mathematical developments and examples of how DDG is applied in practice.

Each of the following lectures will provide a self-contained introduction to a core topic in DDG, including necessary review of concepts from the smooth setting, basic principles of discretization, and several instances of real world examples. Each lecture will be broken up into two one hour segments, with the first hour covering theory (both smooth and discrete) and the second hour covering applications. Most of this material will be at a level comparable to an introductory graduate course, similar to the discrete differential geometry course found at `brickisland.net/DDGSpring2016`. Familiarity with basic PDEs (e.g., heat flow and Laplace's equation) as well as some basic knowledge of curves and surfaces is useful but not essential.

A *"Demo Session"* on the first day will allow participants to get some hands-on interaction with the kinds of algorithms discussed in the lectures, allowing them to see how they work—and where they still fail! Interested participants are also invited to bring their own demos to the session.

Lecture Topics

Discrete Laplace Operators

Max Wardetzky

Max Wardetzky, University of Göttingen

The Laplace operator is perhaps the most prototypical differential operator for various physical phenomena. It describes, e.g., heat diffusion, wave propagation, steady state fluid flow, and it is key to quantum mechanics.Various of these phenomena call for efficient and reliable computer-based physical simulations. Since computers can only deal with a finite number of pieces of information at a given time, this poses the challenge of how to formulate discrete, finite-dimensional versions of differential operators. This challenge entails both discrete versions of the underlying (often curved) geometry and discrete versions of differential operators, such as the Laplacian, acting on

these discrete manifolds. Moreover, for robustness and efficiency, many applications require discrete operators that retain key structural properties inherent in the continuous setting. In this lecture we review some important properties of Laplacians, smooth and discrete. We put special emphasis on a unified framework for Laplacians on Riemannian manifolds alongside discrete Laplacians on graphs and simplicial manifolds by combining perspectives from smooth geometry, discrete geometry, spectral analysis, numerical analysis, and geometry processing. We also discuss important theoretical limitations, namely that discrete Laplacians cannot satisfy all desired properties of the continuous case, such as the maximum principle. Retroactively, this explains the diversity of discrete Laplace operators that to date keep emerging in the literature.

Discrete Parametric Surfaces

Johannes Wallner

Johannes Wallner, TU Graz

Discrete parametric surfaces are discrete analogues of smooth surfaces. The precise manner of discretization is usually not as straightforward as, say, substituting derivatives by differences. Rather, discretization is guided by the principle that discrete surfaces should exhibit a theory of their own: Discrete minimal surfaces are not only discrete approximations of their smooth counterparts (though they can be), but they are geometric combinatorial objects in their own right. It turns out that there is a rich theory of discrete surfaces which is related to discrete integrable systems. It can even be seen as a master theory containing the smooth case as a limit, and which is capable of painlessly explaining certain phenomena exhibited by smooth surfaces that otherwise would not have a systematic explanation. On the application side, this field recently attracted interest from an unexpected source, in connection with freeform architectural designs and the question how to actually build them.

Discrete Mappings

Yaron Lipman

Yaron Lipman, Weizmann Institute

Piecewise-linear triangle meshes are widely popular for surface representation in the digital computer; mappings of meshes are therefore central for applications such as computing good coordinate systems on surfaces (parameterization), finding correspondence between shapes, and physical simulation. However, representation and calculation of mappings in a computer pose several challenges: (i) how to define faithful discrete analogs of properties of smooth mappings (e.g., angle or area preservation), (ii) how to guarantee properties such as injectivity and/or surjectivity, and (iii) how to construct mappings between non-Euclidean (curved) domains.

One particularly interesting sub-class of simplicial mappings is the collection of convex combination mappings [1, 2] where the image of each vertex of the triangulation is restricted to the convex-hull of its immediate neighbors' images. Convex combination mappings can guarantee injectivity, are simple to compute algorithmically, offer a discrete analog to harmonic mappings, and can be used to approximate conformal mappings.

This lecture provides an introduction to convex combination mappings, their generalizations, as well as algorithmic aspects and practical applications.

Discrete Conformal Geometry

Keenan Crane

Keenan Crane, Carnegie Mellon University

Angle-preserving or *conformal* mappings are a central object in complex analysis and surface theory; they have also proven to be an essential component of a broad range of numerical algorithms including surface meshing, comparative data analysis, physical simulation, and computational design. Why such great interest in maps that preserve *angle*? One reason is that, computationally, problems involving conformal maps often reduce to solving easy *linear* problems, allowing algorithms to scale to many millions of degrees of freedom, or providing an effective starting point for more difficult nonlinear problems. Another is that angle preservation is directly linked to real mechanical or constitutive properties of physical systems, where other types of mappings are simply not appropriate.

This lecture gives a broad introduction to smooth conformal geometry and discrete algorithms. The richness of the discrete question arises from the many different possible characterizations of conformal maps in the smooth setting: beyond preservation of basic quantities like angles or lengths, conformal maps can be obtained via solutions to elliptic PDEs like Cauchy–Riemann, or parabolic flows like Yamabe or Ricci flow (to name just a few). Although these descriptions are all essentially equivalent in the smooth setting, each perspective can lead to very different ideas about discretization, which in turn provide different algorithmic guarantees. Specific topics include Thurston's circle packing conjecture, algorithms for circle packing/circle patterns, discrete complex analysis on integer grids and quad graphs, discrete Yamabe flow and its relationship to length cross ratios, as well as recent developments on a discrete theory for surfaces immersed in $\mathbb{R}^3$. We will touch on applications in geometry processing including surface parameterization, landmark correspondence, surface deformation, and metric reconstruction.

Optimal Transportation on Discrete Domains

Justin Solomon

Justin Solomon, Massachusetts Institute of Technology

Inspired by the matching of supply to demand in logistical problems, the optimal transportation (or *Monge–Kantorovich*) problem involves the matching of probability distributions defined over a geometric domain such as a surface or manifold. After discretization, optimal transportation becomes a large-scale linear program, which typically is infeasible to solve efficiently on triangle meshes, graphs, point clouds, and other domains encountered in graphics and machine learning. Recent breakthroughs in numerical optimal transportation enable scalability to orders-of-magnitude larger problems, solvable in a fraction of a second.

In this lecture, we will discuss advances in numerical optimal transport that leverage understanding of both discrete and smooth aspects of the problem. State-of-the-art techniques in discrete optimal transportation combine insight from partial differential equations (PDE) with convex analysis to reformulate, discretize, and optimize transportation problems. The end result is a set of theoretically-justified models suitable for domains with thousands or millions of vertices. Since numerical optimal transport is a relatively new discipline, special emphasis will be placed on identifying and explaining open problems in need of mathematical insight and additional research.

Registration

There are separate fees to register for this Short Course. Advanced registration fees for members are US$114; non-members US$175; and students/unemployed or emeritus members US$62. These fees are in effect until December 20, 2017. If you choose to register on-site, the fees for members are US$148; non-members US$205, and students/unemployed or emeritus members US$83.

Advanced registration starts on **September 11, 2017.** On-site registration will take place on **Monday, January 8, 2017**, exact location to be determined.

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Headshot of Justin Solomon by Lillie Paquette/MIT School of Engineering.

EDITOR'S NOTE: Keenan Crane and Max Wardetzky's article, "A Glimpse into Discrete Differential Geometry" will appear in the upcoming November issue of *Notices*.

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OPINION

A Formula Goes to Court: Partisan Gerrymandering and the Efficiency Gap

Mira Bernstein and Moon Duchin

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

ABSTRACT. Recently, a proposal has been advanced to detect unconstitutional partisan gerrymandering with a simple formula called the *efficiency gap*. The efficiency gap is now working its way towards a possible landmark case in the Supreme Court. This note explores some of its mathematical properties in light of the fact that it reduces to a straight proportional comparison of votes to seats. Though we offer several critiques, we assess that *EG* can still be a useful component of a courtroom analysis. But a famous formula can take on a life of its own and this one will need to be watched closely.

Gerrymandering is drawing political boundary lines with an ulterior motive. This idea has great currency right now, with particular attention paid to manipulating shapes of US congressional and legislative districts in order to obtain a preferred outcome. Gerrymandering comes in many flavors, including *racial gerrymandering*, where a minority group is subject to dilution of its voting strength; *partisan gerrymandering*, where one political party controls the process and tries to exaggerate its own political dominance; and *incumbent gerrymandering*, where officials try to create safe seats for incumbents on both sides of the aisle. All kinds of gerrymandering use some of the same techniques, especially *packing*, where you seek to stuff your opponents into districts with very high percentages, and *cracking*, where you disperse your opponents into several districts in numbers too small to predominate. Both of these techniques generate wasted votes by your opponents and thus reduce your opponents' share of seats relative to their share of the votes cast.

In this note we will focus on partisan gerrymandering. The Supreme Court has heard cases on partisan gerrymandering three times,[1] and each time the justices have balked. They disagreed among themselves about whether partisan gerrymandering was within the Court's purview at all and about what standards might be used to detect it. In the most recent case, the swing vote belonged to Justice Anthony Kennedy, who wrote a lengthy opinion explaining why he was unsatisfied with the standards proposed by the plaintiffs to demonstrate that unconstitutional gerrymandering had occurred. Kennedy also gave some guidelines for what would be needed to satisfy him in the future. For the past ten years, legal scholars and political scientists have pored over Kennedy's opinion, trying to design a standard that he might find convincing.

In 2015, one such team, Nicholas Stephanopoulos and Eric McGhee [3], advanced a new idea to quantify partisan gerrymandering, tailored to Kennedy's guidelines. They propose a simple numerical score called the *efficiency gap* (*EG*) to detect and reject unfair congressional and legislative maps that are rigged to keep one party on top in a way that is unresponsive to voter preferences. *EG* can be computed based on voting data from a single

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See an article on "Gerrymandering, Sandwiches, and Topology" in the Graduate Section (page 1010).

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[1] *Davis v. Bandemer (1986); Vieth v. Jubelirer (2004); LULAC v. Perry (2006)*

election: if the result exceeds a certain threshold, then the districting plan has been found to have discriminatory partisan effect.

Last November, for the first time in thirty years, a federal court invalidated a legislative map as an unconstitutional partisan gerrymander [4].[2] A centerpiece in the district court's ruling was the high efficiency gap in Wiconsin's 2012–2016 elections in favor of Republicans. Now the case is under appeal to the Supreme Court, and many observers are hoping that *EG* will finally provide a legally manageable standard for detecting partisan gerrymanders in time for the 2020 census. If this happens, it will signal a seismic shift in American politics.

In this note, we engage in the following exercise: first, we give a self-contained analysis of *EG* for a mathematical audience, describing what it measures and what it does not. Then, we examine how our findings relate to the original proposal, the press coverage, and the court decisions to date. We close by looking to the future career of this consequential formula.

What is the Efficiency Gap?

The US electoral scene is dominated by the use of geographically-defined districts in which one representative is chosen by a plurality vote. We will follow the *EG* literature by simplifying to the case of only two political parties, A and B. Let's say that our state has S congressional or legislative seats, and denote the set of districts by $\mathcal{D} = \{d_1, \dots, d_S\}$. In a particular election, write $\mathcal{D} = \mathcal{D}^A \sqcup \mathcal{D}^B$ where $\mathcal{D}^P$ is the subset of districts won by party $P \in \{A, B\}$. In what follows, if a value X_i^P is defined with respect to party P and district d_i, we will write

$$X^P = \sum_{i=1}^{S} X_i^P; \quad X_i = X_i^A + X_i^B; \quad \text{and} \quad X = X^A + X^B = \sum_{i=1}^{S} X_i.$$

Let S_i^P be 1 if party P won in district d_i and 0 if not, so that $S^P = |\mathcal{D}^P|$ is the number of seats won statewide by P. Let T_i^P be the number of votes cast in district d_i for party P, so that T_i is the voting turnout in district d_i and T^A is the total number of statewide votes for A. Later we'll make the further simplifying assumption that the districts have not just equal population but equal turnout: $T_i = T/S$.

With this notation, we can write $\tau = \frac{T^A - T^B}{T}$ and $\sigma = \frac{S^A - S^B}{S}$ for the statewide *vote lean* favoring A and the statewide *seat lean* favoring A. Most people's intuitions about fairness would incline towards a districting plan that approximates *proportionality*, or $\sigma \approx \tau$. Historically, the courts have sometimes recognized rough proportionality as a virtue, but have explicitly rejected strict proportionality as a standard.[3]

Wasted votes, in the *EG* formulation, are any votes cast for the losing side or votes cast for the winning side in excess of the 50 percent needed to win. That is, the number of votes wasted by A-voters in district d_i is

$$W_i^A = \begin{cases} T_i^A - \frac{T_i}{2}, & d_i \in \mathcal{D}^A, \\ T_i^A, & d_i \in \mathcal{D}^B \end{cases} = T_i^A - S_i^A \cdot \frac{T_i}{2}.$$

Quick observation: the total number of wasted votes in a district, $W_i = W_i^A + W_i^B$, is always half of the turnout T_i. The question is how the wasted votes are distributed. If (nearly) all the wasted votes belong to the winning side, it's a packed district. If (nearly) all the wasted votes belong to the losing side, it's a competitive district. And if there are several adjacent districts where most of the wasted votes are on the losing side, then it may be a cracked plan.

We can now define the *efficiency gap* associated with districting plan $\mathcal{D}$:

$$EG = \sum_{i=1}^{S} \frac{W_i^A - W_i^B}{T} = \frac{W^A - W^B}{T}.$$

Thus *EG* is a signed measure of how much more vote share is wasted by supporters of party A than B. If *EG* is large and positive, the districting plan is deemed unfair to A. On the other hand, $EG \approx 0$ indicates a fair plan, inasmuch as the two parties waste about an equal number of votes. Stephanopoulos–McGhee write that this definition "captures, in a single tidy number, all of the packing and cracking decisions that go into a district plan."

For a toy example, consider the figure below, which shows three possible districting plans for the same distribution of voters. Each box represents a voter; A-voters are marked ⋆ and B-voters are blank. Since A-voters make up half of the population, intuitively we expect a "fair" plan to have $S^A = S^B$. Plans I and III both do this and it is easy to check that they have $EG = 0$. In contrast, Plan II gives A five of the six seats by packing some B-voters into one district and cracking the rest. This gerrymander is successfully detected: $EG = -1/3$, unfairly favoring Party A. Note that there is a lot of packing and cracking in Plan III as well, but this is not penalized by *EG* because it happens symmetrically to voters of both parties.

Plan I: $EG = 0$ Plan II: $EG = -1/3$ Plan III: $EG = 0$

[2] *This happened only once before, in Davis v. Bandemer (1982), which was later overturned by the Supreme Court.*

[3] *The Supreme Court has a complicated attitude to proportionality. See, for instance, Gaffney v. Cummings (1973), Davis v. Bandemer (1986), and Johnson v. De Grandy (1994). However, it was clearly stated in the Bandemer plurality opinion that "the mere lack of proportional representation will not be sufficient to prove unconstitutional discrimination."*

Of course, in real life, no districting plan will have an efficiency gap of exactly 0. How high is too high? Stephanopoulos and McGhee argue that $EG = .08$ corresponds to a historically robust threshold for unacceptable partisan gerrymandering.[4] In the Wisconsin case, for example, the plaintiffs demonstrated that the last three elections for the State Assembly had efficiency gaps between 0.1 and 0.13 in favor of Republicans. Since it was a Republican legislature that had drawn the map, and there was plentiful evidence that they had intentionally done so to disfavor Democrats, the court ruled that the plan was an unconstitutional partisan gerrymander. QED.

What Does the Efficiency Gap Actually Measure?

But wait! The *EG* formula turns out to simplify quite a bit, in a way that has bearing on our understanding of what it measures. Let's proceed with the assumption of equal voter turnout: $T_i = T/S$.[5] In this case, we get

$$W^A = \sum W_i^A = T^A - S^A \cdot \frac{T}{2S},$$

and thus

$$EG = \frac{T^A - T^B}{T} - \frac{1}{2}\frac{S^A - S^B}{S} = \tau - \frac{1}{2}\sigma.$$

That is: the efficiency gap is just the statewide vote lean favoring A minus half of the statewide seat lean favoring A.[6] It has nothing at all to do with how the voters are distributed among districts, per se. As long as the seat total comes out a certain way, as in Plan III shown above, *EG* does not penalize packing or cracking, or for that matter bizarrely-shaped districts—and indeed, it sometimes incentivizes them, as we will see below.

In its simplified form ($\tau - \frac{1}{2}\sigma$), we can see that *EG* has numerous potentially undesirable properties.

- **Penalizes proportionality.** If Party A has 60 percent of the statewide vote and 60 percent of the seats, *EG* rates this as an unacceptable gerrymander in favor of Party B! ($\tau - \frac{\sigma}{2} = 0.2 - 0.1 > 0.08$.) This is because $EG = 0 \iff \sigma = 2\tau$. That is, the intuitive idea that representation should be proportional to vote share is replaced by the conflicting principle that the seat lean should be *twice* the vote lean.
- **Volatile in competitive races.** *EG* behaves very erratically if there are districts with competitive races, because a genuinely close outcome will produce lopsided vote wastage, but it is unpredictable which side this falls on.[7] If, for instance, all districts are competitive but a last-minute trend pushes voters to one side systematically, then the *plan itself* will be rated as a gerrymander.
- **Fetishizes three-to-one landslide districts.** We've seen that *EG* is not sensitive to any changes in packing and cracking that preserve σ (i.e., that preserve the overall seat outcome). But if anything, *EG* rewards a certain level of district-by-district packing. Recall that every district has a total of 50 percent vote wastage. It immediately follows that the only way to share that fairly in a single district is to have 25 percent on each side, which is a 75–25 vote split. So the only districts viewed by *EG* to be perfectly neutral are highly non-competitive districts, and any plan made up entirely of these landslide districts will be judged perfectly fair.
- **Breaks down in edge cases.** Despite the fact that 75 percent is an artificial sweet spot, 80 percent statewide vote share breaks *EG* completely. If A controls more than 79 percent of the vote in a state, then $\tau > .79 - .21 = .58$. In order to get $\tau - \sigma/2 < .08$, we must have $\sigma > 1$, which is impossible. Thus, in this circumstance *EG* will identify absolutely *any* districting plan as a partisan gerrymander in favor of B.
- **Nongranular.** We have seen that *EG* does no more and no less than compare seats to votes by a double-proportionality standard. This has the added consequence that in states with a small number of districts, the way that *EG* depends on a districting plan is extremely nongranular: for a given vote split, there are only S possible values of the the efficiency gap, as the majority party's seat total ranges from 1 to S. For a particular voting split, a small state may have no outcome at all with a permissibly small *EG*. This makes the score far too coarse for use in many races; twenty one states currently have four or fewer Congressional districts.[8]

How is This Playing Out in Court?

So far we have highlighted, with the help of simple algebra, several grave limitations of *EG* as a stand-alone metric. If the Supreme Court were to enshrine the efficiency gap as a dispositive indicator of partisan gerrymandering, it would be sure to produce false positives as well as false negatives with respect to any common-sense understanding of political unfairness. But has anyone actually proposed

[4] *They propose a somewhat different standard of two excess seats for congressional districting plans.*

[5] *Dropping the equal-turnout assumption only makes matters worse in the critiques of EG that follow, because this corresponds to a weighting of terms that is harder to interpret and defend. Without the equal-turnout simplification, EG is affected as follows: if there is lower average turnout in the districts $\mathcal{D}^A$, then maintaining a low EG requires A to get more seats than party B would have with the same vote share.*

[6] *This can also be written in terms of seat share and vote share rather than seat lean and vote lean:* $EG = 2(T^A/T) - (S^A/S) - 1/2$.

[7] *In a current preprint, Cover* [2, p. 34] *argues persuasively that this provides a stark disincentive for even an honest mapmaker to draw a competitive plan.*

[8] *Cho* [1] *discusses nongranularity at length.*

that it be used that way? Press headlines have touted *EG* as "a formula to end gerrymandering" and a simple way to "end gerrymandering once and for all," trumpeting that "this is how to get rid of gerrymandered districts."[9] But a brief review of the political science literature and court documents shows circumspect writing and multifaceted analysis at all stages: the role of *EG* in the legal landscape is much more complex.

Original Framing

First and importantly, Stephanopoulos and McGhee propose a doctrinal test for partisan gerrymandering in which *EG* can be considered only if several other conditions are met. They address concerns about volatility by requiring evidence of stability: plaintiffs must perform a "sensitivity analysis" to show that their disadvantage would persist under a modest statewide swing to one party or the other and must demonstrate the gap's likely durability over time. Nongranularity is indirectly acknowledged: in their historical analyses, the authors only considered elections with eight or more seats. And edge cases, in the form of extremely lopsided elections, are simply dismissed as never occurring at the statewide level.

Defending the idealization of double-proportionality is a heavier lift. The fact that using *EG* commits you to condemning proportional outcomes is actually observed in a footnote [3, p. 18, note 107], but Stephanopoulos and McGhee defend it as reasonable on the grounds of quantifying an appropriate "seat bonus" for the majority party. On this view, the efficiency gap quantifies the level of bonus that *should* be enjoyed by the winner: a party with 60 percent of the vote should have 70 percent of the seats, a party with 70 percent of the vote should have 90 percent of the seats, etc. We will return to this point below.

The District Court

Many objections to the usefulness of *EG* were introduced in the Wisconsin case in the form of expert reports and testimony for the defense. The court decision endorses a three-pronged test expanding on the proposal described above by requiring proof of discriminatory intent.[10] The majority opinion argues that this protects against false positives: "If a nonpartisan or bipartisan plan displays a high *EG*, the remaining components of the analysis will prevent a finding of a constitutional violation." Thus, for instance, a proportional plan would not be thrown out on the grounds of high *EG*, because the plaintiffs would not be able to demonstrate improper partisan intent. The court affirms *EG* not as a conclusive indicator, but only as persuasive "corroborative evidence of an aggressive partisan gerrymander."

The Supreme Court

The strategy that the Wisconsin plaintiffs will use at the next level is outlined in their motion to appeal. While praising the usefulness and diminishing the critiques of *EG*, this document does emphasize its limited role: "To be clear, Appellees do not ask the Court to endorse any particular measure of partisan asymmetry or any particular technique for demonstrating durability. The [district court] did not do so, nor need the [Supreme Court] in order to affirm. Rather, Appellees advocate the same course of action the Court has followed in other redistricting contexts involving discriminatory effects: namely, the articulation of a standard whose precise contours are filled in through subsequent litigation."

And Beyond

There is a philosophical issue at the heart of this analysis. Can a formula be said to "measure" quantities that are used to compute it, or only those to which it is numerically sensitive? Wasted votes are apparent inputs into *EG*, but their local contributions come out in the wash, and only *deviation from double-proportionality of seats to votes* remains. Setting double-proportionality as a target contravenes the common-sense preference for proportionality, an ideal that even the Supreme Court has recognized despite its insistence that it is not constitutionally required. While political scientists have found evidence of a hyper-proportional seat bonus in real elections, we have seen no persuasive case for the slippage from an empirical description to a specific normative standard (that is, from what *is* the case to what *should be* the case). We assess this as the most serious indictment of the *EG* formula.

Our evaluation suggests a suite of particular circumstances in which *EG* could be a useful component of a broader analysis[11]—and it seems that Wisconsin's State Assembly districts currently present such a case. However, a mathematician could well argue that a formula which is only used to lend numerical corroboration in special and extreme cases is a formula of limited usefulness indeed. This caution has to be weighed against the plain fact that courts have found no manageable standard to date for even the most extreme partisan abuses in redistricting.

To a great extent, critiques of *EG* are mitigated by the limited circumstances in which courts will apply it and

[9] *See coverage in the* Detroit Free Press, New Republic, *and* Washington Post.

[10] *First, plaintiffs must establish the intent to discriminate on the basis of political affiliation. Then, discriminatory effect must be established, and EG can be used to that end. And finally, defendants must fail to provide justification of the necessity of the plan on other legitimate legislative grounds.*

[11] *To use EG, we'd want a state with enough congressional districts for EG to be sufficiently granular, a close enough overall partisan preference split that double-proportionality does not predict outlandish seat margins, few enough uncontested districts to require a minimum of counterfactual speculation in incorporating them in to the numbers, an appropriate balance of competitive districts to pass sensitivity analysis, and an egregious enough partisan power grab to still show up.*

the fact that it may well be endorsed only as a first draft of a general standard that will be refined over time. But major concerns remain. Courts will have safeguards in place, but *EG* is already in play outside of courts, and there is a real risk that it may come to stand in as an operationalized *definition* of partisan gerrymandering. We are seeing hints of this effect not only in the overheated popular press coverage but in more scholarly work as well.[12]

Legal scholars believe that *EG* will appeal to the courts because of its simple, one-shot construction with no technical machinery. As we have seen, the simplicity is actually illusory: a lot of care, including further statistical testing and modeling, is required to use *EG* responsibly. Moreover, *EG* comes on the scene at a time when having a single formula is becoming less important. One of the most promising directions in the detection of gerrymandering is the use of computational methods that can take multiple indicators into account simultaneously. For instance, various teams of researchers have developed sampling tools for comparing a proposed plan against an algorithmically generated batch of alternate plans.[13] Typically these samplers can incorporate both equality constraints and inequality constraints, encoding both legal requirements and preferences. The core idea of *EG* can be coded into a sampling analysis by, for instance, replacing the use of $\tau - \frac{1}{2}\sigma$ as a score with bounds that constrain the deviation from proportionality rather than prescribing it. Alternatively, the seats-to-votes proportionality could be used as an evaluation axis. A plan like the Wisconsin legislative map could be taken as input, and hundreds of thousands of alternate maps would be randomly generated that meet the relevant legal requirements and are scored at least as well by legitimate districting criteria. If a districting plan had a seat share to vote share ratio of $(S^A/S)/(T^A/T) = 1.25$ in a particular election and 95 percent of computer-generated alternatives had ratios of 1.05–1.15 with the same data, then we'd have excellent evidence of excessive partisan skew. Use of sampling comparisons is improving quickly as increased computing power lets the algorithms visit more of the space of possible plans. As the ability to study large samples of neutrally-generated maps rapidly becomes both sophisticated and practicable, the hoped-for breakthrough in adjudicating gerrymanders, partisan and otherwise, may be coming within close reach after all.

The Wisconsin plaintiffs are not asking the court to enshrine *EG* as the one true measure of partisan gerrymandering, but only to accept it as a starting point in building a test to show when entrenched partisan advantage has risen to the level of vote dilution of political opponents. We hope that the Supreme Court agrees with them in a decision that leaves room for *EG* to pave the way for refined metrics and methods in the years to come.

[12] *One such example is* Extreme Maps, *a research report put out by the Brennan Center at NYU, which uses EG without any caveats to assess the current state of partisan gerrymandering in the US.*

[13] *See for instance multiple papers with various co-authors by Jowei Chen and by Jonathan Mattingly, whose teams use Markov chain Monte Carlo, or by Wendy Cho and Yan Liu, who use genetic and evolutionary algorithms.*

References

[1] Wendy K. Tam Cho, Measuring Partisan Fairness: Guarding Against Sophisticated as well as Simple-Minded Modes of Partisan Discrimination, *University of Pennsylvania Law Review Online*, 166, July 2017.

[2] Benjamin Plener Cover, Quantifying Political Gerrymandering: An Evaluation of the Efficiency Gap Proposal, *70 Stanford Law Review* (forthcoming 2018).

[3] N. O. Stephanopoulos and E. M. McGhee, Partisan gerrymandering and the efficiency gap, *The University of Chicago Law Review* (2015), 831–900.

[4] Whitford v. Gill, F.Supp. 3d, 2016 WL 6837229, 15-cv-421-bbc, W.D.Wisc. (Nov. 21, 2016).

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Photo of Mira Bernstein courtesy of Yugo Nakai.
Photo of Moon Duchin courtesy of Tufts Photography.

ABOUT THE AUTHORS

Mira Bernstein splits her time between math education and using mathematics and data science to address social problems. When she has time, she enjoys climbing inside the Voronoi tessellation of the body-centered cubic lattice.

Mira Bernstein

Moon Duchin's research is in geometric group theory, low-dimensional topology, and dynamics. She has recently begun to work on the many mathematical aspects of electoral redistricting.

Moon Duchin

AMS on Social Networks

"Like" us—and find others who "Like" the AMS—at our AMS Facebook page.

Follow and comment on AMS blogs for students, mentors and mathematicians.

Follow us on Twitter.

Join the AMS LinkedIn® Group to participate in discussions on math and career information.

Subscribe to our videos, share them, comment on them and embed them in your own sites from the AMS YouTube channel.

Share research, news, and sites of interest with the math community on google+.

As part of the Society's commitment to the open flow of communication and community engagement, the AMS uses several networking tools to supplement the channels currently in place for members, press and the general public.

We invite you to share AMS website content and set up RSS feeds for website updates and blogs.

www.ams.org/social

AMS
American Mathematical Society

Report of the Treasurer (2016)

Introduction

While in 2016 the net operating income of the American Mathematical Society (AMS) was down from that of the two previous years, overall the organization experienced a financially successful year for the year that ended December 31, 2016. The main factors positively impacting the bottom line for 2016 were a gift from the estate of Franklin and Marilyn Peterson, amounting to $625,000 and the growth of the board-designated spendable income from investments in the Operating Support Fund (OSF), which contributed $2.5 million to the 2016 operating revenues. Additionally, the AMS book program experienced a significant increase in sales. In 2016, the net operating income of the Society was approximately $1.6 million, as compared to a net income of $2.4 million in 2015. We expand upon these statements in this report.

The Report of the Treasurer is presented in the *Notices* annually and discusses the financial condition of the Society as of the immediately preceding fiscal year-end and the results of its operations for the year then ended. One of the key responsibilities of the Treasurer is to lead the Board of Trustees in the oversight of financial activities of the Society. This is done through close contact with the executive staff of the Society, review of internally generated financial reports, review of audited financial statements, and twice yearly meetings with the Society's independent auditors. Through these and other means, the Trustees gain an understanding of the finances of the Society and the important issues surrounding its financial reporting.

When reviewing the financial results of the AMS presented here, it is important to note that the financial support for its membership and professional programs is derived from multiple sources. First, the OSF provided $2,500,000 in operating support to the membership and professional programs in 2016. The OSF is a fund that has grown throughout the years from operating net income as well as investment gains; because the fund is dependent upon market conditions, the amount provided varies from year to year. In addition, the membership and professional programs are supported through dues income and contributions. Finally, the margin from the publication programs supports these services as well. Without the margin from publications and the OSF income, dues and contributions alone would not provide enough support to continue professional programs, such as MathJobs, scholarships, fellowships, and *Notices*.

The Society segregates its net assets, and the activities that increase or decrease net assets, into three types: unrestricted, temporarily restricted, and permanently restricted. Total net assets at the end of 2016 were $140 million. Unrestricted net assets are those that have no requirements as to their use placed on them by donors outside the Society. A substantial majority of the Society's net assets are in this category. Temporarily restricted net assets are those with donor-imposed restrictions or conditions that will lapse upon the passage of time or the accomplishment of a specified purpose. Examples of the Society's temporarily restricted net assets and related activities include grant awards and the spendable income from prize and other income- restricted endowment funds. Permanently restricted net assets are those that must be invested in perpetuity and are commonly referred to as endowment funds. The accompanying financial infor-

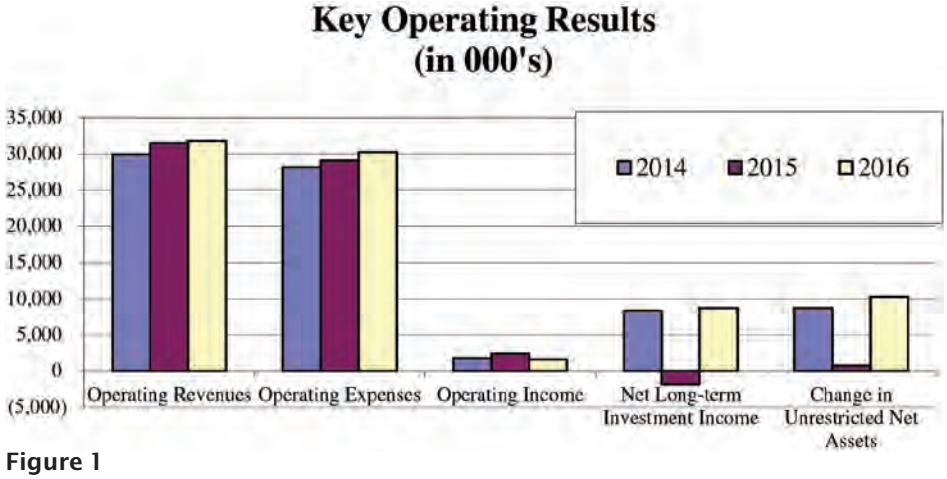


Figure 1

All currency discussed in this report refers to US dollars.

"k" denotes thousand.

"m" denotes million.

mation principally relates to the unrestricted net assets, as this category includes the operating activities of the Society.

Operating Results

Apart from low investment returns in 2015, Figure 1 shows that the past few years, 2014 through 2016, have been good years, financially, for the Society. Figure 1 also illustrates how important the unrestricted, long- term investments are to the financial health of the organization, as the returns on the investments are generally much higher than the operating income.

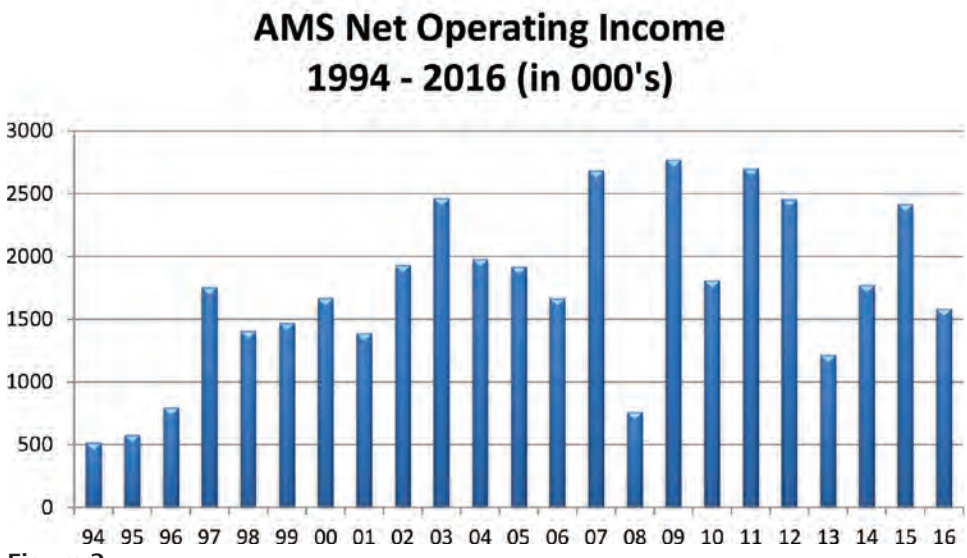


Figure 2

As mentioned in the opening paragraph, the positive net operating income of $1.6 million in 2016 benefited from the receipt of a large bequest, totaling about $625,000. Without the bequests the Society has received in recent years, operating incomes would have been much lower. This underscores the importance of donors' bequests, as they are helping to support the Society's operations during a time that strategic plan implementation is occurring. As shown in Figure 2, the Society has maintained a positive net income for more than two decades. For many years now, it has been important for the Society's management to ensure that expenses grow moderately, because publishing revenues, the Society's major source of revenue, are suffering from subscription attrition. In order to increase revenues, fundraising efforts have increased in recent years, and there is a corresponding increase in development revenues. Some long-term strategic planning initiatives being developed and implemented now and in the near future by the AMS, will address stagnant publishing revenues as well as a continued decline in membership and related dues income.

In 2016, the Society's revenues increased by 1 percent over 2015 revenues. There were two major sources of revenue increases. One major increase was in the book program revenues, which after many years of stagnant or decreasing revenues, experienced a sharp increase in sales of about 18 percent due in part to sales of recently published books and to sales through the new online bookstore. Another major increase was in spendable income from the long-term investments, increasing 22 percent over 2015. There was also a gain of about $360,000 over the 2015 income from short-term investments, contributing to the AMS operating revenues.

In 2016, expenses increased by 4 percent over the prior year. Wages and benefit costs contributed the most to this increase, due to large rises in benefits costs, normal wage increases, and the addition of new staff, mostly related to new strategic initiatives. While the governance of the AMS consists of volunteers, (elected and appointed with the approval of the Council), the execution of the activities of the Society that fulfill its mission are carried out primarily by professional staff at the AMS. Figure 3 shows the amounts spent on major expense categories in 2016 for more detailed information regarding the Society's operating results, please see the financial statements, including the Statements of Activities, located at the end of this report.

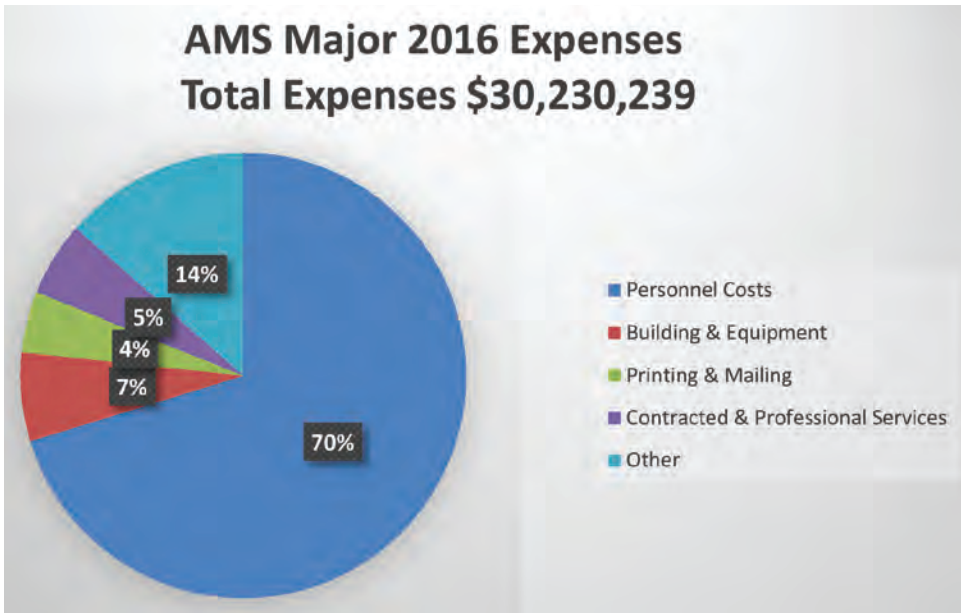


Figure 3

Highlights of Balance Sheets Changes from 2015 to 2016	Commentary
Accounts Receivable decreased $597k or 52% from the prior year	The decrease was primarily due to the receipt of two receivables from donor bequests that were outstanding at December 31, 2015, totaling $567k.
Land, building and equipment, net increased $707k or 16% over the prior year	The increase is related to major fixed asset additions: 1) $363k for capitalized labor related to a Personify software upgrade, 2) $291k for IT related equipment including a network storage platform and desktop computers, 3) $201k for a printing press and 4) $267k for new accounting software and $146k for related capitalized labor. These additions were offset by depreciation.
Long-term investments increased by approximately $13,082k or 10%.	Increase in long-term investments was due to appreciation in investments from unrealized gains and dividends and interest income reinvested.
Net assets increased by $11,970k or about 9.3%	Increase was driven largely by investment gains of 9.9% offset by releases from the endowment.

Table 1

2016 Balance Sheets Highlights

Another report within the financial statements, referred to as the Balance Sheets, is also at the end of this financial review. Balance sheets provide a snapshot of the financial position of the Society at the end of 2016; the Society continues to maintain healthy balance sheets. Total net assets of the organization are $140 million, of which $122 million are unrestricted. Table 1 shows highlights of the Society's 2016 Balance Sheets.

2016 Statements of Invested Funds

The Statements of Invested Funds are divided into the permanently restricted funds that have been acquired from donations in the form of endowment funds, and the funds that have been designated by the Board of Trustees for specific purposes (which we refer to as quasi-endowment funds).

The Society's Statements of Invested Funds is a listing of the Society's individual endowment and quasi- endowment funds. In addition, the invested funds of the Society contain a temporarily restricted fund, the Beal Prize, which at year-end amounted to $1.348 million. The corpus of this fund, $1,000,000, is set aside to fund a prize for solving the Beal Conjecture. The spendable income from the fund supports the Erdos Lecture and other programs. Overall, the 2016 Statements of Invested Funds show an increase of $12.6 million over the prior year. The operations of the AMS generated enough cash so that approximately $2,000,000 was returned to the investment portfolio at year-end, which offset the outflows from spendable income. The investment return was 9.9 percent as compared to a 0.17 percent return in 2015.

The quasi-endowment funds are set aside for various purposes. For example, the Kathleen Baxter Memorial fund provides spendable income to support the American Mathematical Society's Centennial Fellow. The Economic Stabilization Fund (ESF) is a fund set aside to cover the postretirement benefit obligation and 50 percent of the current annual operating expenses in case of disaster. The ESF also contains about $1.7 million to self-insure against flood risk. The Society's largest quasi-endowment fund, the Operating Support Fund (OSF), valued at approximately $95 million, provided $2,500,000 in spendable income to the AMS operations in 2016.

Summary Financial Information

The following Statements of Activities and Balance Sheets are from the audited financial statements of the AMS, and the Statements of Invested Funds are from the internal financial records of the AMS. Any member may contact the AMS to request the full audited statements of the Society. The Treasurer will be happy to answer any questions members may have regarding the financial affairs of the Society.

Respectfully submitted,
Jane M. Hawkins
AMS Treasurer

AMERICAN MATHEMATICAL SOCIETY

Balance Sheets

	December 31,	
	2016	*2015*
Assets		
Cash	$ 1,131,379	$ 1,018,324
Certificates of deposit	660,000	710,000
Short-term investments	14,600,782	14,454,171
Accounts and contributions receivable, net of allowances of $284,980 and $258,480 in 2016 and 2015, respectively	553,200	1,150,407
Deferred prepublication costs	594,587	568,295
Completed books	1,360,939	1,291,914
Prepaid expenses and deposits	1,632,127	2,038,938
Land, buildings and equipment, net	5,086,655	4,379,852
Long-term investments	140,116,402	127,034,621
Total assets	**$ 165,736,071**	**$ 152,646,522**
Liabilities and Net Assets		
Liabilities:		
Accounts payable and accrued expenses	$ 4,190,837	$ 3,748,485
Accrued study leave pay	736,298	698,508
Deferred revenue	12,926,112	12,613,091
Postretirement benefit obligation	7,646,939	7,321,355
Total liabilities	**25,500,186**	**24,381,439**
Net assets:		
Unrestricted:		
Undesignated		120,955
Designated	122,198,789	111,782,413
	122,198,789	111,903,368
Temporarily restricted	11,667,789	10,665,546
Permanently restricted	6,369,307	5,696,169
Total net assets	**140,235,885**	**128,265,083**
Total liabilities and net assets	**$ 165,736,071**	**$ 152,646,522**

AMERICAN MATHEMATICAL SOCIETY

Statements of Activities

	Years Ended December 31, 2016	2015
Changes in unrestricted net assets:		
Operating revenue, including net assets released from restrictions:		
Mathematical reviews	$ 11,877,717	$ 11,521,492
Journals	5,171,245	5,206,573
Books	4,134,261	3,494,449
Dues, services, and outreach	3,378,939	3,613,378
Investment returns appropriated for spending	2,537,418	2,074,382
Other publications-related revenue	590,102	605,080
Grants, prizes and awards	1,473,577	1,753,884
Meetings	1,438,623	1,321,735
Unrestricted contributions	797,693	1,813,725
Short-term investment income	394,068	64
Other	22,006	68,216
Total operating revenue	**31,815,649**	**31,472,978**
Operating expenses:		
Mathematical reviews	8,189,326	7,696,350
Journals	1,488,098	1,515,997
Books	3,629,068	3,442,729
Publications indirect	1,373,895	1,216,181
Customer services, warehousing and distribution	1,615,466	1,625,478
Other publications-related expense	188,623	141,647
Membership, services and outreach	4,804,083	4,533,481
Grants, prizes and awards	1,405,161	2,138,628
Meetings	1,344,479	1,268,016
Governance	642,822	569,277
Member and professional services indirect	1,054,673	891,823
General and administrative	4,418,657	3,915,508
Other	75,888	100,011
Total operating expenses	**30,230,239**	**29,055,126**
Excess of operating revenue over operating expenses	**1,585,410**	**2,417,852**
Nonoperating revenues and expenses:		
Investment returns less investment returns available for spending	8,512,302	(1,872,939)
Use of board designated funds from Endowment Income Stabilization Fund, Backfile Digitization and Strategic Initiative	(82,332)	(6,680)
Capitalization of in-house software development labor	509,745	
Depreciation of in-house software development labor	(57,438)	(53,810)
Postretirement benefit-related changes other than net periodic cost	(172,266)	247,745
Change in unrestricted net assets	10,295,421	732,168
Changes in temporarily restricted net assets:		
Contributions	$ 105,377	$ 332,307
Investment returns	1,549,217	13,503
Net assets released from restrictions	(652,351)	(730,744)
Change in temporarily restricted net assets	1,002,243	(384,934)
Change in permanently restricted net assets:		
Contributions	673,138	158,041
Change in permanently restricted net assets	673,138	158,041
Change in net assets	**11,970,802**	**505,275**
Net assets, beginning of year	128,265,083	127,759,808
Net assets, end of year	**$ 140,235,885**	**$ 128,265,083**

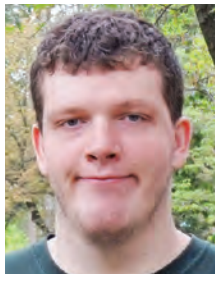
American Mathematical Society-Statements of Invested Funds
As of December 31, 2016 and 2015

Income Restricted Endowment:	**Original Gift**	**12/31/16**	**12/31/15**
Endowment Funds:	**at 12/31/16**	**Total Value**	**Total Value**
Research Prize Funds			
Steele	145,511	810,858	762,236
Birkhoff	50,132	101,799	95,695
Veblen	58,599	90,090	84,688
Wiener	29,773	53,985	50,748
Bocher	32,557	54,843	51,554
Conant	9,477	54,040	50,800
Cole Number Theory	52,313	76,607	71,773
Cole Algebra	51,963	76,265	71,452
Satter	49,720	88,917	83,585
Chevalley Fund	115,000	123,515	116,108
Doob Prize	80,000	104,542	98,274
Robbins Prize	41,250	62,172	58,443
Eisenbud Prize	40,000	58,226	54,734
Grenander (New in 2016)	51,045	51,093	0
Bertrand Russell (New in 2016)	100,000	100,000	0
Other Prize and Award Funds			
Morgan Prize	25,000	58,809	55,282
Albert Whiteman Prize	95,459	142,488	133,902
Arnold Ross Lectures	105,934	142,258	131,363
Trjitzinsky	196,030	651,502	612,435
C.V. Newsom	100,000	303,174	284,994
Centennial	61,183	161,716	152,019
Menger	97,250	147,297	138,464
Ky Fan (China)	366,757	520,773	489,545
Impact Award	22,110	30,260	28,446
Green Fund	25,000	25,447	0
Epsilon	2,166,482	3,074,571	2,803,104
Early Career Mathematician	403,000	417,874	0
Einstein Lecture	100,000	150,760	141,720
Exemplary Program	100,000	149,838	140,853
Mathematical Art	20,000	29,968	28,171
Subtotal (Income Restricted)	**4,791,546**	**7,913,686**	**6,790,388**
Endowment	113,200	1,007,499	946,521
Morita	100,000	178,541	167,967
Henderson	548,223	5,324,001	5,008,701
Schoenfeld/Mitchell	573,447	1,009,407	949,627
Laha	189,309	339,123	319,039
Ritt	51,347	317,196	298,411
Moore	2,575	29,900	28,129
Subtotal (Income Unrestricted)	**1,578,101**	**8,205,666**	**7,718,395**
Total Endowment Funds	**6,369,647**	**16,119,353**	**14,508,783**
Quasi-Endowment Funds (Board-Designated):			
Journal Archive Fund		1,872,852	1,657,495
Young Scholars		896,980	843,852
Economic Stabilization Fund (ESF)		24,163,443	30,131,910
Endowment Income Stabilization Fund (EISF)		0	482,844
Backfile Digitization Fund		68,401	111,389
Strategic Initiative Fund		310,657	250,000
Kathleen Baxter Memorial Fund		281,288	263,859
Operations Support Fund (OSF)		94,606,082	78,041,064
Total Quasi-Endowment Funds		**122,199,703**	**111,782,413**
Owed to Operations		449,077	
Beal Prize (Temporarily Restricted)	1,000,000	1,348,288	1,236,302
Total Invested Funds	**$7,369,647**	**$140,116,421**	**$127,527,498**

Inside the AMS

Math in Moscow Scholarships Awarded


Andres Mejia


Noah Riggenbach


Lucy Yang

The AMS has made scholarship awards of US$10,200 each to four mathematics students to attend the Math in Moscow program in the fall of 2017. The names of the awardees and their institutions follow.

- Robert Argus, George Mason University
- Andres Mejia, Bard College
- Noah Riggenbach, University of Scranton
- Lucy Yang, *University of Minnesota—Twin Cities*

—AMS Professional Programs Department

Photo Credits

Photo of Andres Mejia by Logn Stapleton.
Photo of Noah Riggenbach by Ginny Jones.
Photo of Lucy Yang by Jessica Shin.

Attention Graduate Students!

In July the AMS Graduate Student Blog featured a post[1] by Jacob A. Gross that provides a handy list of eight programs graduate students can apply to for funding their studies. Each program is briefly described, and links are provided to further information.

Check out all the AMS blogs at `blogs.ams.org`.

—An Announcement of AMS Graduate Student Blog

[1] `blogs.ams.org/mathgradblog/2017/07/19/funding-opportunities-graduate-students-mathematics`.

From the AMS Public Awareness Office

Feature Column. Recent topics include "The Joy of Barycentric Subdivision," by Bill Casselman, "Surface Topology in Bach Canons, II: The Torus," by Tony Phillips, "Remembering Bill Thurston (1946–2012)," by Joe Malkevitch, and "Patterns in Permutations," by David Austin. Find the current column, explore the archive to use in the classroom, or simply read for pleasure, at `www.ams.org/featurecolumn`.

New on Mathematical Imagery. See beautiful digital symmetry works based on photographs of everyday scenes and objects by Frank Farris and stunning origami by Robert J. Lang at `www.ams.org/mathimagery`.

AMS on Social Media. As part of our commitment to community engagement and the open flow of communication, AMS uses social media to interact with our members and the diverse, worldwide mathematical community. We invite you to use these social networks and tools to communicate with the AMS, connect with the math community, and develop your professional presence online. Follow and comment on news and mathematics, and use hashtags #Math, #AppliedMath, #Mathart, #RealFaceofMath, #WhyILoveMath, and #AMSmtg in your posts for others to see and share. `www.ams.org/social`.

AMS at the SACNAS and AMATYC Conferences. Please stop by the AMS exhibit at the National SACNAS Conference in Salt Lake City, Utah, October 19–21, and at the AMATYC Annual Conference in San Diego, California, November 9–12. Learn about programs for students and faculty in the mathematical sciences, see AMS book publications, pick up free posters, and talk with staff.

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

Mathematics People

Goldreich Awarded Knuth Prize

Oded Goldreich

Oded Goldreich of the Weizmann Institute of Science has been awarded the 2017 Donald E. Knuth Prize for "fundamental and lasting contributions to theoretical computer science in many areas, including cryptography, randomness, probabilistically checkable proofs, inapproximability, property testing, as well as complexity theory in general." According to the prize citation, Goldreich has "advanced these fields through many survey articles and several first-class textbooks. He has contributed eminent results, new basic definitions and pointed to new directions of research. Goldreich has been one of the driving forces for the theoretical computer science community for three decades." Goldreich received his PhD at the Technion—Israel Institute of Technology in 1983. He has been professionally affiliated with the Massachusetts Institute of Technology (1983–1986) and the Technion (1983–1994) and joined the faculty of the Weizmann Institute in 1994. He is interested in politics, sociology, philosophy, and psychology and has written essays concerning issues related to the politics of academia.

The Knuth Prize for outstanding contributions to the foundations of computer science is awarded every 1.5 years by the Association for Computing Machinery Special Interest Group on Algorithms and Computation Theory (ACM-SIGACT) and the Institute of Electrical and Electronics Engineers Technical Committee on the Mathematical Foundations of Computing. The prize includes a cash award of US$5,000.

—From an ACM/IEEE announcement

Grima Awarded 2017 COSCE Prize

Clara Grima

Clara Grima, associate professor of applied mathematics at the University of Seville, has been awarded the 2017 Prize for the Communication of Science by the Confederation of Scientific Societies of Spain (COSCE) with the collaboration of the Ramón Areces Foundation. Grima has authored prize-winning mathematics blogs and has approximately 23,000 followers on Twitter. She participated in the television program *Orbit Laika*, has given popular lectures for all ages, and has participated in plays. Grima tells the *Notices*: "Although mathematics has been a passion since I learned to add, I never worried about how to teach or popularize it until my children were six and eight years old. Their curiosity and, above all, their skepticism and critical spirit inspired me to present mathematics as stories and adventures for children. 'Children' includes all curious, restless, and hungry-to-learn persons, regardless of age. The main theorem I want to prove is: 'Everybody likes math, but some do not know it yet.' When I was young I wanted to be like Madonna, on stage in front of a crowd, or a writer. Now, thanks to math, those dreams have come true."

—From a University of Seville announcement

US Team Wins First Place at European Girls' Mathematical Olympiad

US EGMO team members (l–r) Qi Qi, Angela Deng, Wanlin Li, and Siye Zhu.

The team from the United States took first place at the European Girls' Mathematical Olympiad (EGMO) held April 6–12, 2017, in Zurich, Switzerland. The team from Ukraine finished second, and the team from the Russian Federation took third place. The 2017 EGMO US team members were Angela Deng, Siye Zhu, Qi Qi, and Wanlin Li. Sherry Gong served as team leader and Jenny Iglesias as deputy leader. Each member of the team was awarded a gold medal for individual performance. Qi received a perfect score.

Students from forty-three countries participated in the competition for female high school students. Sixteen students were awarded gold medals, twenty-seven received silver, and forty-three bronze medals. The US team is organized by the Mathematical Association of America as part of the MAA American Mathematics Competition.

—From an MAA announcement

2017 SIAM Prizes

The Society for Industrial and Applied Mathematics (SIAM) has awarded several prizes for 2017.

The John von Neumann Lectureship was awarded to Bernard J. Matkowsky of Northwestern University. The lectureship is awarded for outstanding and distinguished contributions to the field of applied mathematical sciences and for the effective communication of these ideas to the community.

The Prize for Distinguished Service to the Profession was awarded to Ya-xiang Yuan of the Chinese Academy of Sciences. The prize is awarded to an applied mathematician who has made distinguished contributions to the furtherance of applied mathematics on the national level.

The Ralph E. Kleinman Prize was awarded to Emmanuel Candès of Stanford University. The prize is awarded for outstanding research or other contributions that bridge the gap between mathematics and applications.

The George Pólya Prize for Mathematical Exposition was awarded to Nicholas Trefethen of the University of Oxford. The prize is awarded every two years to an outstanding expositor of the mathematical sciences.

The W. T. and Idalia Reid Prize in Mathematics was awarded to Jean-Michel Coron of Universityé Pierre et Marie Curie. The prize is given for research in or other contributions to the broadly defined areas of differential equations and control theory.

The James H. Wilkinson Prize in Numerical Analysis and Scientific Computing was awarded to Lek-Heng Lim of the University of Chicago. The prize is awarded for research in or other contributions to numerical analysis and scientific computing during the six years preceding the award.

The I. E. Block Community Lectureship was awarded to Emily Shuckburgh of the British Antarctic Survey. The lecture is intended to encourage public appreciation of the excitement and vitality of science.

The AMS-MAA-SIAM Gerald and Judith Porter Public Lectureship was awarded to Ingrid Daubechies of Duke University; her lecture is titled "Mathematics for Art Investigation." This lecture on a mathematical topic accessible to the broader community is given each year at the Joint Mathematics Meetings.

The SIAM-ACM Prize in Computational Science and Engineering was awarded to Thomas J. R. Hughes. The prize is given in recognition of outstanding contributions to the development and use of mathematical and computational tools and methods for the solution of science and engineering problems.

The Award in the Mathematical Contest in Modeling went to Nanjing University of Posts and Telecommunications, People's Republic of China, and North Carolina State University. It is awarded to two of the teams judged "outstanding" in the Mathematical Contest in Modeling (MCM).

The Outstanding Paper Prizes are given for outstanding papers published in SIAM journals. The 2017 prizes were awarded to the following authors:

- Jared L. Aurentz, Thomas Mach, Raf Vandebril, and David S. Watkins for their paper "Fast and backward stable computation of roots of polynomials," *SIAM Journal on Matrix Analysis and Applications* **36** (2015).
- Niv Buchbinder, Moran Feldman, Joseph (Seffi) Naor, and Roy Schwartz for their paper "A tight linear time (1/2)-approximation for unconstrained submodular maximization," *SIAM Journal on Computing* **44** (2015).
- Theodore Vo, Richard Bertram, and Martin Wechselberger for their paper "Multiple geometric viewpoints of mixed mode dynamics associated with pseudo-plateau bursting," *SIAM Journal on Applied Dynamical Systems* **12** (2013).

NEWS

The SIAM Student Paper Prizes are given to the most outstanding papers submitted to the SIAM student paper competition. The 2017 prizes were awarded to the following authors:

- Zachary J. Grant, University of Massachusetts Dartmouth, "Explicit strong stability preserving multistage two-derivative time-stepping schemes."
- Bamdad Hosseini, Simon Fraser University, "Well-posed Bayesian inverse problems: Priors with exponential tails."
- Shuyang Ling, University of California Davis, "Self-calibration and biconvex compressive sensing."

—From SIAM announcements

Prizes of the London Mathematical Society

The London Mathematical Society (LMS) has awarded a number of prizes for 2017.

The Pólya Prize was awarded to Alex Wilkie of the University of Oxford for his profound contributions to model theory and to its connections with real analytic geometry.

A Senior Whitehead Prize was awarded to Peter Cameron of the University of St. Andrews for his exceptional research contributions across combinatorics and group theory. His fertile imagination and encouragement of others have sparked activity in many fields.

A Naylor Prize and Lectureship was awarded to John R. King of the University of Nottingham for his profound contributions to the theory of nonlinear PDEs and applied mathematical modelling.

A Senior Anne Bennett Prize was awarded to Alison Etheridge of the University of Oxford in recognition of her outstanding research on measure-valued stochastic processes and applications to population biology and for her impressive leadership and service to the profession.

The Berwick Prize was awarded to Kevin Costello of the Perimeter Institute, Canada, for his paper "The partition function of a topological field theory," published in the *Journal of Topology* in 2009, which characterizes the function as the unique solution of a master equation in a Fock space.

Whitehead Prizes were awarded to the following individuals:

Julia Gog of the University of Cambridge for her wide-ranging contributions to the mathematical understanding of disease dynamics, particularly influenza, based on both mathematical mastery and profound biological insight, gained from her long-standing collaborations with immunologists and epidemiologists.

András Máthé of the University of Warwick for his original insights into deep problems from geometric measure theory, combinatorics, and real analysis.

Ashley Montanaro of the University of Bristol for his outstanding and strikingly diverse contributions across the field of quantum computation and quantum information theory.

Oscar Randal-Williams of the University of Cambridge for his contributions to algebraic topology and in particular the study of moduli spaces of manifolds.

Jack Thorne of the University of Cambridge for his contributions to number theory and in particular to the Langlands program.

Michael Wemyss of the University of Glasgow for the profound applications of algebraic and homological techniques to algebraic geometry.

—From an LMS announcement

Photo Credits

Photo of Oded Goldreich by Dana Ron, courtesy of Oded Goldreich.
Photo of Clara Grima courtesy of the Grima family.
Photo of US EGMO team courtesy of MAA American Mathematics Competitions.

Twenty Years Ago in the *Notices*

October 1997:

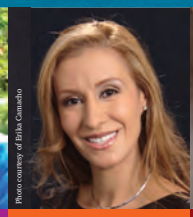
Ennio De Giorgi (1928–1996)
by Jacques-Louis Lions and Francois Murat
www.ams.org/notices/199709/murat.pdf

This obituary memorializes Ennio De Giorgi, an exceptional mathematician and human being. Also appearing in the same issue is an interview with Ennio De Giorgi (www.ams.org/notices/199709/emmer.pdf), by Michele Emmer. The obituary includes discussions of his contributions to minimal surfaces and geometric measure theory, partial differential equations, and logic. The wide-ranging interview reflects a life devoted to the quest for knowledge, as De Giorgi muses on the nature of mathematics and the sciences and on creativity and the imagination. Uno Spirito Puro, a biography of De Giorgi written by Andrea Perlangeli, was reviewed by Enrico Bombieri in the June/July 2016 *Notices* (www.ams.org/journals/notices/201606/rnoti-p640.pdf).


Marcelo Aguiar


Mariel Vazquez


Federico Ardila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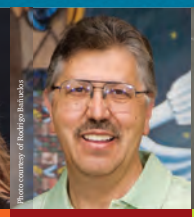
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Minerva Cordero


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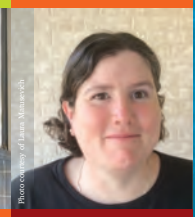
Ricardo Cortez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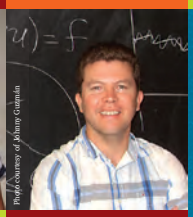

Johnny Guzmán

LATIN@S AND HISPANICS IN THE MATHEMATICAL SCIENCES

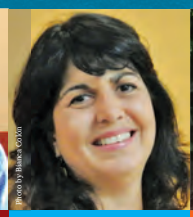

Herbert Medina


Rosa Orellana


Juan Meza


Luis David García Puente


José Mijares


Ivelisse Rubio

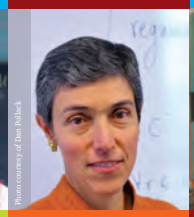

Nancy Rodriguez


Brisa Sánchez


Javier Rojo


Carol Schumacher


Santiago Schnell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Mathematics Opportunities

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

AMS Travel Grants for ICM 2018

The American Mathematical Society has applied to the National Science Foundation (NSF) for funds to permit partial travel support for US mathematicians attending the 2018 International Congress of Mathematicians (ICM 2018), August 1–9, 2018, in Rio de Janeiro, Brazil. Subject to the award decision by the NSF, the Society is preparing to administer the selection process. Instructions on how to apply for support will be available on the AMS website at www.ams.org/programs/travel-grants/icm . The application period is **September 1–November 15, 2017**. This travel grants program, if funded, will be administered by the Professional Programs Department, AMS, 201 Charles Street, Providence, RI 02904-2294. You can contact us at prof-serv@ams.org; 800-321-4267, ext. 4096; or 401-455-4096.

This program is open to US mathematicians (those who are currently affiliated with a US institution or affiliated with a US institution at the time of travel). Early-career mathematicians (those within six years of the doctorate), women, and members of US groups underrepresented in mathematics are especially encouraged to apply.

Applications will be evaluated by a panel of mathematical scientists, and application results will be known by late February 2018.

Visit www.ams.org/programs/travelgrants/icm for more details. All information currently available about the ICM 2018 program, organization, and registration procedure is located on the ICM 2018 website, www.icm2018.org/.

—AMS Professional Programs Department

*NSF Conferences and Workshops in the Mathematical Sciences

The National Science Foundation (NSF) supports conferences, workshops, and related events (including seasonal schools and international travel by groups). Proposals for such activities may request funding of any amount and for durations of up to three years. Proposals may be submitted only by universities and colleges or by nonprofit nonacademic institutions and must be submitted to the appropriate disciplinary program in accordance with the lead-time requirements specified on the program web page. For more information, see www.nsf.gov/funding/pgm_summ.jsp?pims_id=11701&org=DMS.

—NSF announcement

News from the Mathematical Sciences Research Institute, Berkeley, California

The Mathematical Sciences Research Institute (MSRI) will hold the following workshops during the spring of 2018.

- *Connections for Women: Enumerative Geometry Beyond Numbers* (January 18–19, 2018). See www.msri.org/workshops/814.
- *Introductory Workshop: Enumerative Geometry Beyond Numbers* (January 22–26, 2018). See www.msri.org/workshops/815.
- *Connections for Women: Group Representation Theory and Applications* (February 1–2, 2018). See www.msri.org/workshops/817.

**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.

- *Introductory Workshop: Group Representation Theory and Applications* (February 5–9, 2018). See www.msri.org/workshops/818.
- *Critical Issues in Mathematics Education 2018: Access to Mathematics by Opening Doors for Students Currently Excluded from Mathematics* (February 21–23, 2018). See www.msri.org/workshops/877.
- *Hot Topics: The Homological Conjectures: Resolved!* (March 12–16, 2018). See www.msri.org/workshops/842.
- *Structures in Enumerative Geometry* (March 19–23, 2018). See www.msri.org/workshops/816.
- *Representations of Finite and Algebraic Groups* (April 19–23, 2018). See www.msri.org/workshops/820.

Established researchers, postdoctoral fellows, and graduate students are invited to apply for funding. MSRI actively seeks to achieve diversity in its workshops, and a strong effort is made to remove barriers that hinder equal opportunity, particularly for those groups that have been historically underrepresented in the mathematical sciences.

MSRI has a resource to assist visitors with finding child care in Berkeley. For more information, please contact Sanjani Varkey at sanjani@msri.org .

—MSRI announcement

Organizing the 2019 AMS Short Course

The AMS Short Course Subcommittee invites preliminary proposals for the next Short Course, to be held January 14–15, 2019, preceding the Joint Mathematics Meetings in Baltimore, Maryland. Designed to provide a rich introduction to an emergent area of applied mathematics, the Short Course provides participants from a wide array of mathematical backgrounds with an opportunity for professional development, continuing mathematical education, or an introduction to a new area of inquiry. Traditionally, the format has been a sequence of lectures, and a preliminary proposal has contained synopses. However, the Subcommittee is open to other approaches that have potential to engage participants in person as well as remotely in the proposed topic. The Short Course presents an opportunity for the organizers to bring their mathematical topic to an audience of newcomers with a great deal of curiosity, willingness to discover, and potential to dig deeper. Proceedings of the Short Course typically appear in the AMS series Proceedings of Symposia in Applied Mathematics.

For fuller information, visit www.ams.org/meetings/short-courses/2019call, and contact aed-mps@ams.org with questions and preliminary proposals. **Submissions should be made by December 18, 2017.**

—AMS Meetings and Professional Services

Mathematics Research Communities 2018

The AMS invites mathematicians just beginning their research careers—those who are close to finishing their doctorates or have recently finished—to become part of Mathematics Research Communities (MRC), a unique and successful program that builds social and collaborative networks through which individuals inspire and sustain each other in their work. Women and underrepresented minorities are especially encouraged to participate. Partially supported by the National Science Foundation, the structured program engages and guides all participants as they start their careers. Those accepted into the program will receive support for the summer conference and will be partially supported for their participation in the Joint Mathematics Meetings that follow in January 2019. The 2018 MRC Summer Conferences are held at the Whispering Pines Conference Center, West Greenwich, Rhode Island, where participants can enjoy the natural beauty and a collegial atmosphere. The program also includes discussion networks by research topic and a longitudinal study of early-career mathematicians.

Five conferences will be held in summer 2018 on the following topics:

Week 1a, June 3–9, 2018: The Mathematics of Gravity and Light
Organizers:
Charles Keeton (Rutgers University)
Arlie Petters (Duke University)
Marcus Werner (Kyoto University)

Week 1b, June 3–9, 2018: Harmonic Analysis: New Developments on Oscillatory Integrals
Organizers:
Philip T. Gressman (University of Pennsylvania)
Larry Guth (Massachusetts Institute of Technology)
Lillian B. Pierce (Duke University)

Week 2a: June 10–16, 2018: Quantum Symmetries: Subfactors and Fusion Categories
Organizers:
David Penneys (The Ohio State University)
Julia Plavnik (Texas A&M University)
Noah Snyder (Indiana University)

Week 2b: June 10–16, 2018: Number Theoretic Methods in Hyperbolic Geometry
Organizers:
Benjamin Linowitz (Oberlin College)
David Ben McReynolds (Purdue University)
Matthew Stover (Temple University)

NEWS

Week 3, June 17–23, 2018: Agent-Based Modeling in Biological and Social Systems

Organizers:
Andrew Bernoff (Harvey Mudd College)
Leah Edelstein-Keshet (University of British Columbia)
Alan Lindsay (University of Notre Dame)
Chad Topaz (Williams College)
Alexandria Volkening (Mathematical Biosciences Institute at Ohio State)
Lori Ziegelmeier (Macalester College)

Individuals who are one to two years prior to receiving their PhDs or one to five years after receiving their PhDs are welcome to apply. Most of those supported by NSF funds to participate in the MRC program will be US-based, that is, employed by or a full-time student at a US institution at the time of the MRC summer conference. However, the terms of the grant allow for a limited number of individuals who are not US-based. All participants are expected to be active in the full MRC program. Detailed instructions are available at `www.ams.org/programs/research-communities/mrc-18`. Applications are due no later than **February 15, 2018**.

For further information on Mathematics Research Communities, visit the website `www.ams.org/mrc` or contact Steven Ferrucci at `ams-mrc@ams.org`.

—Steven Ferrucci
AMS Senior Program Coordinator

AMS Employment Center

San Diego Convention Center, San Diego, California

January 10–13, 2018

Kate Awtrey, JMM 2017 Photographer.

The Employment Center offers a convenient, safe and practical meeting place for employers and jobseekers attending the Joint Meetings. The focus of the Employment Center is on PhD-level mathematical scientists and those that seek to hire them from academia, business, and government.

2018 Employment Center Schedule:

December 20, 2017, is the deadline for table registration. After this date, only "One Day Tables" will be available for purchase. This is also the deadline to register for the JMM badge, needed for admittance to the EC, at Advance Registration Prices.

Hours of Operation (Please note there is no access to the EC prior to the opening times listed):

Wednesday, January 10, 2018 – 8:00 am–5:30 pm
Thursday, January 11, 2018 – 8:00 am–5:30 pm
Friday, January 12, 2018 – 8:00 am–5:30 pm
Saturday, January 13, 2018 – 9:00 am–12:00 noon

Location: Hall A, San Diego Convention Center, San Diego, California.

Do not schedule an interview to begin until 15 minutes after opening.

Employment Center Web Services

Employment Center registration information should be accessed through the MathJobs.Org system. The website and all information will be available beginning in early September 2017 and will remain accessible through January 13, 2018, (the last day of the Employment Center). While some schools may delay appointment setting until late December 2017, virtually all scheduling will be done before any Joint Mathematics Meetings (JMM) travel takes place, so applicants should expect few or no additional appointments to be available after arrival. Registering on-site, for applicants, serves no real purpose.

No Admittance Without a JMM Badge

All applicants and employers planning to enter the Employment Center—even just for one interview—must present a 2018 Joint Meetings Registration badge. Meeting badges are obtained by registering for the JMM and paying a meeting registration fee. The advanced registration deadline is December 20, 2017. See the JMM website at: `jointmathematicsmeetings.org/jmm` for registration instructions and rates.

Employers: Choose a Table

There are three table types available for employers, based on the number of interviewers who will be present at any given time:

- One or two interviewers per table in the **"Quiet Area"** (US $350), each additional table (US$195).
- Three to six interviewers per table in the **"Committee Table"** area (US $440), each additional table (US$215).
- Free electricity is supplied to every table with purchase of the table.
- **"One Day Tables"** allow for on-site interviewing for one day without placing an ad. These tables, which can accommodate up to three interviewers, may only be purchased starting December 21, 2017, through January 12, 2018. The fee is (US$195). Please register online at `www.mathjobs.org` and choose the "EC-One Day Table purchase."

All Employment Center data and registration must be entered on the MathJobs.Org site. An existing account can be used for accessing Employment Center services and for paying applicable fees. If no account exists, participants can start an account solely for Employment Center use.

Employers are expected to create their own interview schedules as far in advance as possible by using the assisted-email system in MathJobs.Org or by using other means of communication. Please do not schedule an interview to begin until fifteen minutes after the Employment Center opens.

Please mark appointments as confirmed in your MathJobs.Org account, as this will allow the appointments to display in the applicants' schedules. At the time of interview, meet the applicant in the on-site waiting area and escort him or her to your table.

Employers: How to Register

- Registration runs from early September 2017 through December 20, 2017, at the following website: www.mathjobs.org. After December 20, only "One-Day Tables" will be available. They should be reserved and paid for through MathJobs.Org .
- Use your existing MathJobs.Org account or create a new Employer account at www.mathjobs.org. Once a table is reserved, the ad can be placed at any time (or never) and will run until late January.
- For new users of MathJobs.Org, click the NEW EMPLOYER link on the main page of www.mathjobs.org. Choose your table type and fill out the New Employer Form.
- For existing users of MathJobs.Org, go to www.mathjobs.org. Log into your existing account. Purchase a table by clicking the "EmpCent" logo in the menus along the top tool bar. Use the "buy tables" link. Then post a job using the NewJob link or attach an existing job to your table.
- Each person who will need to enter the Employment Center area must have a meeting badge (obtained by registering for the JMM and paying a meeting registration fee).

To display an ad on-site, and use no Employment Center services at all, submit your one page paper ad on-site in San Diego to the Employment Center staff. There is no fee for this service.

For complete information, visit www.ams.org/emp-reg/ .

Applicants: Making the Decision to Attend

- Past attendees have pointed out that all interviews are arranged in advance, and there is no opportunity to make connections on-site if it has not happened before the meeting.
- The Employment Center offers no guarantees of interviews or jobs. Hiring decisions are not made during or immediately following interviews. In the current job market, the ratio of applicants to employers is about 6:1, and many applicants go completely unnoticed.
- There will ordinarily be no research-oriented postdoctoral positions listed or discussed at the Employment Center.
- Interviews will go to applicants who applied to jobs during the fall and are now being sought out by the institutions for in person meetings during the JMM.
- There will be no opportunity to speak to employers without a prearranged interview, and no walk-up job information tables. Scheduling of interviews will be complete prior to the JMM.

The majority of Employment Center employers are academic departments of mathematical sciences seeking to meet a short list of applicants who applied for their open positions during the fall. Each year, a few government or industry employers are present. Often, they are seeking US citizens only due to existing contracts.

All job postings are available on the website in advance, and now that this electronic service is in place, there is no other messaging conducted on paper.

Please visit the Employment Center website for further advice, information and program updates at www.ams.org/emp-reg/ .

Applicants: How to Register

- Early registration is vital since most employers will finalize schedules before arriving in San Diego.
- To register, applicants should log into their MathJobs.Org accounts or create a new account, look for the EmpCent icon across the top tool bar and mark that they will be attending by clicking the link, "click here if you are attending the Employment Center." You can then upload documents and peruse the list of employers attending and the positions available. You do not have the option to request an interview with an employer. However, if you are interested in any position, you can apply to the job. The employer will be aware that you are also attending the event and will contact you directly if interested in setting up an interview.

There are no Employment Center fees for applicants; however, admission to the Employment Center room requires a 2018 JMM badge, obtainable by registering (and paying a fee) for the JMM. To register for the meeting, go to the website: jointmathematicsmeetings.org/jmm .

It is possible to attend one or more privately arranged interviews without an official Employment Center registration; however, a meeting badge is required to access the interview room.

Applicants should keep track of their interview schedules. If invited for an interview at a conflicting time, please ask the employer to offer a new time or suggest one.

For complete information, visit www.ams.org/emp-reg/ .

Questions about the Employment Center registration and participation can be directed to Pamela Morin, AMS Professional Programs Department, at 800-321-4267, ext. 4060 or by e-mail to emp-info@ams.org .

The Mathematician's Shiva

A Review by Dennis DeTurck

The Mathematician's Shiva
by Stuart Rojstaczer
Penguin Random House, 2014
384 pages

An often-told story about GH Hardy concerns his evocation of the Riemann Hypothesis as a defense against fate. Every year he visited his friend Harald Bohr on the continent, and "proving the Riemann Hypothesis" was always on their agenda. One day, about to embark on a crossing of the English Channel during a particularly dangerous storm, he sent a postcard to Bohr, claiming that he had solved the problem. Even though he was an atheist, Hardy was certain that God would not give him the satisfaction of going down with the ship and leaving the world to believe that his proof had gone down with him.

Stuart Rojstaczer's novel *The Mathematician's Shiva* is built around a premise that is reminiscent of the Hardy story. It is told from the perspective of Alexander (Sasha) Karnokovitch, whose mother, Rachela, is rumored to have solved one of the fundamental mathematical problems of our time, namely to prove that the initial-value problem for the Navier–Stokes equations is well posed. The story begins with Rachela telephoning Sasha, who is about to give a talk in the atmospheric sciences department at the University of Nebraska, to tell him to come home because "I'm going to die today." The rumors and gossip about her putative proof have so penetrated the mathematical community that the immediate reaction of Sasha's mathematician friend Yakov is to say, "She must have finished today."

The rumors are taken so seriously because Rachela has been an imposing presence in the community for decades: a student of the great Soviet mathematician Kolmogorov, she is credited with solving one of the famous Hilbert problems, namely the fifteenth, which concerns the rigorous justification of the Schubert calculus in enumerative geometry. After her defection from the Soviet Union in the 1950s, she became a professor at the University of Wisconsin, where she mentored numerous well-known and successful mathematicians.

a book about mathematics, mathematicians, and mathematical culture

The first part of the novel describes Rachela's death and uses the gathering of the family in Madison to provide a detailed account of the son's life, his knowledge of the family's history, his reasons for not going into mathematics, his failed marriage, and the relationships among the various very strong personalities within the family. Rojstaczer uses the device of interspersing chapters from Sasha's ongoing translation of Rachela's unpublished autobiography with his narration of more-current events and recollections about his family and about life in a home that often included recent Soviet defectors and itinerant mathematicians. In her memoir, Rachela describes how, as a Polish Jew, she and her family were shipped off to a work camp near the Barents Sea and details the hardship, deprivation, and hunger that she experienced there, as well as the discovery of her incipient interest in and talent for mathematics.

In the second part of the book, mathematicians from all over the world descend on the family after the news spreads of Rachela's death, and they insist on participating in the week-long Shiva, or mourning ritual. The resulting conclave is strangely reminiscent of actual intensive

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gatherings of mathematicians around contemporary problems (the Bonn Arbeitstagung and the meetings of the Bourbaki and Besse groups come to mind), as the mathematicians spend their days at the Karnokovitch home and their nights at the Wisconsin math department working frantically on the Navier–Stokes problem. The group of mathematicians includes some of Rachela's former students, co-authors, and colleagues, but also one of her greatest rivals, Vladimir Zhelezniak. Despite Rojstaczer's disclaimer that "the living mathematicians in the novel are all made up," it is hard not to notice the parallels between the mathematical careers of Zhelezniak and the eminent mathematician Vladimir Arnold: the two are respectively fictitious and real students of Kolmogorov who, while still students, solved Hilbert's thirteenth problem[1] based on earlier work of Kolmogorov, although in the novel Zhelezniak confesses to having appropriated the work that Rachela did on the problem when she was a student, hence the root of their animosity.

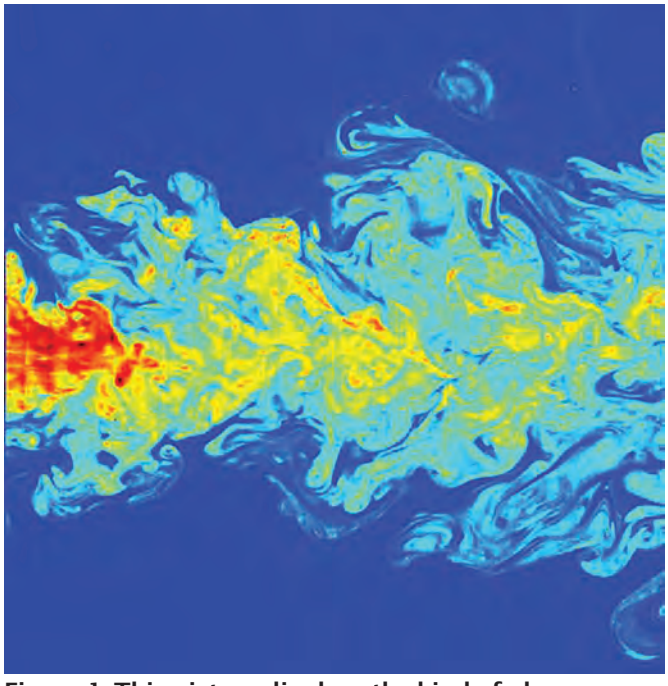


Figure 1. This picture displays the kind of phenomena modeled by the Navier–Stokes equations—and also evokes the complexity and turbulence exhibited in the lives of the characters in *The Mathematician's Shiva*. It shows a false-color image of the far-field of a submerged turbulent jet, made visible by means of laser induced fluorescence.

Throughout the novel, Rojstaczer writes with warmth, empathy, and wit. *The Mathematician's Shiva* is not a mathematics book, but it is a book *about* mathematics, mathematicians, and mathematical culture, all of which are essential to the story. Although he is a scientist and not a mathematician, Rojstaczer nonetheless provides penetrating insight into the frustrating but rewarding nature of mathematical research, particularly the duality between the individual and communal aspects of the enterprise. Without indulging too much in caricature or stereotype, the author explores the way the abstraction and other-worldliness of pure mathematics often gives rise to social awkwardness and a lack of self-awareness on the part of its practitioners. He illustrates this in a good-natured way, providing numerous vignettes that are by turns heartwarming, humorous, and hilarious—for instance, Zhelezniak's arrest for late-night drunken cross-country skiing in the university Arboretum, or the mathematicians' attempt to elicit meaningful information from the family parrot, an African gray named Pascha, whose first words in the book (in Polish no less) are "It has a singularity."

"To ignore math in this story would be akin to listening to Frank Zappa without ever having taken hallucinogens."

Occasionally, though, Rojstaczer does bring the reader face to face with mathematics. For instance, in describing his youth, Sasha tells how his father (also a mathematician) often gave him interesting problems to grapple with, and he goes on to explain in some detail a simplified version of the Königsberg Bridge problem (an educational technique that might remind the reader of the book *In Code: A Mathematical Journey* by Sarah Flannery and David Flannery[2]). At another point, in an effort to explain mathematical proof in her memoir, Rachela illustrates by means of a proof of the Pythagorean theorem. And even though he is a meteorologist, Sasha makes a valiant effort at an explanation of the Navier–Stokes problem and describes some of his own work using the equation to model atmospheric phenomena. Why does Rojstaczer do this, even though the story could proceed without the mathematical exposition? "Why am I making your life difficult?" Sasha asks rhetorically, and then responds that while mathematics might seem obscure and irrelevant to you, "it isn't to me, and it wasn't to my mother or father. It is like breathing to us, and to ignore math in this story would be akin to listening to Frank Zappa without ever having taken hallucinogens, an incomplete experience."

This quote illustrates what *is* perhaps the central theme of the novel, namely that the complexity of human identity, and how we often derive a fierce or even defiant pride from belonging, or even from only peripherally belonging, to a clan or group, particularly a group that

[1] *on expressing functions of many variables via chains of compositions of functions of only two variables, as in F(x,y,z) = g(x, h(y,z))*

[2] *Reviewed by Rafe Jones in the April 2003* Notices, `www.ams.org/notices/200304/rev-jones.pdf`.

is somewhat removed from mainstream society. Many such groups are featured, or at least touched upon, in the novel: immigrants, mathematicians, Jews, particularly Eastern European Jews who experienced but escaped both World War II and Soviet oppression (the book is liberally sprinkled with Yiddish and Polish, with a little Hebrew, German, and Russian mixed in), and women (particularly women scientists and mathematicians). For instance, there is a lengthy discussion among the mathematicians at the Shiva about why Rachela never received the Fields Medal—was it discrimination against Jews, Soviets, women, or some combination of these? Throughout the novel there are many instances of unflattering comparison between Russian and American attitudes towards mathematics, science, education, and hard work. From another direction, Sasha provides a compelling description of his feelings of only partially belonging to various groups—though born in the Soviet Union, he emigrated at a young enough age to be thoroughly Americanized; his work is mathematical but he is not a mathematician; at the Shiva he meets his estranged daughter and a granddaughter whom he didn't know existed.

The question of whether Rachela has indeed produced and concealed a solution of the Navier–Stokes problem, or whether the mathematicians gathered at her Shiva will make significant progress, generates some suspense along the lines of the play *Proof* by David Auburn.[3] *Spoiler alert:* In contrast to that play, which leaves mostly ambiguity when the curtain falls, all of these questions are resolved by the end of the novel, perhaps somewhat too tidily: Rachela's proof is unearthed, deemed correct, and published posthumously in *Communications in Pure and Applied Mathematics;* her family receives the Clay Millennium Prize; and Sasha marries again and moves back to Madison.

All in all, *The Mathematician's Shiva* is a complicated tale that weaves together scientific, social, familial, and emotional themes in a compelling, sensitive, humorous, and even affectionate manner. Despite its focus on a very specific and unusual group of people, the writing invites the reader to become at least an honorary member of the tribe. After I read the book I recommended it to a few non-mathematician friends who, despite finding the novel's soupçon of mathematics somewhat intimidating, also thoroughly enjoyed the writing and the story. Stuart Rojstaczer has produced a successful first novel, and I hope we can look forward to many more.

Image Credits

Figure 1 by C. Fukushima and J. Westerweel. Used under the Creative Commons Attribution 3.0 Unported License.
Photo of the reviewer courtesy of Dennis DeTurck.

[3] *The production of* Proof *at City Center in New York City was reviewed by Dave Bayer in the October 2000* Notices, `www.ams.org/notices/200009/rev-bayer.pdf`, *and the movie version was reviewed by Daniel Ullman in the March 2006 issue,* `www.ams.org/notices/200603/rev-ullman.pdf`.

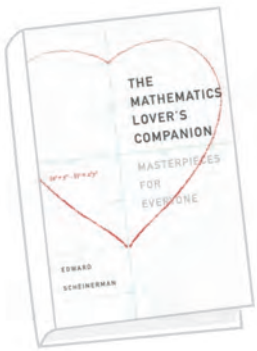
ABOUT THE REVIEWER

Dennis DeTurck is a recovering administrator and professor of mathematics. He is also the faculty director of Riepe College House, where he enjoys hanging out with about 500 of his closest friends.

Dennis DeTurck

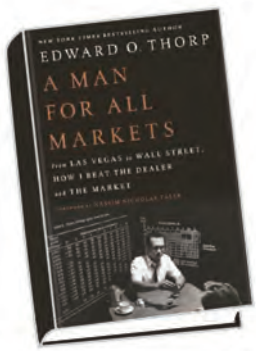
BOOKSHELF

New and Noteworthy Titles on Our Bookshelf
October 2017



The Mathematics Lover's Companion: Masterpieces for Everyone, by Edward Scheinerman (Yale University Press, March 2017)

The first word in this book, "Joy," reverberates through the entire approximately 270 pages. Scheinerman has picked out a collection of "masterpieces"—he characterizes them as the mathematical equivalents of the Mona Lisa, Hamlet, or the discovery of DNA—and describes them with joyous enthusiasm. He does not so much try to make the material interesting as trust that it *is* interesting if presented in a clear and simple way that brings out the main ideas. Each of the book's three sections—"Number," "Shape," and "Uncertainty"—showcases several classic mathematical ideas, as well as some less-standard ones that have caught Scheinerman's fancy. In "Number," he discusses prime numbers, irrational numbers, transcendental numbers, and infinity, as well as that counterintuitive conundrum known as Benford's Law. Imaginary numbers—often confusing as much for their name as for the way they are pulled like rabbits out of hats—are demystified and their beauty and usefulness revealed. In the section "Shape," Scheinerman discusses, among other topics, the Platonic solids. A proof that there are only five of them follows a careful and gentle introduction to the Euler formula. The section on "Uncertainty" includes a description of dynamical systems and elucidates the often-misunderstood topic of chaos. The discussion of each topic is short and proceeds directly to its conclusion. Side comments are presented exactly as that: The book's pages have wide right-hand margins where Scheinerman tucks in little nuggets that veer slightly off the main thread. The style, while friendly and appealing, never quite slides into folksiness. Every so often Scheinerman suggests the reader carry out a little calculation, making the point that mathematics is not a spectator sport. For general readers whose mathematical sensitivity was dulled by endless drill and cookbook procedures typical of school mathematics, this book might very well be the perfect antidote.



A Man for All Markets: From Las Vegas to Wall Street, How I Beat the Dealer and the Market, by Edward O. Thorp (Random House, January 2017)

How to define a mathematician? One possibility is the following: A mathematician is a person who refuses to accept anything on authority, believing only what can be investigated and verified directly. That definition captures the personality of Edward O. Thorp. He became widely known for his 1962 book *Beat the Dealer,* which was the first to mathematically prove how card counting could overcome the house advantage in blackjack. In the present book, Thorp describes his long and adventurous life as a mathematician and a beater-of-odds, both in gambling houses and in financial markets. A razor-sharp and systematic thinker who teases out order where others might see chaos, Thorp is also an excellent storyteller with a very good story to tell. Starting with his childhood in the Great Depression, he covers his progression from a math PhD student at UCLA (he received his degree in 1958 under Angus Taylor), to casino-beater extraordinaire (some casinos barred him and even threatened his life), to hedge-fund manager (he helped build the field of quantitative finance). While much of the book focuses on gambling and finance, it also has parts that take place in the mathematical world—and there is even a mention of the *Notices.* Around 1960, Thorp intended to speak about his work at an AMS meeting in Washington, DC. He writes: "I submitted an abstract of my talk titled 'Fortune's Formula: The Game of Blackjack' for the program booklet (*The Notices*)." At that time, the *Notices* carried abstracts of talks at AMS meetings. The near-unanimous decision of the AMS abstracts committee was to reject Thorp's submission, because it seemed to be one of the many crackpot abstracts the committee routinely receives. Number theorist John Selfridge, who had known Thorp at UCLA and was on the committee, eventually got the decision reversed. All in all, this is an engaging autobiography that ranges over many subjects but has its heart very much in mathematics.

The BookShelf is prepared each month by Allyn Jackson. 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.

THE BACK PAGE

The June/July Contest Winner Is...

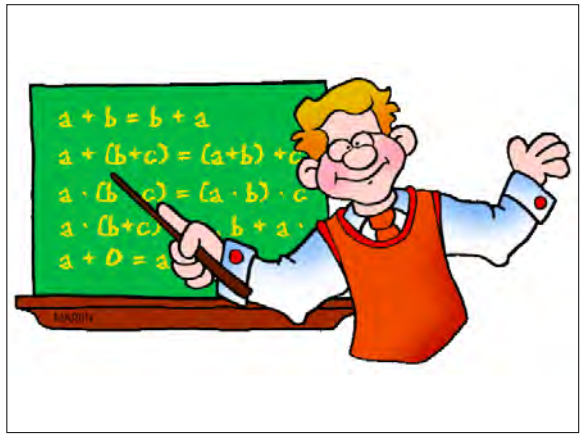
Reinhard Suck, who receives our book award.

Drawn by James F. Bredt, © Frank Morgan.

"...divided by the number of arms gives the correct value."

The October Caption Contest:

What's the Caption?



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Submit your entry to captions@ams.org by October 25. The winning entry will be posted here in the January 2018 issue.

From the oral arguments of Briscoe v. Virginia before the Supreme Court on January 11, 2010 tinyurl.com/OrthogonalSupremeCourt:

MR. FRIEDMAN: I think that issue is entirely orthogonal to the issue here...

CHIEF JUSTICE ROBERTS: I'm sorry. Entirely what?

MR. FRIEDMAN: Orthogonal. Right angle. Unrelated. Irrelevant.

CHIEF JUSTICE ROBERTS: Oh.

JUSTICE SCALIA: What was that adjective? I liked that.

MR. FRIEDMAN: Orthogonal.

CHIEF JUSTICE ROBERTS: Orthogonal.

MR. FRIEDMAN: Right, right.

JUSTICE SCALIA: Orthogonal, ooh.

(Laughter.)

...

JUSTICE SCALIA: I think we should use that in the opinion.

"I was very quick at math. I could quickly grasp any problem they threw at me and solve it in my head. I often stood in for Lydia Mikhailovna when she had to go into the city or run her own errands. She trusted me to conduct the math class. I taught basic arithmetic to the other children."

—Soviet Premier Khrushchev. Submitted by Domenico Rosa.
[Khrushchev Remembers: The Glasnost Tapes, Little, Brown and Co., 1990, pp. 5–6.]

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**.

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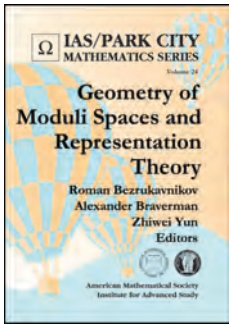
Algebra and Algebraic Geometry



Geometry of Moduli Spaces and Representation Theory

Roman Bezrukavnikov, *Massachusetts Institute of Technology, Cambridge, MA*, **Alexander Braverman**, *University of Toronto, ON, Canada, Perimeter Institute for Theoretical Physics, Waterloo, ON, Canada, and Skolkovo Institute for Science and Technology, Moscow, Russia*, and **Zhiwei Yun**, *Yale University, New Haven, CT*, Editors

This book is based on lectures given at the Graduate Summer School of the 2015 Park City Mathematics Institute program "Geometry of moduli spaces and representation theory", and is devoted to several interrelated topics in algebraic geometry, topology of algebraic varieties, and representation theory.

Geometric representation theory is a young but fast developing research area at the intersection of these subjects. An early profound achievement was the famous conjecture by Kazhdan–Lusztig about characters of highest weight modules over a complex semi-simple Lie algebra, and its subsequent proof by Beilinson-Bernstein and Brylinski-Kashiwara. Two remarkable features of this proof have inspired much of subsequent development: intricate algebraic data turned out to be encoded in topological invariants of singular geometric spaces, while proving this fact required deep general theorems from algebraic geometry.

Another focus of the program was enumerative algebraic geometry. Recent progress showed the role of Lie theoretic structures in problems such as calculation of quantum cohomology, K-theory, etc. Although the motivation and technical background of these constructions is quite different from that of geometric Langlands duality, both theories deal with topological invariants of moduli spaces of maps from a target of complex dimension one. Thus they are at least heuristically related, while several recent works indicate possible strong technical connections.

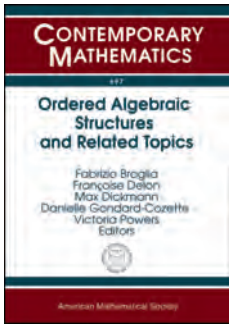
The main goal of this collection of notes is to provide young researchers and experts alike with an introduction to these areas of active research and promote interaction between the two related directions.

Titles in this series are co-published with the Institute for Advanced Study/Park City Mathematics Institute. Members of the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) receive a 20% discount from list price. *NOTE: This discount does not apply to volumes in this series co-published with the Society for Industrial and Applied Mathematics (SIAM).*

Contents: M. A. de Cataldo, Perverse sheaves and the topology of algebraic varieties; **X. Zhu**, An introduction to affine Grassmannians and the geometric Satake equivalaence; **Z. Yun**, Lectures on Springer theories and orbital intgegrals; **N. G. Châu**, Perverse sheaves and fundamental lemmas; **A. Okounkov**, Lectures on K-theoretic computations in enumerative geometry; **H. Nakajima**, Lectures on perverse sheaves on instanton moduli spaces.

IAS/Park City Mathematics Series, Volume 24

November 2017, 448 pages, Hardcover, ISBN: 978-1-4704-3574-5, LC 2017018956, 2010 *Mathematics Subject Classification:* 14N35, 14M17, 14D24, 22E57, 22E67, **AMS members US$83.20**, List US$104, Order code PCMS/24



Ordered Algebraic Structures and Related Topics

Fabrizio Broglia, *Universitá di Pisa, Italy*, **Françoise Delon**, *Université Paris Diderot, France*, **Max Dickmann**, *Université Paris Diderot, France*, **Danielle Gondard-Cozette**, *Université Pierre et Marie Curie, Paris, France*, and **Victoria Ann Powers**, *Emory University, Atlanta, Ga*, Editors

This volume contains the proceedings of the international conference "Ordered Algebraic Structures and Related Topics", held from October 12–16, 2015, at CIRM, Luminy, Marseilles, France.

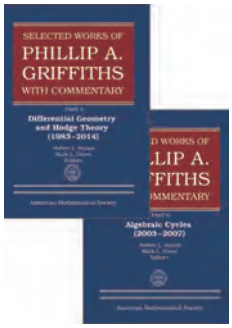
Papers contained in this volume cover topics in real analytic geometry, real algebra, and real algebraic geometry including complexity issues, model theory of various algebraic and differential structures, Witt equivalence of fields, and the moment problem.

This item will also be of interest to those working in logic and foundations.

Contents: F. Acquistapace, **F. Broglia**, and **J. F. Fernando**, Some results on global real analytic geometry; **M. Aschenbrenner**, **L. van den Dries**, and **J. van der Hoeven**, Dimension in the realm of transseries; **V. Astier** and **T. Unger**, Stability index of algebras with involution; **S. Basu** and **C. Riener**, Efficient algorithms for computing the Euler-Poincaré characteristic of symmetric semi-algebraic sets; **L. Chua**, **D. Plaumann**, **R. Sinn**, and **C. Vinzant**, Gram spectrahedra; **M. Dickmann**, **F. Miraglia**, and **A. Petrovich**, Constructions in the category of real semigroups; **A. Fehm** and **F. Jahnke**, Recent progress on definability of Henselian valuations; **J. F. Fernando**, **M. Gamboa**, and **C. Ueno**, Polynomial, regular and Nash images of Euclidean spaces; **P. Gładki**, Witt equivalence of fields: A survey with a special emphasis on applications of hyperfields; **M. Infusino** and **S. Kuhlmann**, Infinite dimensional moment problem: Open questions and applications; **T.-L. Kriel**, A new proof for the existence of degree bounds for Putinar's Positivstellensatz; **F.-V. Kuhlmann**, **K. Kuhlmann**, and **F. Sonaallah**, Coincidence point theorems for ball spaces and their applications; **F.-V. Kuhlmann** and **S. Kuhlmann**, Valuation theory of exponential Hardy fields II: Principal parts of germs in the Hardy field of o-minimal exponential expansions of the reals; **H. Lombardi** and **A. Mahboubi**, Théories géométriques pour l'algèbre des nombres réels; **V. Mantova** and **M. Matusinski**, Surreal numbers with derivation, Hardy fields and transseries: A survey; **C. Scheiderer** and **S. Wenzel**, Polynomials nonnegative on the cylinder; **N. Schwartz**, Positive semifields and their ideals; **M. Tressl**, On the strength of some topological lattices; **D. Trotman** and **G. Valette**, On the local geometry of definably stratified sets.

Contemporary Mathematics, Volume 697

October 2017, 384 pages, Softcover, ISBN: 978-1-4704-2966-9, LC 2017015042, 2010 *Mathematics Subject Classification:* 03Cxx, 06Fxx, 11Exx, 12-XX, 14Pxx, 14Qxx, 32Sxx, 44A60, 54C30, 58A07, **AMS members US$88.80**, List US$111, Order code CONM/697



Selected Works of Philip A. Griffiths with Commentary (The Set)

Robert L. Bryant, *Duke University, Durham, NC*, and **Mark L. Green**, *University of California, Los Angeles, CA*, Editors

In the period since the original four volumes of Phillip Griffiths's Selecta were published (*Selected Works of Phillip A. Griffiths with Commentary*), Parts 1–4, Collected Works, Volume 18), Griffiths has continued to produce beautiful and important work. The current two-part publication brings Griffiths's Selecta up to date by including the majority of his recent articles, as well as two older papers on differential geometry whose length had precluded their inclusion in the original Selecta.

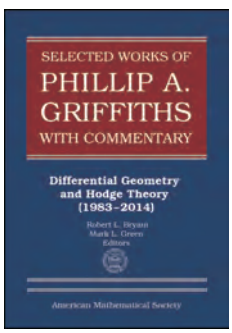
The papers are organized along the three main topics: Differential Geometry and Hodge Theory (Part 5) and Algebraic Cycles (Part 6). In addition to his papers, Griffiths has been an author of a number of research monographs. To give the reader an overview of what these monographs contain, introductions to some of these are also included.

This item will also be of interest to those working in geometry and topology.

Each volume in this set is sold separately. For a description of each volume, see the New Publication entries that follow.

Collected Works, Volume 26

Set: November 2017, 785 pages, Hardcover, ISBN: 978-1-4704-3655-1, LC 2017010885, 2010 *Mathematics Subject Classification:* 14C15, 14C25, 14C30, 14D07, 20G05, 32G20, 32M10, 32S35, 58C15, 53B25, 53C42, 58A15, **AMS members US$200**, List US$250, Order code CWORKS/26



Selected Works of Philip A. Griffiths with Commentary

Differential Geometry and Hodge Theory (1983–2014)

Robert L. Bryant, *Duke University, Durham, NC*, and **Mark L. Green**, *University of California, Los Angeles, CA*, Editors

In the period since the original four volumes of Phillip Griffiths's Selecta were published (*Selected Works of Phillip A. Griffiths with Commentary*, Parts 1–4, Collected Works, Volume 18), Griffiths has continued to produce beautiful and important work. The current two-part publication brings Griffiths's Selecta up to date by including the majority of his recent articles, as well as two older papers on differential geometry whose length had precluded their inclusion in the original Selecta.

The papers are organized along the three main topics, with Part 5 containing papers on Differential Geometry and Hodge Theory and Part 6 containing papers on Algebraic Cycles. In addition

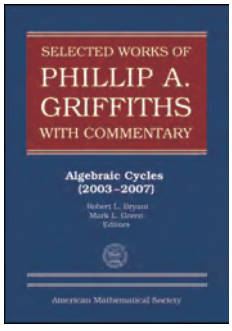
to his papers, Griffiths has been an author of a number of research monographs. To give the reader an overview of what these monographs contain, introductions to some of these are also included.

This item will also be of interest to those working in geometry and topology.

Contents: J. Carlson, **M. Green**, and **P. Griffiths**, Variations of Hodge structure considered as an exterior and differential system: Old and new results; **M. Green** and **M. Kerr**, Introduction from Mumford-Tate groups and domains: Their geometry and arithmetic; **M. Green** and **M. Kerr**, Introduction from Introduction to Hodge theory, complex geometry, and representation theory; **E. Berger**, **R. Bryant**, and **P. Griffiths**, The Gauss equations and rigidity of isometric embeddings; **R. L. Bryant**, **P. A. Griffiths**, and **D. Yang**, Characteristics and existence of isometric embeddings; **M. Green**, **P. Griffiths**, and **C. Robles**, Extremal degenerations of polarized Hodge structures; **P. Griffiths**, **C. Robles**, and **D. Toledo**, Quotients of non-classical flag domains are not algebraic; **M. Green**, **P. Griffiths**, and **M. Kerr**, Néron models and boundary components for degenerations of Hodge structure of mirror quintic type; **M. Green**, **P. Griffiths**, and **M. Kerr**, Néron models and limits of Abel-Jacobi mappings.

Collected Works, Volume 26, Part 1

November 2017, 489 pages, Hardcover, ISBN: 978-1-4704-3656-8, LC 2017010885, 2010 *Mathematics Subject Classification:* 14C15, 14C25, 14C30, 14D07, 20G05, 32G20, 32M10, 32S35, 58C15, 53B25, 53C42, 58A15, **AMS members US$126.40**, List US$158, Order code CWORKS/26.1



Selected Works of Philip A. Griffiths with Commentary

Algebraic Cycles (2003–2007)

Robert L. Bryant, *Duke University, Durham, NC*, and **Mark L. Green**, *University of California, Los Angeles, CA*, Editors

In the period since the original four volumes of Phillip Griffiths's Selecta were published (*Selected Works of Phillip A. Griffiths with Commentary*, Parts 1–4, Collected Works, Volume 18), Griffiths has continued to produce beautiful and important work. The current two-part publication brings Griffiths's Selecta up to date by including the majority of his recent articles, as well as two older papers on differential geometry whose length had precluded their inclusion in the original Selecta.

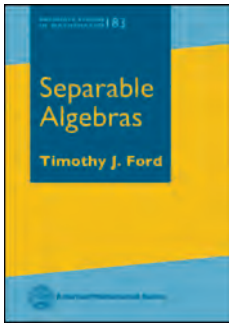
The papers are organized along the three main topics, with Part 6 containing papers on Algebraic Cycles and Part 5 containing papers on Differential Geometry and Hodge Theory. In addition to his papers, Griffiths has been an author of a number of research monographs. To give the reader an overview of what these monographs contain, introductions to some of these are also included.

This item will also be of interest to those working in geometry and topology.

Contents: M. Green, **P. A. Griffiths**, and **K. H. Paranjape**, Cycles over fields of transcendence degree 1; **M. Green** and **P. Griffiths**, Hodge-theoretic invariants for algebraic cycles; **M. Green** and **P. Griffiths**, An interesting 0-cycle; **M. Green** and **P. Griffiths**, Formal deformation of Chow groups; **M. Green** and **P. Griffiths**, On the tangent space to the space of algebraic cycles on a smooth algebraic variety; **M. Green** and **P. Griffiths**, Algebraic cycles and singularities of normal functions, I; **M. Green** and **P. Griffiths**, Algebraic cycles and singularities of normal functions, II.

Collected Works, Volume 26, Part 2

November 2017, 296 pages, Hardcover, ISBN: 978-1-4704-3657-5, LC 2017010885, 2010 *Mathematics Subject Classification:* 14C15, 14C25, 14C30, 14D07, 20G05, 32G20, 32M10, 32S35, **AMS members US$126.40**, List US$158, Order code CWORKS/26.2



Separable Algebras

Timothy J. Ford, *Florida Atlantic University, Boca Raton, FL*

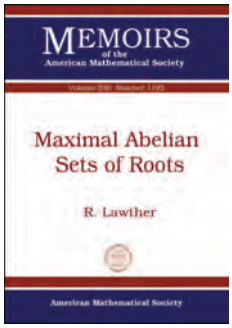
This book presents a comprehensive introduction to the theory of separable algebras over commutative rings. After a thorough introduction to the general theory, the fundamental roles played by separable algebras are explored. For example, Azumaya algebras, the henselization of local rings, and Galois theory are rigorously introduced and treated. Interwoven throughout these applications is the important notion of étale algebras. Essential connections are drawn between the theory of separable algebras and Morita theory, the theory of faithfully flat descent, cohomology, derivations, differentials, reflexive lattices, maximal orders, and class groups.

The text is accessible to graduate students who have finished a first course in algebra, and it includes necessary foundational material, useful exercises, and many nontrivial examples.

Contents: Background material on rings and modules; Modules over commutative rings; The Wedderburn-Artin theorem; Separable algebras, definition and first properties; Background material on homological algebra; The divisor class group; Azumaya algebras, I; Derivations, differentials and separability; Étale algebras; Henselization and splitting rings; Azumaya algebras, II; Galois extensions of commutative rings; Crossed products and Galois cohomology; Further topics; Acronyms; Glossary of notation; Bibliography; Index.

Graduate Studies in Mathematics, Volume 183

October 2017, 637 pages, Hardcover, ISBN: 978-1-4704-3770-1, LC 2017013677, 2010 *Mathematics Subject Classification:* 16H05, 15B05, 13A15, 13C20, 14F20, 14B25, 16-01, 13-01, **AMS members US$75.20**, List US$94, Order code GSM/183



Maximal Abelian Sets of Roots

R. Lawther, *Centre for Mathematical Sciences, Cambridge University, United Kingdom*

Contents: Introduction; Root systems of classical type; The strategy for root systems of exceptional type; The root system of type G_2; The root system of

type F_4; The root system of type E_6; The root system of type E_7; The root system of type E_8; Tables of maximal abelian sets; Appendix A. Root trees for root systems of exceptional type; Bibliography.

Memoirs of the American Mathematical Society, Volume 250, Number 1192

October 2017, 219 pages, Softcover, ISBN: 978-1-4704-2679-8, 2010 *Mathematics Subject Classification:* 17B22, **Individual member US$45**, List US$75, Institutional member US$60, Order code MEMO/250/1192

A First Course in Sobolev Spaces

Second Edition

Giovanni Leoni, *Carnegie Mellon University, Pittsburgh, PA*

This book is about differentiation of functions. It is divided into two parts, which can be used as different textbooks, one for an advanced undergraduate course in functions of one variable and one for a graduate course on Sobolev functions. The first part develops the theory of monotone, absolutely continuous, and bounded variation functions of one variable and their relationship with Lebesgue–Stieltjes measures and Sobolev functions. It also studies decreasing rearrangement and curves. The second edition includes a chapter on functions mapping time into Banach spaces.

The second part of the book studies functions of several variables. It begins with an overview of classical results such as Rademacher's and Stepanoff's differentiability theorems, Whitney's extension theorem, Brouwer's fixed point theorem, and the divergence theorem for Lipschitz domains. It then moves to distributions, Fourier transforms and tempered distributions.

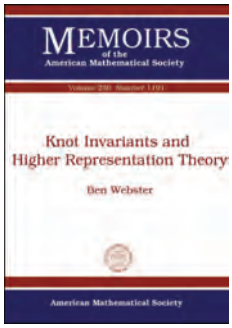
The remaining chapters are a treatise on Sobolev functions. The second edition focuses more on higher order derivatives and it includes the interpolation theorems of Gagliardo and Nirenberg. It studies embedding theorems, extension domains, chain rule, superposition, Poincaré's inequalities and traces.

A major change compared to the first edition is the chapter on Besov spaces, which are now treated using interpolation theory.

Contents: *Part 1. Functions of one variable:* Monotone functions; Functions of bounded pointwise variation; Absolutely continuous functions; Decreasing rearrangement; Curves; Lebesgue–Stieltjes measures; Functions of bounded variation and Sobolev functions; The infinite-dimensional case; *Part 2. Functions of several variables:* Change of variables and the divergence theorem; Distributions; Sobolev spaces; Sobolev spaces: Embeddings; Sobolev spaces: Further properties; Functions of bounded variation; Sobolev spaces: Symmetrization; Interpolation of Banach spaces; Besov spaces; Sobolev spaces: Traces; Appendix A. Functional analysis; Appendix B. Measures; Appendix C. The Lebesgue and Hausdorff measures; Appendix D. Notes; Appendix E. Notation and list of symbols; Bibliography; Index.

Graduate Studies in Mathematics, Volume 181

November 2017, approximately 731 pages, Hardcover, ISBN: 978-1-4704-2921-8, LC 2017009991, 2010 *Mathematics Subject Classification:* 46E35; 26A27, 26A30, 26A42, 26A45, 26A46, 26A48, 26B30, 30H25, **AMS members US$75.20**, List US$94, Order code GSM/181



Knot Invariants and Higher Representation Theory

Ben Webster, *University of Virginia, Charlottesville, VA*

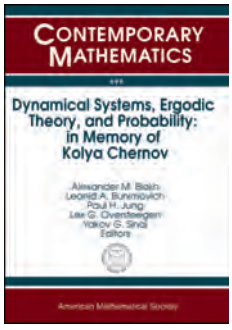
This item will also be of interest to those working in geometry and topology.

Contents: Introduction; Categorification of quantum groups; Cyclotomic quotients; The tensor product algebras; Standard modules; Braiding functors; Rigidity structures; Knot invariants; Comparison to category $\mathcal{O}$ and other knot homologies; Bibliography.

Memoirs of the American Mathematical Society, Volume 250, Number 1191

October 2017, 133 pages, Softcover, ISBN: 978-1-4704-2650-7, 2010 *Mathematics Subject Classification:* 16G99, 17B37, 18D10, 57M25, **Individual member US$45**, List US$75, Institutional member US$60, Order code MEMO/250/1191

Analysis



Dynamical Systems, Ergodic Theory, and Probability: in Memory of Kolya Chernov

Alexander M. Blokh, *University of Alabama at Birmingham, AL*, **Leonid A. Bunimovich**, *Georgia Institute of Technology, Atlanta, GA*, **Paul H. Jung**, *Korea Advanced Institute of Science and Technology, Daejeon, South Korea*, **Lex G. Oversteegen**, *University of Alabama at Birmingham, AL*, and **Yakov G. Sinai**, *Princeton University, NJ*, Editors

This volume contains the proceedings of the Conference on Dynamical Systems, Ergodic Theory, and Probability, which was dedicated to the memory of Nikolai Chernov, held from May 18–20, 2015, at the University of Alabama at Birmingham, Birmingham, Alabama.

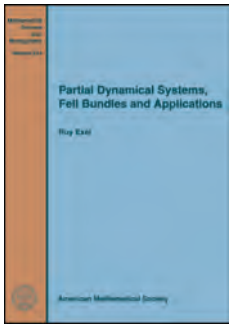
The book is devoted to recent advances in the theory of chaotic and weakly chaotic dynamical systems and its applications to statistical mechanics. The papers present new original results as well as comprehensive surveys.

Contents: L. Bunimovich, N. I. Chernov (1956-2014); **T. Adams** and **J. Rosenblatt**, Joint coboundaries; **P. Bálint**, **N. Chernov**,

and **D. Dolgopyat**, Convergence of moments for dispersing billiards with cusps; **E. Catsigeras**, **M. Cerminara**, and **H. Enrich**, Weak pseudo-physical measures and Pesin's entropy formula for Anosov C^1-diffeomorphisms; **C. Cox** and **R. Feres**, No-slip billiards in dimension two; **C. P. Dettmann**, How sticky is the chaos/order boundary?; **G. Galperin** and **M. Levi**, Bouncing in gravitational field; **N. T. A. Haydn** and **F. Yang**, A derivation of the Poisson law for returns of smooth maps with certain geometrical properties; **K. Khanin** and **S. Kocić**, Rigidity for a class of generalized interval exchange transformations; **C. C. Moxley** and **N. J. Simanyi**, Homotopical complexity of a 3*D* billiard flow; **M. Jakobson**, Mixing properties of some maps with countable Markov partitions; **Ya. G. Sinai** and **I. Vinogradov**, Eigenfunctions of Laplacians in some two-dimensional domains; **D. Szász**, Multidimensional hyperbolic billiards; **X. Xia** and **P. Zhang**, Homoclinic intersections for geodesic flows on convex spheres; **H. Zhang**, Decay of correlations for billiards with flat points I: Channel effects; **H. Zhang**, Decay of correlations for billiards with flat points II: Cusps effect.

Contemporary Mathematics, Volume 698

October 2017, 328 pages, Softcover, ISBN: 978-1-4704-2773-3, 2010 *Mathematics Subject Classification:* 11J70, 37A25, 37A35, 37A50, 37A60, 37C20, 37C29, 37D50, 37E10, **AMS members US$88.80**, List US$111, Order code CONM/698



Partial Dynamical Systems, Fell Bundles and Applications

Ruy Exel, *Universidade Federal de Santa Catarina, Florianópolis-SC, Brazil*

Partial dynamical systems, originally developed as a tool to study algebras of operators in Hilbert spaces, has recently become an important branch of algebra. Its most powerful results allow for understanding structural properties of algebras, both in the purely algebraic and in the C*-contexts, in terms of the dynamical properties of certain systems which are often hiding behind algebraic structures. The first indication that the study of an algebra using partial dynamical systems may be helpful is the presence of a grading. While the usual theory of graded algebras often requires gradings to be saturated, the theory of partial dynamical systems is especially well suited to treat nonsaturated graded algebras which are in fact the source of the notion of "partiality". One of the main results of the book states that every graded algebra satisfying suitable conditions may be reconstructed from a partial dynamical system via a process called the partial crossed product.

Running in parallel with partial dynamical systems, partial representations of groups are also presented and studied in depth.

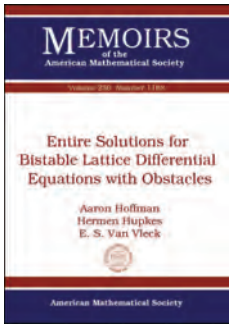
In addition to presenting main theoretical results, several specific examples are analyzed, including Wiener–Hopf algebras and graph C*-algebras.

Contents: Introduction; *Partial actions:* Partial actions; Restriction and globalization; Inverse semigroups; Topological partial dynamical sysytems; Algebraic partial dynamical systems; Multipliers; Crossed products; Partial group representations; Partial group algebras; C*-algebraic partial dynamical systems; Partial isometries; Covariant representations of C*-algebraic dynamical systems; Partial representations subject to relations; Hilbert modules and Morita-Rieffel-equivalence; *Fell bundles:* Fell bundles; Reduced cross-sectional algebras; Fell's absorption principle; Graded C*-algebras; Amenability for Fell bundles; Functoriality for Fell bundles; Functoriality for partial actions; Ideals in graded algebras; Pre-Fell-bundles; Tensor products of Fell bundles; Smash product; Stable Fell bundles as partial crossed products; Globalization in the C*-context; Topologically free partial actions; *Applications:* Dilating partial representations; Semigroups of isometries; Quasi-lattice ordered groups; C*-algebras generated by semigroups of isometries; Wiener-Hopf C*-algebras; The Toeplitz C*-algebra of a graph; Path spaces; Graph C*-algebras; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 224

October 2017, 321 pages, Hardcover, ISBN: 978-1-4704-3785-5, LC 2017013411, 2010 *Mathematics Subject Classification:* 46L55, 46L45, 37A55, 16S35, 16S40, **AMS members US$92.80**, List US$116, Order code SURV/224

Differential Equations



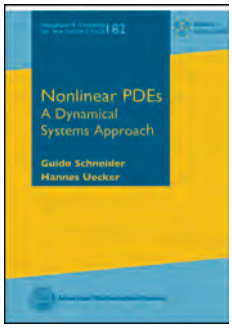
Entire Solutions for Bistable Lattice Differential Equations with Obstacles

Aaron Hoffman, *Franklin W. Olin College of Engineering, Needham, MA*, **Hermen Hupkes**, *Mathematisch Instituut, Universiteit Leiden, The Netherlands*, and **E. S. Van Vleck**, *University of Kansas, Lawrence, KS*

Contents: Introduction; Main results; Preliminaries; Spreading speed; Large disturbances; The entire solution; Various limits; Proof of Theorem 2.3; Discussion; Acknowledgments; Bibliography.

Memoirs of the American Mathematical Society, Volume 250, Number 1188

October 2017, 117 pages, Softcover, ISBN: 978-1-4704-2201-1, 2010 *Mathematics Subject Classification:* 34K31, 37L15, **Individual member US$45**, List US$75, Institutional member US$60, Order code MEMO/250/1188



Nonlinear PDEs

A Dynamical Systems Approach

Guido Schneider, *Universität Stuttgart, Germany*, and **Hannes Uecker**, *Carl von Ossietzky Universität Oldenburg, Germany*

This is an introductory textbook about nonlinear dynamics of PDEs, with a focus on problems over unbounded domains and modulation equations. The presentation is example-oriented, and new mathematical tools are developed step by step, giving insight into some important classes of nonlinear PDEs and nonlinear dynamics phenomena which may occur in PDEs.

The book consists of four parts. Parts I and II are introductions to finite- and infinite-dimensional dynamics defined by ODEs and by PDEs over bounded domains, respectively, including the basics of bifurcation and attractor theory. Part III introduces PDEs on the real line, including the Korteweg-de Vries equation, the Nonlinear Schrödinger equation and the Ginzburg-Landau equation. These examples often occur as simplest possible models, namely as amplitude or modulation equations, for some real world phenomena such as nonlinear waves and pattern formation. Part IV explores in more detail the connections between such complicated physical systems and the reduced models. For many models, a mathematically rigorous justification by approximation results is given.

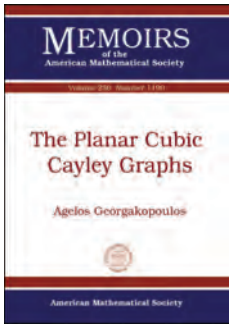
The parts of the book are kept as self-contained as possible. The book is suitable for self-study, and there are various possibilities to build one- or two-semester courses from the book.

Contents: Basic ODE dynamics; Dissipative dynamics; Hamiltonian dynamics; PDEs on an interval; The Navier-Stokes equations; Some dissipative PDE models; Three canonical modular equations; Reaction-diffusion systems; Dynamics of pattern and the GL equation; Wave packets and the NLS equation; Long waves and their modular equations; Center manifold reduction and spatial dynamics; Diffusive stability; Bibliography; Index; List of symbols.

Graduate Studies in Mathematics, Volume 182

November 2017, 584 pages, Hardcover, ISBN: 978-1-4704-3613-1, LC 2017012328, 2010 *Mathematics Subject Classification:* 35-01, 35Bxx, 35Qxx, 37Kxx, 37Lxx, **AMS members US$79.20**, List US$99, Order code GSM/182

Discrete Mathematics and Combinatorics



The Planar Cubic Cayley Graphs

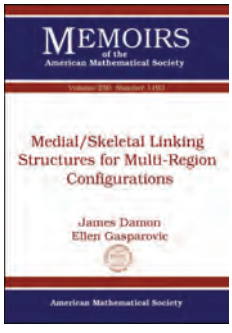
Agelos Georgakopoulos, *Mathematics Institute, University of Warwick, United Kingdom*

Contents: Introductory material and basic facts; The finite and 1-ended cubic planar Cayley graphs; The planar multi-ended Cayley graphs with 2 generators; The planar multi-ended Cayley graphs generated by 3 involutions; Outlook; Bibliography.

Memoirs of the American Mathematical Society, Volume 250, Number 1190

October 2017, 82 pages, Softcover, ISBN: 978-1-4704-2644-6, 2010 *Mathematics Subject Classification:* 05C25, 20F65, **Individual member US$45**, List US$75, Institutional member US$60, Order code MEMO/250/1190

Geometry and Topology



Medial/Skeletal Linking Structures for Multi-Region Configurations

James Damon, *University of North Carolina, Chapel Hill, NC*, and **Ellen Gasparovic**, *Union College, Schenectady, NY*

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

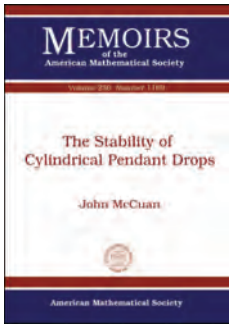
Contents: Introduction; *Part 1. Medial/Skeletal Linking Structures:* Multi-region configurations in $\mathbb{R}^{n+1}$; Skeletal linking structures for multi-region configurations in $\mathbb{R}^{n+1}$; Blum medial linking structure for a generic multi-region configuration; Retracting the full Blum medial structure to a skeletal linking structure; *Part 2. Positional Geometry of Linking Structures:* Questions involving positional geometry of a multi-region configuration; Shape operators and radial flow for a skeletal structure; Linking flow and curvature conditions; Properties of regions defined using the linking flow; Global geometry via medial and skeletal linking integrals; Positional geometric properties of multi-region configurations; *Part 3. Generic Properties of Linking Structures via Transversality Theorems:* Multi-distance and height-distance functions and partial multi-jet spaces; Generic Blum linking properties via transversality theorems; Generic properties of Blum linking structures; Concluding generic properties of Blum linking structures; *Part 4. Proofs and Calculations for the Transversality Theorems:* Reductions of the proofs of the transversality theorems;

Families of perturbations and their infinitesimal properties; Completing the proofs of the transversality theorems; Appendix A. List of frequently used notation; Bibliography.

Memoirs of the American Mathematical Society, Volume 250, Number 1193

October 2017, 163 pages, Softcover, ISBN: 978-1-4704-2680-4, 2010 *Mathematics Subject Classification:* 53A07, 58A35; 68U05, **Individual member US$45**, List US$75, Institutional member US$60, Order code MEMO/250/1193

Mathematical Physics



The Stability of Cylindrical Pendant Drops

John McCuan, *Georgia Institute of Technology, Atlanta, GA*

Contents: Introduction; Normalization, stability condition, and elementary properties; One Parameter Families; Definition of s_2; Stability; Infinitely long drops; Zero gravity and soap bubbles; Open problems; Appendix 1: Explicit formulas; Appendix 2: Sturm-Liouville theory; Appendix 3: Elliptic integrals; Acknowledgement; Bibliography.

Memoirs of the American Mathematical Society, Volume 250, Number 1189

October 2017, 111 pages, Softcover, ISBN: 978-1-4704-0938-8, **Individual member US$45**, List US$75, Institutional member US$60, Order code MEMO/250/1189

Probability and Statistics

Markov Chains and Mixing Times

Second Edition

David A. Levin, *University of Oregon, Eugene, OR*, and **Yuval Peres**, *Microsoft Research, Redmond, WA*

Markov Chains and Mixing Times *is a magical book, managing to be both friendly and deep. It gently introduces probabilistic techniques so that an outsider can follow. At the same time, it is the first book covering the geometric theory of Markov chains and has much that will be new to experts. It is certainly THE book that I will use to teach from. I recommend it to all comers, an amazing achievement.*

—Persi Diaconis, Mary V. Sunseri Professor of Statistics and Mathematics, Stanford University

Mixing times are an active research topic within many fields from statistical physics to the theory of algorithms, as well as having intrinsic interest within mathematical probability and exploiting discrete analogs of important geometry concepts. The first edition became an instant classic, being accessible to advanced undergraduates and yet bringing readers close to current research frontiers. This second edition adds chapters on monotone chains, the exclusion process and hitting time parameters. Having both exercises and citations to important research papers it makes an outstanding basis for either a lecture course or self-study.

—David Aldous, University of California, Berkeley

Mixing time is the key to Markov chain Monte Carlo, the queen of approximation techniques. With new chapters on monotone chains, exclusion processes, and set-hitting, Markov Chains and Mixing Times *is more comprehensive and thus more indispensable than ever. Prepare for an eye-opening mathematical tour!*

—Peter Winkler, Dartmouth College

The study of finite Markov chains has recently attracted increasing interest from a variety of researchers. This is the second edition of a very valuable book on the subject. The main focus is on the mixing time of Markov chains, but there is a lot of additional material.

In this edition, the authors have taken the opportunity to add new material and bring the reader up to date on the latest research. I have used the first edition in a graduate course and I look forward to using this edition for the same purpose in the near future.

—Alan Frieze, Carnegie Mellon University

This book is an introduction to the modern theory of Markov chains, whose goal is to determine the rate of convergence to the stationary distribution, as a function of state space size and geometry. This topic has important connections to combinatorics, statistical physics, and theoretical computer science. Many of the techniques presented originate in these disciplines.

The central tools for estimating convergence times, including coupling, strong stationary times, and spectral methods, are developed. The authors discuss many examples, including card shuffling and the Ising model, from statistical mechanics, and present the connection of random walks to electrical networks and apply it to estimate hitting and cover times.

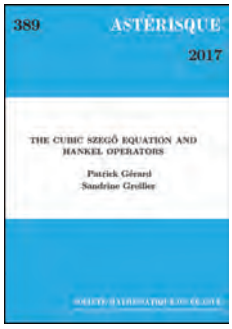
The first edition has been used in courses in mathematics and computer science departments of numerous universities. The second edition features three new chapters (on monotone chains, the exclusion process, and stationary times) and also includes smaller additions and corrections throughout. Updated notes at the end of each chapter inform the reader of recent research developments.

Contents: *Basic methods and examples:* Introduction to finite Markov chains; Classical (and useful) Markov chains; Markov chain Monte Carlo: Metropolis and Glauber chains; Introduction to Markov chain mixing; Coupling; Strong stationary times; Lower bounds on mixing times; The symmetric group and shuffling cards; Random walks on networks; Hitting times; Cover times; Eigenvalues; *The plot thickens:* Eigenfunctions and comparison of chains; The transportation metric and path coupling; The Ising model; From shuffling cards to shuffling genes; Martingales and evolving sets; The cutoff phenomenon; Lamplighter walks; Continuous-time chains; Countable state space chains; Monotone chains; The exclusion process; Cesàro mixing time, stationary times, and hitting large sets; Coupling from the past; Open problems; Background material; Introduction to simulation; Ergodic theorem; Solutions to selected exercises; Bibliography; Notation index; Index.

November 2017, 464 pages, Hardcover, ISBN: 978-1-4704-2962-1, LC 2017017451, 2010 *Mathematics Subject Classification:* 60J10, 60J27, 60B15, 60C05, 65C05, 60K35, 68W20, 68U20, 82C22, **AMS members US$67.20**, List US$84, Order code MBK/107

New AMS-Distributed Publications

Differential Equations



The Cubic Szegő Equation and Hankel Operators

Patrick Gérard, *Université Paris-Sud, Orsay, France*, and **Sandrine Grellier**, *Université d'Orléans, France*

This monograph is devoted to the dynamics on Sobolev spaces of the cubic Szegő equation on the circle $\mathbb{S}^1$, $i\partial_t u = \Pi(|u|^2 u)$. Here Π denotes the orthogonal projector from $L^2(\mathbb{S}^1)$ onto the subspace $L^2_+(\mathbb{S}^1)$ of functions with nonnegative Fourier modes. The authors construct a nonlinear Fourier transformation on $H^{1/2}(\mathbb{S}^1) \cap L^2_+(\mathbb{S}^1)$, allowing them to describe explicitly the solutions of this equation with data in $H^{1/2}(\mathbb{S}^1) \cap L^2_+(\mathbb{S}^1)$.

This explicit description implies almost-periodicity of every solution in this space. Furthermore, it allows the authors to display the following turbulence phenomenon. For a dense G_δ subset of initial data in $C^\infty(\mathbb{S}^1) \cap L^2_+(\mathbb{S}^1)$, the solutions tend to infinity in H^s for every $s > \frac{1}{2}$ with super-polynomial growth on some sequence of times, while they go back to their initial data on another sequence of times tending to infinity.

This transformation is defined by solving a general inverse spectral problem involving singular values of a Hilbert–Schmidt Hankel operator and of its shifted Hankel operator.

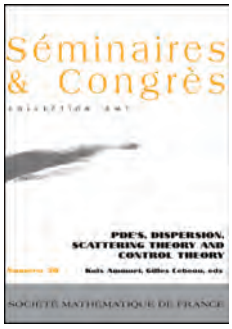
This item will also be of interest to those working in analysis.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Astérisque, Number 389

May 2017, 114 pages, Softcover, ISBN: 978-2-85629-854-1, 2010 *Mathematics Subject Classification:* 35B15, 47B35, 37K15, **AMS members US$41.60**, List US$52, Order code AST/389

Discrete Mathematics and Combinatorics



PDEs, Dispersion, Scattering Theory and Control Theory

Kaïs Ammari, *Université de Monastir, Tunisie*, and **Gilles Lebeau**, *Université de Nice, Sophia Antipolis, France*

This book results from notes of the lectures given in Monastir from June 10–14, 2013 during the workshop about the dispersion and scattering theory and control theory of partial differential equations. This volume contains surveys of active research topics, along with original research papers containing exciting new results on PDEs, dispersion, scattering and control theory. It will, therefore, benefit both graduate students and researchers.

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

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Séminaires et Congrès, Number 30

July 2017, 153 pages, Softcover, ISBN: 978-2-85629-858-9, 2010 *Mathematics Subject Classification:* 35Q40, 35B65, 35J10, 35P20, 47A10, 35Q55, 35B40, 34B45, 39A10, 35R01, 35A17, 35A18, 35B45, 35L20, 93B28, 93B07, 47A05, 65J10, 35Q30, 35A02, 35B30, 76D05, 49N35, 49J20, 35P25, **AMS members US$41.60**, List US$52, Order code SECO/30

General Interest

Séminaire Bourbaki: Volume 2015/2016 Exposés 1104–1119

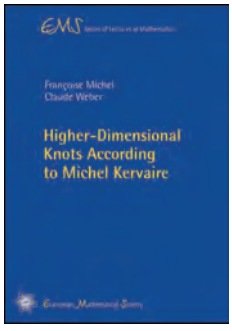
The 68th volume of Bourbaki Seminar contains the texts of the sixteen survey lectures done during the year 2015/2016: analytic number theory, binormal flow and the Schrödinger equation, combinatorics and the independence property in model theory, formal moduli problems, geometric Landlands program, Hilbert-Smith conjecture in differential geometry, Hodge theory of the decomposition theorem, Monge-Ampère equation in complex algebraic geometry, motives and periods, resolution of underdetermined linear systems, sofic entropy, subriemannian geometry, and spectral theory.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Astérisque, Number 390

June 2017, 533 pages, Softcover, ISBN: 978-2-85629-855-8, 2010 *Mathematics Subject Classification:* 11H99, 14C30, 14F42, 18G55, 19E15, 32G20, 14E20, 14D22, 57S10, 57M60, 57S05, 57N10, 54H15, 55M35, 35P20, 35P25, 37A35, 37A15, 20E15, 14F05, 14H60, 11S37, 14D24, 22E55, 22E57, 14B12, 14A20, 53C55, 32J27, 32P05, 53C17, 49K21, 28A15, 03C68, 03C45, 03C98, 05C69, 05D10, 28E05, 58A14, 32S60, 32S35, 55N33, 60G15, 60G60, 35B05, 34L20, 58J40, 52B55, 62H12, 42B05, 35Q55, 35C06, 35B35, 76B47, 76B03, 11N25, 11N64, **AMS members US$77.60**, List US$97, Order code AST/390

Geometry and Topology



Higher-Dimensional Knots According to Michel Kervaire

Françoise Michel, *Université Paul Sabatier, Toulouse, France*, and **Claude Weber**, *Université de Genève, Switzerland*

Michel Kervaire wrote six papers which can be considered fundamental to the development of higher-dimensional knot theory. They are not only of historical interest but naturally introduce some of the essential techniques in this fascinating theory.

This book is written to provide graduate students with the basic concepts necessary to read texts in higher-dimensional knot theory and its relations with singularities. The first chapters are devoted to a presentation of Pontrjagin's construction, surgery, and the work of Kervaire and Milnor on homotopy spheres. The authors explore Kervaire's fundamental work on the group of a knot, knot modules, and knot cobordism and then consider developments due to Levine. Tools such as open books, handlebodies, and plumbings, which are often used but hard to find in original articles, are presented in appendices.

The authors conclude with a description of the Kervaire invariant and the consequences of the Hill–Hopkins–Ravenel results in knot theory.

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 Series of Lectures in Mathematics, Volume 28

July 2017, 144 pages, Softcover, ISBN: 978-3-03719-180-4, 2010 *Mathematics Subject Classification:* 57Q45, 57R65, 32S55, **AMS members US$30.40**, List US$38, Order code EMSSERLEC/28

Classified Advertisements

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

AUSTRIA

IST Austria
Professor or Assistant Professor (Tenure Track) Positions in areas of Mathematics, Statistics and Optimization

IST Austria invites applications for Professor and Assistant Professor (Tenure Track) positons in areas of Mathematics, Statistics and Optimization.

We offer:

- Competitive start-up package and salary
- Guaranteed, annual base funding
- Support and benefits for acquiring third party funds
- Multiple positions are open

IST Austria is a young international institute dedicated to world-class basic research and graduate education in the natural and mathematical sciences. Our PhD program involves a multi-disciplinary course schedule and rotations in research labs. Currently 40 research groups are active in the fields of biology, neuroscience, physics, mathematics, and computer science. The institute will grow to about 90 research groups by 2026. We hire scholars from diverse international backgrounds. Our working language is English. The campus of IST Austria is located about 15 km distant from Vienna, a city with high quality of life.

Candidates for tenured positions must be internationally accomplished scientists in their respective research fields and have at least six years of experience in leading a research group.

Assistant Professors receive independent group leader positions with an initial contract of six years, at the end of which they are evaluated by international peers. The outcome of this evaluation determines if an Assistant Professor is promoted to a tenured Professor position.

Successful candidates are expected to apply for external research funds and participate in graduate teaching.

Please apply online at: `www.ist.ac.at/professor-applications`

Applications should include a curriculum vitae, a list of publications, as well as a research statement, including a description of the most important scientific achievements and planned future research activities.

The closing date for applications is November 2, 2017.

IST Austria values diversity and is committed to equal opportunity. Female researchers are especially encouraged to apply.

00021

CALIFORNIA

University of California, Los Angeles
Department of Mathematics
Faculty Positions 2018–19

Tenured/Tenure-Track positions 2018–19 (subject to administrative approval)

The Department of Mathematics at the University of California, Los Angeles, invites applications for tenure-track or tenured faculty positions starting July 1, 2018. Outstanding candidates in all areas of mathematics may be considered.

Applicants must possess a PhD and should have outstanding accomplishments in both research and teaching.

Duties include mathematical research, undergraduate and graduate teaching, and departmental and university service. Level of appointment will be based on qualifications, with appropriate salary per UC pay scales.

As a campus with a diverse student body, we encourage applications from women, minorities, and individuals with a history of mentoring under-represented minorities in the sciences. The Department of Mathematics welcomes candidates whose experience in teaching, research, or community service has prepared them to contribute to our commitment to diversity and excellence.

The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability, age or protected veteran status. For the complete University of California nondiscrimination and affirmative action policy see: UC Nondiscrimination and Affirmative Action Policy (policy.ucop.edu/doc/4000376/NondiscrimAffirmAct).

The University of California asks that applicants complete the Equal Opportunity Employer survey for Letters and Science at the following URL: cis.ucla.edu/facultysurvey/ . Under Federal Law, the University of California may employ only individuals who are legally authorized to work in the United States as established by providing documents specified in the Immigration Reform and Control Act of 1986.

Applications and supporting documentation for all positions must be submitted online via www.mathjobs.org .

Applications will be accepted until the position is filled. To guarantee full consideration, the application should be received by November 15, 2017.

Temporary Faculty Positions 2018–19
The Department of Mathematics at the University of California, Los Angeles, invites applications for temporary and visiting appointments in the categories 1–4 below. Depending on the level, candidates must give evidence of potential or demonstrated distinction in scholarship and teaching. Applicants must possess a Ph.D. and should have outstanding accomplishments in both research and teaching. Postdoctoral Positions:

(1) E.R. Hedrick Assistant Professorships: Appointments are for three years. The teaching load is four one-quarter courses per year.

(2) Computational and Applied Mathematics (CAM) Assistant Professorships: Appointments are for three years. The teaching load is normally reduced by research funding to two one-quarter courses per year.

(3) Program in Computing (PIC) Assistant Adjunct Professorships: Applicants for these positions must show very strong promise in teaching and research in an area related to computing. The teaching load is four one-quarter programming courses each year and one additional course every two years. Initial appointments are for one year and possibly longer, up to a maximum service of four years.

(4) Assistant Adjunct Professorships and Research Postdocs: Appointments are normally for one year, with the possibility of renewal. Strong research and teaching background required. The teaching load for is six one-quarter courses per year.

Appointments will be effective July 1, 2018 or later. Applications will be accepted until all positions are filled. **For fullest consideration, all application materials should be submitted on or before November 15, 2017.**

Applications and supporting documentation must be submitted online via www.mathjobs.org .

All letters of evaluation are subject to UCLA campus policies on confidentiality. Refer potential reviewers to the UCLA statement of confidentiality at www.apo.ucla.edu/policies/the-call/summary-of-procedures/summary-10-statement-of-confidentiality .

Lecturer Positions in Mathematics
The UCLA Department of Mathematics receives on an ongoing basis applications for quarter positions (Fall/Winter/Spring or for Summer Session) for Lecturers to teach undergraduate Mathematics, Financial Actuarial Mathematics, or Math Education courses. Positions are very limited and temporary. Responsibilities include lecturing, conducting office hours, writing and grading exams and supervising teaching assistants. Previous teaching experience at the college level or extensive actuary experience is required and a PhD is preferred. Applications will be accepted until all positions are filled.

Applications and supporting documentation must be submitted online via www.mathjobs.org .

00023

CHINA

National Chengchi University
Open Faculty Positions (Tenure Track)

The Department of Mathematical Sciences at National Chengchi University in Taipei, Taiwan anticipates openings for several tenure-track faculty positions. The candidate must hold a doctoral degree in (Applied) Mathematics and be able to communicate in Chinese and English. For more information, please visit www.math.nccu.edu.tw/app/news.php?Sn=718 .

00015

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.

00008

ILLINOIS

University of Chicago
Department of Mathematics

The University of Chicago Department of Mathematics invites applications for the following positions:

1. L.E. Dickson Instructor: This is open to mathematicians who have recently completed or will soon complete a doctorate in mathematics or a closely related field, and whose work shows remarkable promise in mathematical research. The initial appointment is typically up to three years with the possibility of

renewal. The teaching obligation is up to four one-quarter courses per year.

2. Assistant Professor: This is open to mathematicians who are further along in their careers, typically two or three years past the doctorate. These positions are intended for mathematicians whose work has been of outstandingly high caliber. Appointees are expected to have the potential to become leading figures in their fields. The appointment is generally for three years, with the possibility for renewal and a teaching obligation of up to three one-quarter courses per year.

Applicants will be considered for any of the positions above which seem appropriate. Complete applications consist of (a) a cover letter, (b) a curriculum vitae, (c) three or more letters of reference, at least one of which addresses teaching ability, and (d) a description of previous research and plans for future mathematical research. Applicants are strongly encouraged to include information related to their teaching experience, such as a teaching statement or evaluations from courses previously taught, as well as an AMS cover sheet. If you have applied for an NSF Mathematical Sciences Postdoctoral Fellowship, please include that information in your application, and let us know how you plan to use it if awarded. Applications must be submitted online through www.mathjobs.org . Questions may be directed to apptsec@math.uchicago.edu . We will begin screening applications on November 1, 2017. Screening will continue until all available positions are filled.

The University of Chicago is an Affirmative Action/Equal Opportunity/Disabled/Veterans Employer and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender identity, national or ethnic origin, age, status as an individual with a disability, protected veteran status, genetic information, or other protected classes under the law. For additional information please see the University's Notice of Nondiscrimination at www.uchicago.edu/about/non_discrimination_statement/ . Job seekers in need of a reasonable accommodation to complete the application process should call 773-702-7328 or email jgarza@math.uchicago.edu with their request.

00017

MASSACHUSETTS

Massachusetts Institute of Technology
Cambridge, MA

The Mathematics Department at MIT is seeking to fill positions in Pure and Applied Mathematics at the level of Assistant Professor or higher beginning July 2018 (for the 2018–2019 academic year, or as soon thereafter as possible). Appointments are based primarily on exceptional research qualifications. Appointees will be required to fulfill teaching duties and pursue their own research program. PhD in Mathematics or related field required by employment start date.

For more information and to apply, please visit www.mathjobs.org . To receive full consideration, submit applications by December 1, 2017. MIT is an Equal Opportunity, Affirmative Action Employer.

00027

Massachusetts Institute of Technology
Cambridge, MA

The Mathematics Department at MIT is seeking to fill positions in Pure and Applied Mathematics, and Statistics at the level of Instructor beginning July 2018 (for the 2018–2019 academic year). Appointments are based primarily on exceptional research qualifications. Appointees will be expected to fulfill teaching duties and pursue their own research program. PhD in Mathematics or related field required by employment start date.

For more information and to apply, please visit www.mathjobs.org . To receive full consideration, submit applications by December 1, 2017. MIT is an Equal Opportunity, Affirmative Action Employer.

00028

NEW JERSEY

Princeton University
Program in Applied and Computational Mathematics
Postdoctoral Research Associate

The Program in Applied and Computational Mathematics invites applications for Postdoctoral Research Associates or more senior to join in research efforts of interest to its faculty. Domains of interest include nonlinear partial differential equations, computational fluid dynamics and material science, dynamical systems, numerical analysis, stochastic problems and stochastic analysis, graph theory and applications, mathematical biology, financial mathematics and mathematical approaches to signal analysis, information theory, and structural biology and image processing. Appointments are made for one year, renewable yearly for up to three years, if funding is available and performance is satisfactory. For details on specific faculty members and their research interests, please go to www.pacm.princeton.edu/sites/default/files/Faculty%20interests.pdf .

Applicants must submit a cover letter, CV, bibliography/publications list, statement of research and three letters of recommendation online at www.mathjobs.org/jobs . PhD required. This position is subject to the University background check policy.

Princeton University is an Equal Opportunity/Affirmative Action Employer and all qualified applicants will receive consideration for employment without regard to age, race, color, religion, sex, sexual orientation, gender identity or expression, national origin, disability status, protected veteran status, or any other characteristic protected by law.

00022

Rutgers University–New Brunswick
Mathematics Department

The Mathematics Department of Rutgers University—New Brunswick invites applications for the following positions which may be available September 2018.

TENURE-TRACK ASSISTANT/TENURED ASSOCIATE/TENURED FULL PROFESSORSHIP: Subject to availability of funding, the Department expects at least two openings at the level of Tenure-Track Assistant Professor. In exceptional cases, there may be the possibility of appointment at a higher level. Candidates must have a PhD and have a strong record of research accomplishments in pure or applied mathematics as well as effective teaching. The Department has hiring priorities in Mathematical Data Analysis and in Analysis/Probability. However, outstanding candidates in any field of pure or applied mathematics will be considered. The normal teaching load for research-active faculty is 2-1. Review of applications begins November 1, 2017.

HILL AND OTHER ASSISTANT PROFESSORSHIPS: These are three-year nontenure-track, nonrenewable, Post-Doctoral appointments. Subject to availability of funding, the department expects three positions of this nature. These positions carry a reduced teaching load of 2–1 for research; candidates should have received a PhD and show outstanding promise of research ability in pure or applied mathematics as well as a capacity for effective teaching. Review of applications begins December 1, 2017.

Applicants for the above positions should submit a curriculum vitae (including a publication list) and arrange for four letters of reference to be submitted, one of which evaluates teaching. Applicants should first go to the website www.mathjobs.org/jobs and fill out the AMS Cover Sheet electronically. It is essential to fill out the cover sheet completely, including naming the type of position being applied for (TTAP,PD respectively). The strongly preferred way to submit the CV, references, and any other application materials is online at: www.mathjobs.org/jobs . Alternatively, the materials may be filed at the listing at jobs.rutgers.edu .

Rutgers, the State University of New Jersey, is an Equal Opportunity / Affirmative Action Employer. Qualified applicants will be considered for employment without regard to race, creed, color, religion, sex, sexual orientation, gender identity or expression, national origin, disability status, genetic information, protected veteran status, military service or any other

category protected by law. As an institution, we value diversity of background and opinion, and prohibit discrimination or harassment on the basis of any legally protected class in the areas of hiring, recruitment, promotion, transfer, demotion, training, compensation, pay, fringe benefits, layoff, termination or any other terms and conditions of employment.

00025

NEW YORK

Cornell University
H.C. Wang Assistant Professor

The Mathematics Department at Cornell University invites applications for H.C. Wang Assistant Professor(s), non-tenure track, non-renewable, 3-year position beginning July 1, 2018. Successful candidates are expected to pursue independent research at Cornell and teach three courses per year. A Ph.D. in mathematics is required. The Department actively encourages applications from women and minority candidates. Applicants must apply electronically at www.mathjobs.org . Deadline December 1, 2017.

00019

Cornell University
Lecturer

The Mathematics Department of Cornell University invites applications for a potential non-tenure track renewable 3-year Lecturer position beginning July 1, 2018. Responsibilities include teaching four courses per year, serving on committees and contributing to overall the educational mission of the Department. A PhD in mathematics is required. The Department actively encourages applications from women and minority candidates. Applicants must apply electronically at www.mathjobs.org . Deadline December 1, 2017.

00020

PUBLICATIONS FOR SALE

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Books Available

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00026

RHODE ISLAND

Brown University
J. D. Tamarkin Assistant Professorships

One or more three-year non-tenured non-renewable appointments, beginning July 1, 2018. The teaching load is one course one semester, and two courses the other semester and consists of courses of more than routine interest. Candidates are required to have received a PhD degree or equivalent by the start of their appointment, and they may have up to three years of prior academic and/or postdoctoral research experience.

Applicants should have strong research potential and a commitment to teaching. Field of research should be consonant with the current research interests of the department.

For full consideration, applicants must submit a curriculum vitae, an AMS Standard Cover Sheet, and three letters of recommendation by November 20, 2017. (Later applications will be reviewed to the extent possible.) In addition, applicants are required to identify a Brown faculty member with similar research interests. Please submit all application materials on line at protect-us.mimecast.com/s/0JwpBbURMvJc7?domain=mathjobs.org . Email inquiries should be addressed to juniorsearch@math.brown.edu . Brown University is committed to fostering a diverse and inclusive academic global community; as an EEO/AA employer, Brown considers applicants for employment without regard to, and does not discriminate on the basis of, gender, race, protected veteran status, disability, or any other legally protected status.

Please send the invoice for this advertisement to my attention.

00030

SINGAPORE

National University of Singapore (NUS)
Department of Mathematics

The Department of Mathematics at the National University of Singapore (NUS) invites applications for the following positions beginning in August 2018.

1) Tenured/tenure-track faculty positions at all levels
2) Peng Tsu Ann Assistant Professorship (Appointments are for two years with the possibility of a one-year renewal).

NUS is a leading global university centred in Asia. The Department of Mathematics has about 60 faculty members and teaching staff whose expertise cover major areas of contemporary mathematical research.

We seek promising scholars and established mathematicians with outstanding track records in any field of pure and applied mathematics. The Department, housed in a spacious building equipped with state-of-the-art facilities, offers internationally competitive salary with start-up research grants, as well as an environment conducive to active research, and ample opportunities for career development. The teaching load for junior faculty is kept especially light.

The Department is particularly interested in, but not restricted to, considering applicants specializing in any of the following areas:

- Optimization and Data Science
- Quantitative Finance with focus in Data Analytics and Modelling
- PDE and Geometric Analysis
- Homogeneous Dynamics

Please submit your application at www.mathjobs.org/jobs/jobs/10408

1. Cover Letter
2. Curriculum Vitae/Publication List
3. Personal Data Consent Form www.nus.edu.sg/careers/potentialhires/applicationprocess/NUS-Personal-Data-Consent-for-Job-Applicants.pdf
4. Research Statement (max. 3 pages)
5. Teaching Statement (max. 3 pages)
6. Evaluation on teaching from faculty members or students of your current institution, where applicable;
7. Three or more Reference Letters (to be submitted by the reference writers at mathjobs.org)

Review process will begin on 15 October, and will continue until positions are filled. Enquiries may be sent tosearch@math.nus.edu.sg

For further information about the department, please visit www.math.nus.edu.sg .

00016

SOUTH AFRICA

Gottfried Wilhelm Leibniz
Basic Research Institute
Researchers Wanted

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

SOUTH KOREA

Institute for Basic Science (IBS)
Center for Geometry and Physics

The IBS Center for Geometry and Physics (IBS-CGP) invites applications for several postdoctoral research fellowship positions.

IBS-CGP is working to bring the world's leading scientists in mathematics together with young researchers to collaborate on research projects with passion and commitment. To this end, the center recruits based on scientific excellence and creative ideas, rather than pre-determined goals or demonstrated practical outcomes. IBS-CGP provides an open and autonomous research environment. The existing members of IBS-CGP are working in symplectic geometry and topology, dynamical sys-

tems, algebraic geometry, number theory, and mathematical aspects of quantum field and string theory.

IBS-CGP is located on the campus of Pohang University of Science and Technology (POSTECH) in Pohang, South Korea.

Successful candidates for postdoctoral research fellowship positions will be new or recent PhD's with outstanding research potential. These non-tenure-track appointments are for two or three years, and the salary range is KRW 57,000,000 – 66,000,000 (approximately USD 50,000 – 57,800).

These are purely research positions, and research fellows will have no teaching duties.

IBS-CGP offers annual travel funds of KRW 8,000,000 in addition to basic research equipment and comprehensive benefits including medical and travel insurance and retirement funds.

A complete application packet should include:

1. Cover letter
2. Curriculum vitae which includes a publication list
3. Research statement
4. At least 3 recommendation letters

For full consideration, applicants should (1) submit items 1, 2, and 3 on the Apply page of the CGP website and (2) have their recommendation letters emailed to cgp@ibs.re.kr by January 15, 2017. Recommendation letters forwarded by an applicant will not be considered valid.

IBS encourages applications from individuals of diverse backgrounds.

IBS-CGP Website: cgp.ibs.re.kr .

00007

TENNESSEE

Vanderbilt University,
Nashville, Tennessee
Non Tenure-Track Assistant Professor Positions

We invite applications for several visiting and non tenure-track assistant professor positions in the research areas of the Mathematics Department beginning fall 2018. Most of these positions will be three-year appointments with a 2–1 teaching load and a stipend to support research.

We are looking for individuals with outstanding research potential and a strong commitment to excellence in teaching. Preference will be given to recent doctorates. Submit your application and supporting materials electronically through the AMS website Mathjobs.org via the link www.mathjobs.org/jobs . Alternatively, application materials may be sent to: NTT Appointments Committee, Vanderbilt University, Department of Mathematics, 1326 Stevenson Center, Nashville, TN 37240. These materials should include a letter of application, a curriculum vitae, a publication list, a research statement, a teaching statement, at least four letters of recommendation and the AMS Cover Sheet. One of the letters must discuss the applicant's teaching qualifications. Reference letter writers should be asked to submit their letters online through Mathjobs.org. Evaluation of the applications will commence on December 1, 2017 and continue until the positions are filled. For information about the Department of Mathematics at Vanderbilt University, please consult the web at as.vanderbilt.edu/math/ .

00024

UTAH

University of Utah
Department of Mathematics

The Department of Mathematics at the University of Utah invites applications for the following positions:

- Full-time tenure-track or tenured appointments at the level of Assistant, Associate, or Full Professor in all areas of mathematics.
- Full-time tenure-track or tenured appointments at the level of Assistant, Associate, or Full Professor in all areas of statistics. These positions are part of a University-wide cluster hiring effort in statistics, with particular emphasis in mathematics, computer science, and bioengineering. Successful candidates will have strong interdisciplinary interests.
- Three-year Burgess, Tucker, and Wylie Assistant Professor Lecturer positions.

Please see our website at www.math.utah.edu/positions for information regarding available positions and application requirements. Applications must be completed through www.mathjobs.org/jobs/Utah . Review of complete applications for tenure-track positions will begin on October 23, 2017, and will continue until the positions are filled. Completed applications for postdoctoral positions received before January 1, 2018, will receive full consideration.

The University of Utah is an Equal Opportunity/Affirmative Action employer and educator. Minorities, women, veterans, and those with disabilities are strongly encouraged to apply. Veterans' preference is extended to qualified veterans. Reasonable disability accommodations will be provided with adequate notice. For additional information about the University's commitment to equal opportunity and access see: www.utah.edu/nondiscrimination/ .

00029

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.

September 2017

16 – 17 **Twenty-Eighth Meeting of the Palmetto Number Theory Series (PANTS XVIII)**
Location: *University of Tennessee, Knoxville, TN.*
URL: www.math.utk.edu/PANTS

18 – 20 **Mathematical Challenges from the Life Sciences**
Location: *Oculus Building, the University of Warwick, United Kingdom.*
URL: warwick.ac.uk/zeemanlaunch

October 2017

3 – 6 **IV International Seminar Nonlinear Phenomenology Advances**
Location: *Peter the Great St. Petersburg Polytechnic University, Saint Petersburg Hero City Leningrad, Russia.*
URL: ivnpa.tut.su

11 – 12 **The 2017 Ahlfors Lectures**
Location: *Harvard University Science Center, Hall A, Cambridge, Massachusetts.*
URL: www.math.harvard.edu/conferences/ahlfors17

12 – 12 **Journée de Contrôle and EDP/Day of Control and PDE**
Location: *Laboratoire de Mathématiques de Versailles, Université Versailles St-Quentin, France.*
URL: lmv.math.cnrs.fr/evenements-scientifiques/journee-controle-et-edp

13 – 15 **NEAM 2017: Second Northeastern Analysis Meeting**
Location: *University at Albany SUNY, Albany, New York.*
URL: www.albany.edu/math/NEAM2017

December 2017

14 – 18 **Conference on Transformation Groups 2017**
Location: *Moscow, Russia.*
URL: https://www.mccme.ru/tg2017

January 2018

22 – 26 **Seventh Iberoamerican Congress on Geometry**
Location: *Valladolid University, Spain.*
URL: iberoamericangeometry2018.uva.es

February 2018

5 – 9 **Winterbraids VIII**
Location: *CIRM, Marseille, France.*
URL: conferences.cirm-math.fr/1892.html

12 – 16 **Knotted Embeddings in Dimensions 3 and 4**
Location: *CIRM, Marseille, France.*
URL: conferences.cirm-math.fr/1893.html

March 2018

5 – 9 **Forty-Ninth Southeastern International Conference on Combinatorics, Graph Theory, and Computing**
Location: *Florida Atlantic University Boca Raton, Florida.*
URL: www.math.fau.edu/combinatorics/index.php

May 2018

21 – 25 **New Methods in Finsler Geometry**
Location: *Centro di Ricerca Matematica Ennio de Giorgi, Pisa, Italy.*
URL: crm.sns.it/event/415

June 2018

17 – 23 **Eighth International Conference on Mathematical Analysis, Differential Equation, and Applications MADEA 8 Dedicated to the Eightieth Birthday of Academician A. M. Samoilenko**
Location: *Kyrgyz-Turkish Manas University, Cholpon-Ata (Issyk-Kul), Kyrgyz Republic.*
URL: madea2018.manas.edu.kg

18 – 22 **International Conference on Emerging Trends in Applied Mathematics and Mechanics 2018**
Location: *Jagiellonian University in Krakow, Krakow, Poland.*
URL: sites.google.com/view/etamm2/home

July 2018

1 – 7 **Paweł Domański Memorial Conference**
Location: *The Mathematical Research and Conference Center, Będlewo, Poland.*
URL: analytic.wmi.amu.edu.pl

MEETINGS & CONFERENCES OF THE AMS

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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

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2019

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2021

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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 .

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
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 38, Issue 3

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

Inwon C Kim, UCLA, *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, **Sogol Jahanbekam** and **Paul Wenger**, Rochester Institute of Technology.

Algebraic Topology, **Claudia Miller**, Syracuse University, and **Inna Zakharevich**, Cornell University.

Automorphic Forms and L-functions, **Mahdi Asgari**, Oklahoma State University, and **Joseph Hundley**, University at Buffalo—SUNY.

CR Geometry and Partial Differential Equations in Complex Analysis, **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, **Miodrag Iovanov**, University of Iowa, **Mihai D. Staic**, Bowling Green State University, and **Alin Stancu**, Columbus State University.

Geometric Group Theory, **Joel Louwsma**, Niagara University, and **Johanna Mangahas**, University at Buffalo—SUNY.

High Order Numerical Methods for Hyperbolic PDEs and Applications, **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, **Hans Boden**, McMaster University, and **David Rosenthal**, St. John's University.

Knots, 3-manifolds and their Invariants, **William Menasco** and **Adam Sikora**, University at Buffalo—SUNY, and **Stephan Wehrli**, Syracuse University.

Nonlinear Dispersive Partial Differential Equations, **Santosh Bhattrai**, Trocaire College, and **Sharad Silwal**, Jefferson College of Health Sciences.

Nonlinear Evolution Equations, **Marius Beceanu**, SUNY Albany, and **Dan-Andrei Geba**, University of Rochester.

Nonlinear Partial Differential Equations Arising from Life Science, **Junping Shi**, College of William and Mary, and **Xingfu Zou**, University of Western Ontario.

Nonlinear Wave Equations, Inverse Scattering and Applications, **Gino Biondini**, University at Buffalo—SUNY.

Polynomials in Enumerative, Algebraic, and Geometric Combinatorics, **Robert Davis** and **Bruce Sagan**, Michigan State University.

Recent Advancements in Representation Theory, **Yiqiang Li**, University at Buffalo—SUNY, and **Gufang Zhao**, University of Massachusetts.

Recent Progress in Geometric Analysis, **Ovidiu Munteanu**, University of Connecticut, **Terrence Napier**, Lehigh University, and **Mohan Ramachandran**, University at Buffalo.

Structural and Chromatic Graph Theory, **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, **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
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 38, Issue 4

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

Christine Heitsch, Georgia Institute of Technology, *Strings, trees, and {RNA} folding*.

Jonathan Kujawa, University of Oklahoma, *Realizing the spectrum of tensor categories*.

Christopher D Sogge, Johns Hopkins University, *On the concentration of eigenfunctions*.

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, **Ram N Mohapatra**, University of Central Florida, and **Turhan Koprubasi**, Kastamonu University (Turkey).

Algebraic Curves and their Applications, **Lubjana Beshaj**, The University of Texas at Austin.

Applied Harmonic Analysis: Frames, Samplings and Applications, **Dorin Dutkay**, **Deguang Han**, and **Qiyu Sun**, University of Central Florida.

Categorical Methods in Representation Theory, **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, **Joseph Brennan**, University of Central Florida, and **Alina Iacob** and **Saeed Nasseh**, Georgia Southern University.

Complex Analysis, Harmonic Analysis, and Approximation Theory, **Alexander V Tovstolis**, University of Central Florida, and **John Paul Ward**, North Carolina A&T State University.

Differential Equations in Mathematical Biology, **Andrew Nevai**, **Yuanwei Qi**, and **Zhisheng Shuai**, University of Central Florida.

Fractal Geometry, Dynamical Systems, and Their Applications, **Mrinal Kanti Roychowdhury**, University of Texas Rio Grande Valley.

Global Harmonic Analysis and its Applications, **Christopher Sogge** and **Yakun Xi**, Johns Hopkins University, and **Steve Zelditch**, Northwestern University.

Graph Connectivity and Edge Coloring, **Colton Magnant**, Georgia Southern University.

Mathematics of Biomolecules: Discrete, Algebraic, and Topological, **Natasha Jonoska**, University of South Florida, and **Christine Heitsch**, Georgia Institute of Technology.

Modern Statistical Methods for Structured Data, **Marianna Pensky**, University of Central Florida.

Nonlinear Dispersive Equations, **Benjamin Harrop-Griffiths**, New York University, **Jonas Lührmann**, Johns Hopkins University, and **Dana Mendelson**, University of Chicago.

Nonlinear Elliptic Partial Differential Equations, **Luis E Silvestre**, University of Chicago, and **Eduardo V Teixeira**, University of Central Florida.

Operator Algebras and Related Topics, **Zhe Liu**, University of Central Florida.

Progress in Fixed Point Theory and Its Applications, **Clement Boateng Ampadu**, Boston, MA, and **Buthinah A. Bin Dehaish** and **Afrah A. N. Abdou**, King Abdulaziz University, Saudi Arabia.

Recent Developments in Integral Geometry and Tomography, **Alexander Katsevich**, **Alexander Tovbis**, and **Alexandru Tamasan**, University of Central Florida.

Stochastic Analysis and Applications, **Hongwei Long**, Florida Atlantic University, and **Jiongmin Yong**, University of Central Florida.

Structural Graph Theory, **Martin Rolek**, **Zixia Song**, and **Yue Zhao**, University of Central Florida.

Symplectic and Contact Topology and Dynamics, **Basak Gürel**, University of Central Florida, and **Viktor Ginzburg**, University of California, Santa Cruz.

Trends in Applications of Functional Analysis in Computational and Applied Mathematics, **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
Program issue of electronic *Notices*: To be announced
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, Davis, *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, **Goran Radunovic**, University of Zagreb, and **Tim Cobler**, Fullerton College, California.

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.

Foundations of Quantum Theory (Code: SS 26A), **Jukka Virtanen**, University of California, Los Angeles, and **David Weisbart**, University of California, Riverside.

Generalized Geometry (Code: SS 16A), **Daniele Grandini**, Virginia State University, and **Yat-Sun Poon**, University of California, Riverside.

Geometric Analysis (Code: SS 24A), **Zhiqi Lu**, University of California, Irvine, **Jie Qing**, University of California, Santa Cruz, **Guofang Wei**, University of California, Santa Barbara, and **Qi Zhang**, University of California, Riverside.

Geometric Partial Differential Equations and their Applications (Code: SS 29A), **Po-Ning Chen**, University of California, Riverside, **Henri Roesch**, Duke University, and **Richard M. Schoen** and **Xiangwen Zhang**, University of California, Irvine.

Homotopy Theory (Code: SS 28A), **Jonathan Beardsley**, University of Washington.

Mathematical Fluid Mechanics (Code: SS 27A), **James P Kelliher** and **Lizheng Tao**, 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.

Nonlinear Elliptic Differential and Integral Equations (Code: SS 25A), **Mathew Gluck**, University of Oklahoma, and **John Villavert**, University of Texas, Rio Grande Valley.

Particle Methods and Nonlocal Partial Differential Equations (Code: SS 23A), **Katy Craig**, University of California, Santa Barbara, and **Franca Hoffman**, University of Cambridge.

Preparing Students for American Mathematical Competitions (Code: SS 7A), **Adam Glesser**, **Phillip Ramirez**, and **Bogdan D. Suceava**, California State University, Fullerton.

Random Matrices: Theory and Applications (Code: SS 20A), **Ioana Dumitriu**, University of Washington, and **Thomas Trogdon**, University of California, Irvine.

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.

Research in Mathematics by Early Career Graduate Students (Code: SS 22A), **Michael Bishop**, **Stefaan Delcroix**, **Marat Markin**, **Khang Tran**, and **Oscar Vega**, California State University, Fresno.

Riemannian Manifolds of Non-Negative Sectional Curvature (Code: SS 21A), **Owen Dearricott**, University of Melbourne, and **Fernando Galaz-Garcia**, Karlsruhe Institute of Technology.

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 Marriott Marquis San Diego 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).
AMS Associate Secretary: Georgia Benkart
Announcement issue of *Notices*: October 2017
Program first available on AMS website: To be announced

Deadlines

For organizers: Expired
For abstracts: September 26, 2017
The scientific information listed below may be dated. For the latest information, see `www.ams.org/meetings/national.html`.

Joint Invited Addresses

Gunnar Carlsson, Stanford University, *Topological Modeling of Complex Data* (AMS-MAA Invited Address); Wednesday, 11:10 am.

Moon Duchin, Tufts University, *Political Geometry: Voting districts, "compactness," and ideas about fairness,* MAA-AMS-SIAM Gerald and Judith Porter Public Lecture); Saturday, 3:00 pm.

André Neves, University of Chicago, *Minimal surfaces, volume spectrum, and Morse index* (AMS-MAA Invited Address); Friday, 11:10 am.

Jill Pipher, Brown University, *Title to be Announced* (AWM-AMS Noether Lecture); Thursday, 10:05 am.

Joint Prize Session

In order to showcase the achievements of recipients of the various prizes, the AMS and MAA are co-sponsoring this event at 4:25 pm on Thursday. A cash bar reception will immediately follow. All participants are invited to attend. The AMS, MAA, and SIAM will announce the JPBM Communications Award winner. The AMS, MAA, and SIAM will award the Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student. The AMS and SIAM will announce the George David Birkhoff Prize in Applied Mathematics. The AMS will announce the Levi L. Conant Prize, the Frank Nelson Cole Prize in Number Theory, AMS Award for Distinguished Public Service, Bertrand Russell Prize, Chevalley Prize in Lie Theory, the Ulf Grendander Prize in Stochastic Theory and Modeling, Albert Leon Whiteman Memorial Prize, and the Leroy P. Steele Prizes. The MAA will award the Beckenbach Book Prize, the Euler Book Prize, Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching of Mathematics, the Chauvenet Prize, and the Yueh-Gin Gung and Dr. Charles Y. Hu Award for Distinguished Service to Mathematics. The AWM will present the Louise Hay Award for Contributions to Mathematics Education, the M. Gweneth Humphreys Award for Mentorship of Undergraduate Women in Mathematics, the AWM-Sadosky Research Prize in Analysis, and the AWM-Microsoft Research Prize in Algebra and Number Theory.

124th Meeting of the AMS

AMS Invited Addresses

Federico Ardila, San Francisco State University, *Algebraic structures on polytopes*; Thursday, 2:15 pm.

Robert Bryant, Duke University, *Title to be announced* Saturday, 9:00 am (Retiring Presidential Address).

Ruth Charney, Brandeis University, *Searching for hyperbolicity*, Thursday, 3:20 pm.

Cynthia Dwork, Harvard University, *Title to be announced*; (AMS Josiah Willard Gibbs Lecture), Wednesday, 8:30 pm.

Avi Wigderson, Princeton University, *Title to be announced* (AMS Colloquium Lectures: Lecture I), Wednesday, 1:00 pm.

Avi Wigderson, Princeton University, *Title to be announced* (AMS Colloquium Lectures: Lecture II); Thursday, 1:00 pm.

Avi Wigderson, Princeton University, *Title to be announced* (AMS Colloquium Lectures: Lecture III); Friday, 1:00 pm.

Dana Randall, Georgia Institute of Technology, *Emergent phenomena in random structures and algorithms*, Friday, 10:05 am.

Edris Titi, Texas A&M University, *Title to be announced*; Wednesday, 10:05 am.

AMS 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 `jointmathematicsmeetings.org/meetings/abstracts/abstract.pl?type=jmm`.

Some sessions are cosponsored with other organizations. These are noted within the parenthesis at the end of each listing, where applicable.

A Showcase of Number Theory at Liberal Arts Colleges, **Adriana Salerno**, Bates College, and **Lola Thompson**, Oberlin College, Wednesday afternoon.

Accelerated Advances in Mathematical Fractional Programming, **Ram Verma**, International Publications USA, and **Alexander Zaslavski**, Israel Institute of Technology, Thursday morning.

Advances in Applications of Differential Equations to Disease Modeling, **Libin Rong**, Oakland University, **Elissa Schwartz**, Washington State University, and **Naveen K. Vaidya**, University of Missouri—Kansas City, Wednesday and Friday mornings.

Advances in Difference, Differential, and Dynamic Equations with Applications, **Elvan Akin**, Missouri University S&T, and **John Davis**, Baylor University, Saturday afternoon.

Advances in Operator Algebras, **Marcel Bischoff**, Vanderbilt University, **Ian Charlesworth**, University of California, Los Angeles, **Brent Nelson**, University of California, Berkeley, and **Sarah Reznikoff**, Kansas State University, Friday afternoon and Saturday morning.

Advances in Operator Theory, Operator Algebras, and Operator Semigroups, **Asuman G. Aksoy**, Claremont McKenna College, **Zair Ibragimov**, California State University, Fullerton, **Marat Markin**, California State University, Fresno, and **Ilya Spitkovsky**, New York University, Abu Dhabi, Thursday morning and afternoon.

Algebraic, Analytic, and Geometric Aspects of Integrable Systems, Painlevé Equations, and Random Matrices, **Vladimir Dragovic**, University of Texas at Dallas, **Anton Dzhamay**, University of Northern Colorado, and **Sevak Mkrtchyan**, University of Rochester, Wednesday and Thursday afternoons.

Algebraic, Discrete, Topological and Stochastic Approaches to Modeling in Mathematical Biology, **Olcay Akman**, Illinois State University, **Timothy D. Comar**, Benedictine University, **Daniel Hrozencik**, Chicago State University, and **Raina Robeva**, Sweet Briar College, Thursday and Friday mornings.

Alternative Proofs in Mathematical Practice, **John W. Dawson, Jr.**, Pennsylvania State University, York, Saturday morning.

Analysis of Fractional, Stochastic, and Hybrid Dynamic Systems, **John R. Graef**, University of Tennessee at Chattanooga, **Gangaram S. Ladde**, University of South Florida, and **Aghalaya S. Vatsala**, University of Louisiana at Lafayette, Saturday morning.

Analysis of Nonlinear Partial Differential Equations and Applications, **Tarek M. Elgindi**, University of California, San Diego, and **Edriss S. Titi**, Texas A&M University and Weizmann Institute of Science, Wednesday afternoon, Thursday morning and afternoon.

Applied and Computational Combinatorics, **Torin Greenwood**, Georgia Institute of Technology, and **Jay Pantone**, Dartmouth College, Wednesday morning and afternoon.

Arithmetic Dynamics, **Robert L. Benedetto**, Amherst College, **Benjamin Hutz**, Saint Louis University, **Jamie Juul**, Amherst College, and **Bianca Thompson**, Harvey Mudd College, Wednesday morning and Friday afternoon.

Beyond Planarity: Crossing Numbers of Graphs (a Mathematics Research Communities Session), Axel Brandt, Davidson College, Garner Cochran, University of South Carolina, and Sarah Loeb, College of William and Mary Thursday morning and afternoon.

Bifurcations of Difference Equations and Discrete Dynamical Systems, **Arzu Bilgin** and **Toufik Khyat**, University of Rhode Island, Saturday morning.

Boundaries for Groups and Spaces, **Joseph Maher**, CUNY College of Staten Island, and **Genevieve Walsh**, Tufts University, Thursday, Friday, and Saturday morning.

Combinatorial Commutative Algebra and Polytopes, **Robert David**, Michigan State University, and **Liam Solus**, KTH Royal Institute of Technology, Wednesday and Friday afternoon.

Combinatorics and Geometry, **Federico Ardila**, San Francisco State University, **Anastasia Chavez**, MSRI and University of California, Davis, and **Laura Escobar**, University of Illinois at Urbana–Champaign, Thursday and Friday morning.

Commutative Algebra in All Characteristics, **Neil Epstein**, George Mason University, **Karl Schwede**, University of Utah, and **Janet Vassilev**, University of New Mexico, Thursday morning and afternoon.

Computational Combinatorics and Number Theory, **Jeremy F. Alm**, Illinois College, and **David Andrews** and **Rob Hochberg**, University of Dallas, Saturday afternoon.

Connections in Discrete Mathematics: Graphs, Hypergraphs, and Designs, **Amin Bahmanian**, Illinois State University, and **Theodore Molla**, University of Illinois at Urbana–Champaign, Saturday afternoon.

Differential Geometry, **Vincent B. Bonini** and **Joseph E. Borzellino**, Cal Poly San Luis Obispo, **Bogdan D. Suceava**, California State University, Fullerton, and **Guofang Wei**, University of California, Santa Barbara, Wednesday afternoon and Saturday morning.

Diophantine Approximation and Analytic Number Theory in Honor of Jeffrey Vaaler, **Shabnam Akhtari**, University of Oregon, and **Lenny Fukshansky**, Claremont McKenna College, Friday afternoon and Saturday morning.

Discrete Dynamical Systems and Applications, **E. Cabral Balreira**, **Saber Elaydi**, and **Eddy Kwessi**, Trinity University, Wednesday and Thursday morning.

Discrete Neural Networking and Applications, **Murat Adivar**, Fayetteville State University, **Michael A. Radin**, Rochester Institute of Technology, and **Youssef Raffoul**, University of Dayton, Thursday afternoon and Friday morning.

Dynamical Algebraic Combinatorics, **James Propp**, University of Massachusetts, Lowell, **Tom Roby**, University of Connecticu, **Jessica Striker**, North Dakota State University, and **Nathan Williams**, University of California Santa Barbara, Friday morning and Saturday afternoon.

Dynamical Systems: Smooth, Symbolic, and Measurable (a Mathematics Research Communities Session), Kathryn Lindsey, Boston College, Scott Schmieding, Northwestern University, and Kurt Vinhage, University of Chicago,Thursday morning and afternoon.

Dynamical Systems with Applications to Mathematical Biology (Code: SS 79A), **Guihong Fan**, Columbus State University, **Jing Li**, California State University, Northridge, **Chunhua Shan**, University of Toledo, Saturday afternoon.

Emergent Phenomena in Discrete Models, **Dana Randall**, Georgia Institute of Technology, and **Andrea Richa**, Arizona State University, Friday afternoon.

Emerging Topics in Graphs and Matrices, **Sudipta Mallik**, Northern Arizona University, **Keivan Hassani Monfared**, University of Calgary, and **Bryan Shader**, University of Wyoming, Saturday morning and afternoon.

Ergodic Theory and Dynamical Systems, **Julia Barnes**, Western Carolina University, **Rachel Bayless**, Agnes Scott College, **Emily Burkhead**, Duke University, and **Lorelei Koss**, Dickinson College, Wednesday afternoon and Friday morning.

Extremal Problems in Approximations and Geometric Function Theory, **Ram Mohapatra**, University of Central Florida, Saturday afternoon.

Financial Mathematics, Actuarial Sciences, and Related Fields, **Albert Cohen**, Michigan State University, **Nguyet Nguyen**, Youngstown State University, **Oana Mocioalca**, Kent State University, and **Thomas Wakefield**, Youngstown State University, Wednesday morning and afternoon.

Fractional Difference Operators and Their Application, **Christopher S. Goodrich**, Creighton Preparatory School, and **Rajendra Dahal**, Coastal Carolina University, Saturday morning.

Free Convexity and Free Analysis, **J. William Helton**, University of California, San Diego, and **Igor Klep**, University of Auckland, Friday morning and Saturday afternoon.

Geometric Analysis, **Davi Maximo**, University of Pennsylvania, **Lu Wang**, University of Wisconsin—Madison, and **Xin Zhou**, University of California Santa Barbara, Friday and Saturday afternoons.

Geometric Analysis and Geometric Flows, **David Glickenstein**, University of Arizona, and **Brett Kotschwar**, Arizona State University,Wednesday morning and afternoon.

History of Mathematics, **Sloan Despeaux**, Western Carolina University, **Jemma Lorenat**, Pitzer College, **Clemency Montelle**, University of Canterbury, **Daniel Otero**, Xavier University, and **Adrian Rice**, Randolph–Macon College, Wednesday morning and afternoon, Thursday afternoon, and Friday morning.

Homotopy Type Theory (a Mathematics Research Communities Session), Simon Cho, University of Michigan, Liron Cohen, Cornell University, and Edward Morehouse, Wesleyan University, Thursday morning and afternoon.

If You Build It They Will Come: Presentations by Scholars in the National Alliance for Doctoral Studies in the Mathematical Sciences, **Edray Goins** and **David Goldberg**, Purdue University, and **Phil Kutzko**, University of Iowa, Friday morning and afternoon.

Interactions of Inverse Problems, Signal Processing, and Imaging, **M. Zuhair Nashed**, University of Central Florida, **Willi Freeden**, University of Kaiserslautern, and **Otmar Scherzer**, University of Vienna, Thursday and Saturday afternoons.

Markov Chains, Markov Processes and Applications, **Alan Krinik** and **Randall J. Swift**, California State Polytechnic University, Friday afternoon.

Mathematical Analysis and Nonlinear Partial Differential Equations, **Hongjie Dong**, Brown University, **Peiyong Wang**, Wayne State University, and **Jiuyi Zhu**, Louisiana State University, Wednesday and Thursday mornings.

Mathematical Fluid Mechanics: Analysis and Applications, **Zachary Bradshaw** and **Aseel Farhat**, University of Virginia, Wednesday morning and afternoon.

Mathematical Information in the Digital Age of Science, **Patrick Ion**, University of Michigan, **Olaf Teschke**, zbMath Berlin, and **Stephen Watt**, University of Waterloo, Wednesday morning, Thursday afternoon, and Friday morning.

Mathematical Methods in Genomics, **David Koslicki**, Oregon State University, Wednesday morning and afternoon.

Mathematical Modeling and Analysis of Infectious Diseases, **Kazuo Yamazaki**, University of Rochester, Wednesday and Thursday afternoon.

Mathematical Modeling of Natural Resources, **Shandelle M. Henson**, Andrews University, and **Natali Hritonenko**, Prairie View A&M University, Friday morning and afternoon.

Mathematical Modeling, Analysis and Applications in Population Biology, **Yu Jin**, University of Nebraska—Lincoln, and **Ying Zhou**, Lafayette College, Thursday afternoon and Saturday morning.

Mathematical Problems in Ocean Wave Modeling and Fluid Mechanics, **Christopher W. Curtis**, San Diego State University, and **Katie Oliveras**, Seattle University, Saturday afternoon.

Mathematical Relativity and Geometric Analysis, **James Dilts** and **Michael Holst**, University of California, San Diego, Friday morning and afternoon.

Mathematics Research from the SMALL Undergraduate Research Program, **Colin Adams**, **Frank Morgan**, and **Cesar E. Silva**, Williams College, Saturday morning and afternoon.

Mathematics of Gravitational Wave Science, **Andrew Gillette** and **Nikki Holtzer**, University of Arizona, Wednesday morning and afternoon.

Mathematics of Quantum Computing and Topological Phases of Matter, **Paul Bruillard**, Pacific Northwest National Laboratory, **David Meyer**, University of California San Diego, and **Julia Plavnik**, Texas A&M University, Thursday and Saturday afternoons.

Metric Geometrty and Topology (Code: SS 77A), **Christine Escher**, Oregon State University, **Catherine Searle**, Wichita State University, Thursday and Saturday afternoons.

Modeling in Differential Equations—High School, Two-Year College, Four-Year Institution, **Corban Harwood**, George Fox University, **William Skerbitz**, Wayzata High School, **Brian Winkel**, SIMIODE, and **Dina Yagodich**, Frederick Community College, Wednesday morning and afternoon.

Multi-scale Modeling with PDEs in Computational Science and Engineering:Algorithms, Simulations, Analysis, and Applications, **Salim M. Haidar**, Grand Valley State University, Thursday and Saturday mornings.

Network Science, **David Burstein**, Swarthmore College, **Franklin Kenter**, United States Naval Academy, and **Feng Shi**, University of North Carolina at Chapel Hill, Wednesday morning and Friday afternoon.

New Trends in Celestial Mechanics, **Richard Montgomery**, University of California Santa Cruz, and **Zhifu Xie**, University of Southern Mississippi, Thursday and Saturday afternoon.

Nilpotent and Solvable Geometry, **Michael Jablonski**, University of Oklahoma, **Megan Kerr**, Wellesley College, and **Tracy Payne**, Idaho State University, Wednesday morning and afternoon.

Noncommutative Algebras and Noncommutative Invariant Theory, **Ellen Kirkman**, Wake Forest University, and **James Zhang**, University of Washington,Friday morning and afternoon.

Nonlinear Evolution Equations of Quantum Physics and Their Topological Solutions, **Stephen Gustafson**, University of British Columbia, **Israel Michael Sigal**, University of Toronto, and **Avy Soffer**, Rutgers University, Friday morning and afternoon.

Novel Methods of Enhancing Success in Mathematics Classes, **Ellina Grigorieva**, Texas Womans University, and **Natali Hritonenko**, Prairie View A&M University, Thursday morning.

Open and Accessible Problems for Undergraduate Research, **Michael Dorff**, Brigham Young University, **Allison Henrich**, Seattle University, and **Nicholas Scoville**, Ursinus College, Thursday morning and afternoon.

Operators on Function Spaces in One and Several Variables, **Catherine Bénéteau**, University of South Florida, and **Matthew Fleeman** and **Constanze Liaw**, Baylor University, Wednesday morning and afternoon.

Orthogonal Polynomials and Applications, **Abey Lopez-Garcia**, University of South Alabama, and **Xiang-Sheng Wang**, University of Louisiana at Lafayette, Wednesday afternoon.

Orthogonal Polynomials, Quantum Probability, and Stochastic Analysis, **Julius N. Esunge**, University of Mary Washington, and **Aurel I. Stan**, Ohio State University, Saturday afternoon.

Quantum Link Invariants, Khovanov Homology, and Low-dimensional Manifolds, **Diana Hubbard**, University of Michigan, and **Christine Ruey Shan Lee**, University of Texas at Austin, Thursday and Saturday mornings.

Quaternions, **Terrence Blackman**, Medgar Evers College, City University of New York, and **Johannes Familton** and **Chris McCarthy**, Borough of Manhattan Community College, City University of New York, Wednesday and Thursday afternoons.

Recent Trends in Analysis of Numerical Methods of Partial Differential Equations, **Sara Pollock**, Wright State University, and **Leo Rebholz**, Clemson University, Thursday afternoon and Friday morning.

Research by Postdocs of the Alliance for Diversity in Mathematics, **Aloysius Helminck**, University of Hawaii—Manoa, and **Michael Young**, Iowa State University, Wednesday and Thursday mornings.

Research from the Rocky Mountain-Great Plains Graduate Research Workshop in Combinatorics, **Michael Ferrara**, University of Colorado Denver, **Leslie Hogben**, Iowa State University, **Paul Horn**, University of Denver, and **Tyrrell McAllister**, University of Wyoming, Friday afternoon.

Research in Mathematics by Early Career Graduate Students, **Michael Bishop**, **Marat Markin**, **Khang Tran**, and **Oscar Vega**, California State University, Fresno, Saturday afternoon.

Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, **Tamas Forgacs**, CSU Fresno, **Darren A. Narayan**, Rochester Institute of Technology, and **Mark David Ward**, Purdue University (AMS-MAA-SIAM), Wednesday morning, Thursday afternoon, Saturday morning and afternoon.

Set Theory, Logic and Ramsey Theory, **Andrés Caicedo**, Mathematical Reviews, and **José Mijares**, University of Colorado, Denver (AMS-ASL), Wednesday morning, Thursday morning and afternoon.

Set-theoretic Topology (Dedicated to Jack Porter in honor of 50 years of dedicated research), **Nathan Carlson**, California Lutheran University, **Jila Niknejad**, University of Kansas, and **Lynne Yengulalp**, University of Dayton, Saturday morning and afternoon.

Special Functions and Combinatorics (in honor of Dennis Stanton's 65th birthday), **Susanna Fishel**, Arizona State University, **Mourad Ismail**, University of Central Florida, and **Vic Reiner**, University of Minnesota, Wednesday, Thursday, and Saturday mornings.

Spectral Theory, Disorder and Quantum Physics, **Rajinder Mavi** and **Jeffery Schenker**, Michigan State University, Thursday and Saturday afternoon.

Stochastic Processes, Stochastic Optimization and Control, Numerics and Applications, **Hongwei Mei**, University

of Central Florida, **Zhixin Yang** and **Quan Yuan**, Ball State University, and **Guangliang Zhao**, GE Global Research, Thursday and Friday morning.

Strengthening Infrastructures to Increase Capacity Around K–20 Mathematics, **Brianna Donaldson**, American Institute of Mathematics, and **William Jaco** and **Michael Oehrtman**, Oklahoma State University, Friday afternoon.

Structure and Representations of Hopf Algebras: a session in honor of Susan Montgomery, **Siu-Hung Ng**, Louisiana State University, and **Lance Small** and **Henry Tucker**, University of California, San Diego, Wednesday morning and afternoon, and Thursday afternoon.

Theory, Practice, and Applications of Graph Clustering, **David Gleich**, Purdue University, and **Jennifer Webster** and **Stephen J. Young**, Pacific Northwest National Laboratory, Thursday and Saturday afternoons.

Topological Data Analysis, **Henry Adams**, Colorado State University, **Gunnar Carlsson**, Stanford University, and **Mikael Vejdemo-Johansson**, CUNY College of Staten Island, Wednesday afternoon, Friday and Saturday mornings.

Topological Graph Theory: Structure and Symmetry, **Jonathan L. Gross**, Columbia University, and **Thomas W. Tucker**, Colgate University, Wednesday morning and Friday afternoon.

Visualization in Mathematics: Perspectives of Mathematicians and Mathematics Educators, **Karen Allen Keene**, North Carolina State University, and **Mile Krajcevski**, University of South Florida, Friday and Saturday mornings.

Women in Symplectic and Contact Geometry and Topology, **Bahar Acu**, Northwestern University, **Ziva Myer**, Duke University, and **Yu Pan**, Massachusetts Institute of Technology (AMS-AWM), Friday morning and afternoon.

AMS Sessions for Contributed Papers

There will be sessions of ten-minute contributed talks. Although an individual may present only one contributed paper at a meeting, any combination of joint authorship may be accepted, provided no individual speaks more than once on the program. Contributed papers will be grouped together by related subject classifications into sessions.

Submission of Abstracts for AMS Sessions

Authors must submit abstracts of talks through `jointmathematicsmeetings.org/meetings/abstracts/abstract.pl?type=jmm`. Indicate the number of authors for the paper, click on the "New Abstract" button, and you will be taken to the submission form. Simply follow the step-by-step instructions (read them carefully) until you receive your unique abstract receipt number. No submission is complete until you are given this number. **The deadline for all submissions is September 26, 2017**. Late papers cannot be accommodated. Please email `abscoord@ams.org` if you have questions. If you make an inquiry about your specific abstract, please include your abstract receipt number.

Other AMS Sessions

MAA-SIAM-AMS Hrabowski–Gates–Tapia–McBay Session, organized by **Ricardo Cortez,** Tulane University; Wednesday, 9:00–10:20 am. The Hrabowski–Gates–Tapia–McBay Session is named after four influential scientists of color: (1) Freeman Hrabowski, President of the University of Maryland at Baltimore County; (2) James S. Gates, University of Maryland, College Park; (3) Richard Tapia, Rice University; and (4) Shirley McBay, President of Quality Education for Minorities (QEM). Through multiple mechanisms, these Sessions expect to facilitate and accelerate the participation of scientists in the building of sustainable communities of mathematicians and mathematical scientists. In particular, the intention is to systematically recruit, welcome, encourage, mentor, and support individuals from underrepresented groups in the USA. This year the session will consist of a lecture at 9:00 am given by **Talithia Williams**, Harvey Mudd College, *Mathematics for the Masses*, and a short panel discussion after the talk at 9:50 am. The 2018 panel will focus on Access to Quality Mathematics by All. Panelists and attendees will discuss issues related to removing roadblocks in mathematics education (e.g., Tracking, placement, 'weed out' courses, etc) as well as hiring or award selection practices that tend to favor the majority groups that have influence. Panelists will also address the question: What are the roles and responsibilities do mathematicians and mathematics educators have in creating a just and accessible system? Panelists will include **Ron Buckmire**, NSF; **James Alvarez**, University of Texas at Arlington; and **Talithia Williams**, Harvey Mudd College. This event is sponsored by the MAA Committee on Minority Participation in Mathematics, SIAM and the AMS.

AMS Committee on Meetings and Conferences: Collaborative Research Communities in Mathematics, Wednesday, 2:00–3:30 pm. The aim of this panel is to discuss various models of collaborative research communities in mathematics. An example of such a community is the Mathematical Research Communities (MRC) Program. his program has been run by the American Mathematical Society since 2008, with the intention of bringing together peridoctoral stage mathematicians (near Ph. D. degree) to work in a collaborative environment and helping nurture research, professional relationships and career paths. Amongst topics the panel will discuss are: best practices from successful research collaboration programs; raising awareness of the MRC program within the mathematical community and practical advice for writing successful MRC proposals.

AMS Committee on the Profession Panel Discussion: Paths to Collaboration with Scientists, Wednesday, 4:30–6:00 pm

AMS Education and Diversity Department Panel: Strategies for Diversifying Graduate Mathematics Programs, organized by **Helen G. Grundman**, American Mathematical Society; Wednesday, 6:00–7:30 pm. Graduate programs wanting to diversify may find that there are very few students from underrepresented groups who satisfy

their admissions criteria. This panel will discuss ways in which admissions criteria may be leading us away from strong students with non-standard records, ways to find and recruit these students, and methods for increasing the success rate of these "undervalued" applicants, both through helping the students adapt to the programs and through helping the programs adapt to the students. Moderator for this panel will be **Helen G. Grundman**, American Mathematical Society. Panelists are **Edray Goins**, Purdue University, **Richard Laugesen**, University of Illinois, **Richard McGehee**, University of Minnesota, and **Katrin Wehrheim**, University of California, Berkeley.

AMS Informational Session: Report on the findings of the 2015 CBMS survey of undergraduate mathematical and statistical sciences in the US, organized by **Jim Maxwell**, American Mathematical Society; Thursday, 11:00 am–12:00 pm. Presenter for this session will be Ellen Kirkman, Wake Forest University.

AMS Committee on Education Panel Discussion: Preparing mathematics students for non-academic careers, organized by **Erica Flapan**, Pomona College; **Manmohan Kaur**, Benedictine University; **Douglas Mupasiri**, University of Northern Iowa and **Diana White**, University of Colorado—Denver; Thursday, 1:00–2:30 pm.

AMS-MAA Joint Committee on TAs and Part-Time Instructors Panel: Teaching-Focused Faculty at Research Institutions, organized by **Angela Kubena**, University of Michigan; **Jean Marie Linhart**, Central Washington University; **Tom Roby**, University of Connecticut; and **Michael Weingart**, Rutgers University; Thursday, 2:30–3:55 pm. It is increasingly common that a portion of the teaching at research universities is done by full-time teaching-focused faculty (TFF). These faculty are not asked to do research but instead are asked to take on an expanded role in helping the department carry out its teaching. This session will discuss issues around this development, from how such faculty may be supported to issues of evaluating faculty whose primary role is teaching and integrating them into a department culture that is focussed on research. Moderator for this panel will be **Tom Roby**, University of Connecticut. Panelists are **Amy Cohen**, Rutgers University, **John Eggers**, University of California San Diego, **Ellen Golstein**, Boston College, **Robin Gottlieb**, Harvard University, and **Amit Savkar**, University of Connecticut. This panel is sponsored by the AMS-MAA Joint Committee on TAs and Part-Time Instructors.

AMS Forum, sponsored by the US National Committee for Mathematics: ICM 2018 in Rio de Janeiro—The First International Congress of Mathematicians in the Southern Hemisphere, organized and presented by **Marcelo Viana**, Instituto Nacional de Matemática Pura e Aplicada will present; Thursday, 7:30–8:30 pm.

Grad School Fair, Friday, 8:30–10:30 am. Here is the opportunity for undergrads to meet representatives from mathematical sciences graduate programs from universities all over the country. January is a great time for juniors to learn more, and college seniors may still be able to refine their search. This is your chance for one-stop shopping in the graduate school market. At last year's meeting over 300 students met with representatives from 60 graduate programs. If your school has a graduate program and you are interested in participating, for US$125 a table will be provided for your posters and printed materials (**registration for this event must be made by a person already registered for the JMM**), and you are welcome to personally speak to interested students. Complimentary coffee will be served. Co-sponsored by the AMS and MAA.

***AMS Panel: Historical Chief Editors of the* Notices**, organized by Frank Morgan, American Mathematical Society; Friday, 9:00–10:30 am. A panel of the current and past chief editors of the AMS Notices—**Hugo Rossi**, **Harold Boas**, **Andy Magid**, and **Frank Morgan**—offer brief remarks and take questions.

AMS-MAA Joint Committee on TAs and Part-Time Instructors Panel: Panel on The Experiences of Foreign Graduate Students as GTAs, organized by **John Boller,** University of Chicago, **Solomon Friedberg**, Boston College, **Edward Richmond**, Oklahoma State University; Friday, 1:00–2:30 pm. Foreign graduate students make up a significant fraction of all math graduate students. When they serve as GTAs, these students must not only learn how to take on the role of teacher, but must do so in a system and culture that are unfamiliar to them. The goal of this session is to highlight the unique challenges that foreign graduate students encounter as GTAs so that the math community can better help them succeed. The panelists will draw from their own previous experiences as students living in the US for the first time as graduate students, and will offer their perspectives on what is most helpful in supporting similar students as they take on teaching responsibilities in the US The moderator for this panel will be **Solomon Friedberg**, Boston College. Panelists will be composed of current graduate students and recent PhDs who lived in North America for the first time as graduate students. This panel is sponsored by the AMS-MAA Joint Committee on TAs and Part-Time Instructors

Current Events Bulletin, organized by **David Eisenbud**, Mathematical Sciences Research Institute; Friday, 1:00 pm–5:00 pm. Speakers in this session follow the model of the Bourbaki Seminars in that mathematicians with strong expository skills speak on work not their own. Written versions of the talks will be distributed at the meeting and will also be available online at `www.ams.org/ams/current-events-bulletin.html` after the conclusion of the meeting.

AMS Committee on Science Policy Panel Discussion: Funding at Federal Agencies & Advocacy for Grassroots Support, organized by **Scott Wolpert**, University of Maryland; Friday, 2:30–4:00 pm. Panelists are **Charlie Toll**, National Security Agency and **Michael Vogelius**, Rutgers University.

Congressional Fellowship Session, organized by **Karen Saxe**, American Mathematical Society; Friday, 4:30–6:30 pm. This fellowship provides a public policy learning experience, demonstrates the value of science-government interaction and brings a technical background and external

perspective to the decision-making process in Congress. earn more about this program and speak with current and former AMS Fellows. **Margaret Callahan**, AMS Congressional Fellow 2017–2018, will speak at this session. Application deadline for the 2018–2019 AMS Congressional Fellowship is **February 15, 2018.**

Who Wants to Be a Mathematician Championship, organized by **Michael A. Breen**, American Mathematical Society, and **William T. Butterworth**, DePaul University; Saturday, 1:00 pm–2:45 pm. Show your support for top high school students from the US, Canada, and the UK in the first international *Who Wants to Be a Mathematician* as they compete for a US$5,000 first prize for themselves and US$5,000 for their school's math department. Semifinals are at 1:00 pm and finals are at 2:00 pm. Come match wits with the contestants and support their mathematical achievement.

Other AMS Events

Council, Tuesday, 1:30 pm.

Business Meeting, Saturday, 11:45 am. The secretary notes the following resolution of the Council: Each person who attends a business meeting of the Society shall be willing and able to identify himself as a member of the Society. In further explanation, it is noted that each person who is to vote at a meeting is thereby identifying himself as and claiming to be a member of the American Mathematical Society. The Society has a Committee on the Agenda for Business Meetings. The purpose is to make business meetings orderly and effective. The committee does not have legal or administrative power. It is intended that the committee consider what may be called "quasipolitical" motions. The committee has several possible courses of action on a proposed motion, including but not restricted to:

(a) doing nothing,

(b) conferring with supporters and opponents to arrive at a mutually accepted amended version to be circulated in advance of the meeting,

(c) recommending and planning a format for debate to suggest to a business meeting,

(d) recommending referral to a committee, and

(e) recommending debate followed by referral to a committee.

There is no mechanism that requires automatic submission of a motion to the committee. However, if a motion has not been submitted through the committee, it may be thought reasonable by a business meeting to refer it rather than to act on it without benefit of the advice of the committee.

In order that a motion for this business meeting receive the service offered by the committee in the most effective manner, it should be in the hands of the AMS Secretary by **December 13, 2017**.

AMS Short Course on Discrete Differential Geometry

This two-day course will take place on Monday and Tuesday before the meeting actually begins. It is organized by **Keenan Crane, Carnegie Mellon University.**

The emerging field of discrete differential geometry (DDG) studies discrete analogs of smooth geometric objects, providing an essential link between analytical descriptions and computation. In recent years it has unearthed a rich variety of new perspectives on applied problems in computational anatomy/biology, computational mechanics, industrial design, computational architecture, and digital geometry processing at large. The basic idea behind discrete differential geometry (DDG) is that a discrete object like a polyhedron is not merely an approximation of a smooth one, but rather a differential-geometric object in its own right. In contrast to traditional discretization which focuses on eliminating approximation error only in the limit of refinement (e.g., by taking smaller and smaller finite differences), DDG places an emphasis on so-called "mimetic" discretization where key properties of a system are guaranteed to be exactly preserved, no matter how fine or coarse the discretization. For instance, just as algorithms for simulating mechanical systems might seek to exactly preserve energy or momentum, structure-preserving discretizations of geometry might seek to exactly preserve quantities like total curvature. More broadly, DDG focuses on the discretization of differential geometric objects that do not naturally fall under the umbrella of traditional numerical analysis. This course provides an overview of recent themes in DDG, including both mathematical developments and examples of how DDG is applied in practice.

Lecture topics will include *Discrete Laplace Operators*, by **Max Wardetzky**, University of Göttingen; Discrete *Parametric Surfaces* by **Johannes Wallner**, Technische Universität Graz; *Discrete Mappings* by **Yaron Lipman**, Weizmann Institute; *Discrete Conformal Geometry* by **Keenan Crane**, Carnegie Mellon University; and *Optimal Transportation on Discrete Domains* by **Justin Solomon**, Massachusetts Institute of Technology.

There are separate registration fees to participate in this course. Advanced registration fees for members, US$114; non-member, US$175; student, unemployed, or emeritus, US$62. If you choose to register on-site, the fees for members are US$148; nonmembers US$205, and students/unemployed or emeritus members US$83. On-site registration will take place on Monday, January 8, 2017, at the San Diego Convention Center. Please see the complete Short Course article on page 1016 of this issue or go to `www.ams.org/meetings/short-courses/short-course-general`.

NSF-EHR Grant Proposal Writing Workshop

Developing a Competitive Proposal for NSF-EHR, lead by **Ron Buckmire**, National Science Foundation and **Lee Zia**, National Science Foundation; Monday, January 8 (two days before the first day of the JMM), 3:00 pm–

6:00 pm. Workshop goals are to familiarize participants with current direction/priorities in EHR; familiarize participants with key EHR education research and development programs; consider common issues of competitive proposals; and prepare participants to write a competitive proposal. There is no registration fee for this workshop, but attendees must register separately in advance. Please contact the AMS Washington Office at 401-455-4116 or amsdc@ams.org for further information.

Department Chairs Workshop

This annual one-day workshop for department chairs and leaders is held on Tuesday, 8:00 am–6:30 pm, the day before the JMM actually begins, and is lead by **Malcolm Adams**, University of Georgia, **Krista Maxson**, University of Science & Arts of Oklahoma, **Irina Mitrea**, Temple University and **Douglas Mupasiri**, University of Northern Iowa.

What makes a chair different than any other engaged faculty member in the department? This workshop will examine the chair's role in leading a department. The day will be structured to include and encourage networking and sharing of ideas amongst participants. There will be four sessions within this workshop. Session 1, led by **Krista Maxson**, will discuss the view from the top: what responsibilities, duties and expectations do Deans, Provosts and other chief academic officers have for their chairs? Session 2, led by **Malcolm Adams**, will discuss improving students' experience. Possible topics include curriculum and research opportunities, student recruitment and diversity, program assessment, career counseling, and also personnel issues such as faculty development and incentives, and the increasing numbers of non-tenure track faculty. Session 3, led by **Irina Mitrea**, will discuss outreach and communication: building effective internal partnerships. Possible topics include collaborations with other departments, working with university offices such as Honors programs, government relations offices, career and internship offices, development office, and the dean and upper administration. Session 4, led by **Doug Mupasiri**, will discuss outreach and communication: building effective external partnerships. Possible topics include collaborations with local businesses, local school systems, and other regional or national efforts.

There is a separate registration and fee to participate. For further information, please contact the AMS Washington Office at 401-455-4116 or amsdc@ams.org

101st Meeting of the MAA

MAA Invited Addresses

László Babai, University of Chicago, *Groups, graphs, algorithms: The Graph Isomorphism problem*, Wednesday, 3:20 pm.

William Cook, University of Waterloo, *Information, computation, optimization: connecting the dots in the traveling salesman problem,* Thursday, 9:00 am.

Alissa Crans, Loyola Marymount University, *Quintessential quandle queries;* Wednesday, 2:15 pm.

Maria Klawe, Harvey Mudd College, *Transforming learning: building confidence and community to engage students with rigor;* Saturday, 10:05 am.

James Tanton, MAA Mathematician at Large, *HOW MANY DEGREES ARE IN A MARTIAN CIRCLE? And other human—and nonhuman—questions one should ask about everyday mathematics*; Friday, 1:00 pm (Lecture for Students).

Tadashi Tokieda, University of Cambridge**,** *Toy models;* Friday, 9:00 am.

Presentations by MAA Teaching Award Recipients

Friday, 2:30–3:50 pm, organized by MAA Secretary **Barbara Faires**, Westminster College, and MAA President **Deanna Hausperger**, Carleton College. Winners of the Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching will give presentations on the secrets of their success. Speakers for this session will be **Hortensia Soto**, University of Northern Colorado and **Ronald Taylor**, Berry College.

MAA Invited Paper Sessions

Trends in Mathematical and Computational Biology, organized by **Raina Robeva**, Sweet Briar College,**Timothy Comar**, Benedictine University and **Carrie Eaton**, Unity College; Wednesday, 8:00–10:50 am. Mathematical and computational biology encompasses a diverse range of biological phenomena and quantitative methods for exploring those phenomena. The pace of research at this junction continues to accelerate and substantial advancements in problems from gene regulation, genomics, RNA folding, evolution, infectious disease dynamics, neuroscience, growth and control of populations, ecological networks, drug resistance modeling, and medical breakthroughs have increasingly ensued from utilizing mathematical and computational approaches. The session samples from this diversity of important questions from biology and medicine and their mathematical treatments. Speakers will present novel research at a level appropriate for general mathematics audience. This session is sponsored by SIGMAA on Mathematical and Computational Biology (BIO SIGMAA).

Teaching for Equity and Broader Participation in the Mathematical Sciences, organized by **Darryl Yong**, Talithia Williams, **Rachel Levy**, and **Lisette de Pillis**, Harvey Mudd College; Wednesday, 2:15–5:35 pm. Inquiry based learning, cooperative problem-solving activities, and other forms of active teaching strategies have been demonstrated to produce more equitable student learning outcomes. This is one of the reasons that the Conference Board of the Mathematical Sciences has called on higher-education institutions, mathematics departments, and mathematics faculty to ensure that effective active learning is incorporated into post-secondary mathematics classrooms. In this interactive session, mathematics

education researchers will share current thinking on teaching practices to pursue, and which pitfalls to avoid, to best promote equity and broader participation in the mathematical sciences.

MAA Instructional Practices Guide, organized by **Doug Ensley**, MAA, **Martha Abell,** Georgia Southern University, and **Lew Ludwig**, Denison University; Thursday, 8:00–10:50 am. For several years, members of the mathematics and mathematics education communities have been developing the MAA Instructional Practices Guide (IP Guide), which serves as a companion guide to the MAA CUPM Curriculum Guide. In this session, specific sections of the IP Guide and its implementation will be presented by members of the development team from the three main areas of the IP Guide, Classroom Practices, Design Practices, and Assessment Practices. This session will help in the dissemination efforts so that the mathematics and mathematics education communities can become more familiar with the IP Guide and make use of the effective and evidence-based instructional practices included.

Quandle Questions, organized by **Alissa Crans**, Loyola Marymount University, and **Sam Nelson**, Claremont McKenna College; Thursday, 1:00–4:20 pm. Recent exciting advances have been made in the study of knot invariants, a field with strong connections to physics, biochemistry, and other areas. In particular, much work has been done in quandle theory, an analogue of group theory in which axioms capture the essential properties of group conjugation and algebraically encode the Reidemeister moves from classical knot theory. New developments in this area has enabled us to relate knot theory to other branches of mathematics including number theory, Lie theory, and statistical physics, employ tools beyond the traditional ones from algebraic topology, and develop a rich algebraic theory through an investigation of the self-distributive properties of the quandle operation. This MAA Invited Paper Session accompanies **Alissa Crans'** invited address on the same topic.

Research in Improving Undergraduate Mathematical Sciences Education: Examples Supported by the National Science Foundation's IUSE: EHR Program, organized by **Ron Buckmire**, **Sandra Richardson**, and **Lee Zia**, National Science Foundation, Directorate for Education and Human Resources, Division of Undergraduate Education (DUE); Friday, 8:00–10:50 am. This session will highlight research from ongoing IUSE-funded projects, with a focus on the study of the teaching and learning of undergraduate mathematical sciences. Session topics will include research findings from one or more of the following themes related to undergraduate mathematical sciences education: (1) Systemic structures to support effective teaching and broadening participation; (2) Curricular and pedagogical innovations to strengthen student experiences in mathematical sciences learning; and (3) Effective use of digital tools and other sources as teaching and learning resources. Because some projects are in early stages of project development and analysis, research findings may be preliminary.

Polyhedra, Commemorating Magnus J. Wenninger, organized by **Vincent Matsko**, University of San Francisco; Friday, 1:00–3:50 pm. In February 2017, one of the world's most respected polyhedron model builders, Magnus J. Wenninger, passed away. His work was instrumental in inspiring many mathematicians, artists, and geometers to build polyhedron models as well as conduct research into classical polyhedra. This session commemorates Magnus's expertise as a model builder, his remarkable ability to connect those interested in polyhedra, and his warm, generous nature.

As a result of Coxeter's work, an interest in looking at classical ideas—for example, stellations of polyhedra and uniform polytopes in four dimensions—from a more advanced mathematical standpoint has surged. With the advent of increasingly sophisticated computer software, an interest in using mathematical tools to create virtual polyhedra has grown enormously. Talks in this session will reflect this revitalization of an interest in classical geometry.

Research in Undergraduate Mathematics Education: Highlights from the Annual SIGMAA on RUME Conference, organized by **Megan Wawro**, Virginia Polytechnic Institute, **Stacy Brown**, California State Polytechnic University, Pomona, and **Aaron Weinberg**, Ithaca College; Friday, January 6, 8:00–10:50 am. The 2018 MAA Invited Paper Session on Research in Undergraduate Mathematics Education will showcase 5 exemplary research papers that were presented at the 20th Annual SIGMAA on RUME Conference, which took place in San Diego, CA in February 2017. The invited papers were chosen to represent a diverse range of high quality research in this area.

Differential Equations and Their Applications to Neuroscience, organized by **Pengcheng Xiao**, University of Evansville, and **Lixia Duan**, North China University of Technology; Saturday, 1:00–4:15 pm. Neuronal systems are featured by nonlinear and complex patterns in spatial and temporal dimensions. These phenomena carry significant biological information and regulate down-stream biological mechanisms. Understanding the mechanisms underlying such events by quantitative modeling represents a mathematical challenge of current interest. Yet all these systems share the similar dynamical system issues in ordinary/partial different equation such as bifurcation, stability, oscillations, stochastic noise as well as issues in determining model parameters from experimental data sets and computational errors of the models. This IPS offers a forum to exchange the state of the art theoretical advances related to this promising area as well as computational tools.

Accessible Problems in Modern Number Theory, organized by **Jeremy Rouse**, Wake Forest University, and **Kate Thompson**, De Paul University; Saturday, 9:00–11:50 pm. Number theory is a subject with many simple-to-state and open problems, while also playing host to a number of striking developments in the past few years. The goal of this session is to put a focus on mathematics that is accessible to undergraduate students with a reasonable

background, but which also is closely connected to current number theory research.

MAA Minicourses

MAA Minicourses are open only to persons who register for the Joint Meetings and pay the Joint Meetings registration fee in addition to the appropriate minicourse fee. The MAA reserves the right to cancel any minicourse that is undersubscribed. Participants should read the descriptions of each minicourse thoroughly as some require participants to bring their own laptops and special software; laptops will not be provided in any minicourse. The enrollment in each minicourse is limited to 50; the cost is US$100.

Minicourse #1. ***Introduction to Process Oriented Guided Inquiry Learning (POGIL) in Mathematics Courses***, presented by **Catherine Beneteau**, University of South Florida, **Jill E. Guerra**, University of Arkansas Fort Smith and **Laurie Lenz**, Marymount University; Part A, Wednesday, 9:00–11:00 am, and Part B, Friday, 9:00–11:00 am. This workshop-style minicourse will introduce faculty to the guided inquiry instructional method called POGIL (Process Oriented Guided Inquiry Learning). Participants will use hands-on activities to learn the crucial elements in a successful POGIL classroom. In particular, the workshop will provide participants with an introduction to facilitation techniques and an opportunity to reflect on how facilitation can enhance or interfere with student learning, as well as how facilitation strategies can be critical in the development of student process skills. The participants will have the opportunity to examine a POGIL Calculus I activity and be introduced to the way the learning structure that is integrated into all POGIL activities is implemented in a mathematics specific activity. By the end of the course, participants will be familiar with the basics of the particular approach to guided inquiry that POGIL takes, and will be trained to begin implementing guided inquiry activities in their own mathematics classrooms.

Minicourse #2. ***Teaching Introductory Statistics Using the Guidelines from the American Statistical Association***, presented by **Carolyn K. Cuff**, Westminster College; Part A, Wednesday, 9:00–11:00 am, and Part B, Friday, 9:00–11:00 am. This minicourse, intended for instructors new to teaching statistics, exposes participants to the big ideas of statistics and the Guidelines for Assessment and Instruction in Statistics Education recommendations. It considers ways to engage students in statistical thinking, and emphasizes the contrast between conceptual and procedural understanding in the first statistics course. Participants will engage in many of the classic activities that all statistics instructors should know. A set of approximately 6–8 hands-on classroom-ready activities will be given to participants. The activities have been chosen so that they require minimal adaptation for a wide variety of classrooms, use freely available applets and other software and are easy to implement. Each activity includes goals, key ideas, prerequisite skills and concepts, connection to other statistical concepts, objectives, known student difficulties and assessment questions. Internet sources of real data, activities, and best practices articles will be examined. Participants will find out how they can continue to learn about the best practices for the first course in Statistics by becoming involved in statistics education related conferences, newsletters, and groups. This course is sponsored by the SIGMAA on Statistics Education (SIGMAA STAT ED).

Minicourse #3. ***Flipping your Mathematics Course using Open Educational Resources***, presented by **Sarah Eichhorn**, University of California, Irvine, **David Farmer**, American Institute of Mathematics, **Jim Fowler**, The Ohio State University and **Petra Taylor**, Dartmouth University; Part A, Wednesday, 2:15–4:15 pm, and Part B, Friday, 1:00–3:00 pm. The flipped classroom is an instructional strategy in which instructional content is delivered outside of class (often online) and classroom time is utilized for activities traditionally done as homework. Open educational resources (OERs) are openly licensed, online course materials that can be freely used by instructors and students. Participants in this minicourse will learn to design a flipped mathematics course using OERs. The minicourse will be run in a flipped instructional style, allowing participants to experience learning in this format and see a variety of implementation techniques.

Upon completion of this minicourse, participants will be able to apply best practices in flipped classroom design, identify appropriate OER materials for their mathematics courses, design assessments to check for knowledge of pre-class content, facilitate an active, problem-solving based classroom session, and utilize OER materials from the Curated Courses project and provide meaningful feedback for the continuous improvement of these community resources.

Minicourse #4. ***How to Run Successful Math Circles for Students and Teachers***, presented by **Jane Long**, Stephen F. Austin State University, **Brianna Donaldson**, American Institute of Mathematics, **Gabriella Pinter**, University of Wisconsin—Milwaukee and **Diana White**, University of Colorado Denver and National Association of Math Circles; Part A, Wednesday, 2:15–4:15 pm, and Part B, Friday, 1:00–3:00 pm. Math Circles are a unique form of outreach through which mathematics professionals share their passion for mathematics with K–12 students and teachers. During a Math Circle, participants explore, create and communicate substantive mathematics, increase their problem-solving skills, and perhaps most importantly, develop a deeper enjoyment of the subject. Including all types of Math Circles, there are currently over 250 Math Circles across the United States. In this minicourse, participants will experience Math Circle activities and discuss related topics including effective facilitation of sessions, recruiting, logistics, and successful Math Circle models. Participants should be well on their way to starting their own Math Circle after this course. This course is sponsored by the SIGMAA on Math Circles for Students and Teachers (SIGMAA MCST).

Minicourse #5. ***Reach the World: Writing Math Op-Eds for a Post-Truth Culture***, presented by **Kira Hamman**, Pennsylvania State University, Mont Alto and **Francis Su**, Harvey Mudd College; Part A, Wednesday, 2:15–4:15 pm, and Part B, Friday, 1:00–3:00 pm The degeneration of public discourse and the proliferation of fake news is cause for great concern among people who value facts, evidence, and civility. As mathematicians, we are in a unique position to combat this troubling trend with quantitative information, but to be effective we need to be able to reach a general audience. One way to do that is by writing opinion for popular print and online media. Learn to choose compelling topics and angles, distill relevant quantitative information, write at an appropriate level, and get your work into the hands of people who will publish it. Participants will also draft an opinion piece during this minicourse.

Minicourse #6. ***Directing Undergraduate Research***, presented by **Aparna Higgins**, University of Dayton; Part A, Thursday, 9:00–11:00 am, and Part B, Saturday, 9:00–11:00 am. This minicourse is designed for faculty who are new to directing undergraduate research. It will cover many aspects of facilitating research by undergraduates, such as getting students involved in research, finding appropriate problems, deciding how much help to provide, and presenting and publishing the results. Similarities and differences between research conducted during summer programs and research that can be conducted during the academic year will be discussed. Although the examples used will be primarily in the area of discrete mathematics, the strategies discussed can be applied to any area of mathematics.

Minicourse #7. ***Starter Kit for Teaching Modeling—First Differential Equations Course***, presented by **Brian Winkel**, SIMIODE, Cornwall, NY, **Rosemary Farley**, Manhattan College, **Therese Shelton**, Southwestern University, **Patrice Tiffany**, Manhattan College and **Holly Zullo**, Westminster College; Part A, Thursday, 9:00–11:00 am, and Part B, Saturday, 9:00–11:00 am. We offer this minicourse in support of colleagues who wish to start using rich modeling resources to teach differential equations. Our method uses actual experience with classroom materials and discussions on how to initiate such practices in participants' courses. We put participants in the role of students early in a differential equations course in which modeling is the driving force. We offer tested and successful modeling scenarios which engage students and bring forth differential equation notions and concepts through modeling.

Minicourse #8. ***Teaching Statistics using R and RStudio***, presented by **Randall Pruim**, Calvin College; Part A, Thursday, 9:00–11:00 am, and Part B, Saturday, 9:00–11:00 am. R is a freely available language and environment for statistical computing and graphics that has become popular in academia and in many industries. But can it be used with students? This minicourse will introduce participants to teaching applied statistics courses using computing in an integrated way. The presenter has been using R to teach statistics to undergraduates at all levels for the last decade and will share an approach and some favorite examples. Topics will include workflow in the RStudio environment, providing novices with a powerful but manageable set of tools, data visualization, basic statistical inference using R, and resampling. Much of this will be facilitated using the mosaic package. The minicourse is designed to be accessible to those with little or no experience teaching with R, and will provide participants with skills, examples, and resources that they can use in their own teaching. Participants should bring a laptop to the session. Each participant will be given access to and RStudio server account, so it is not necessary to have R or RStudio installed on the laptop. A web browser and internet capability should suffice. This course is sponsored by the SIGMAA on Statistics Education (SIGMAA STAT ED).

Minicourse #9. ***Teaching Undergraduate Mathematics via Primary Source Projects***, presented by **Diana White**, University of Colorado Denver, **Janet Barnett**, Colorado State University–Pueblo, **Kathy Clark**, Florida State University, **Dominic Klyve**, Central Washington University, **Jerry Lodder**, New Mexico State University and **Danny Otero**, Xavier University Part A, Thursday, 1:00–3:00 pm and Part B, Saturday, 1:00–3:00 pm. Mathematics faculty and educational researchers are increasingly recognizing the value of the history of mathematics as a support to student learning. Despite these benefits, there are significant challenges to incorporating primary sources directly into the classroom. This mini-course will introduce participants to an approach which brings history into the mathematics classroom via guided reading projects based on original sources. Participants will have the opportunity to experience this teaching avenue by placing themselves in the role of student as they work together in groups through two specific projects. Following this opportunity to grapple with original sources within a guided reading format, participants will discuss how to implement these Primary Source Projects (PSPs) projects in the undergraduate mathematics classroom. An overview of the general pedagogical benefits of this particular approach to using original sources with students will also be provided. Finally, participants will learn about a seven-institution, ongoing collaborative NSF-funded effort that is designing, testing, and researching the impact of over 50 newly developed PSPs, including opportunities for instructors to receive ongoing implementation support by becoming a site-tester. This course is sponsored by the SIGMAA on the History of Mathematics (HOM SIGMAA).

Minicourse #10. ***Incorporating Mathematical and Statistical Forensics Activities into the Undergraduate Mathematics Classroom,*** presented by **Eugene Fiorini**, **James Russell**, and **Gail Marsella**, Muhlenberg College; Part A, Thursday, 1:00–3:00 pm, and Part B, Saturday, 1:00–3:00 pm. Participants will learn about incorporating mathematical and statistical forensic activities into their classrooms, discuss how to coordinate with other STEM departments, and will conduct some activities themselves. The workshop will have three sections: (1) a short over-

view of curricular goals, what is forensic science, how to coordinate with other STEM fields, and how forensic activities can enhance student learning; (2) activities and discussions in small groups on specific projects including blood spatter analysis, print analysis, estimating time of death, cyber and environmental forensics, among others; and (3) a conclusion including a discussion on a final exam staged crime scene.

Minicourse #11. ***Authoring Integrated Online Textbooks with MathBook XML***, presented by **Karl-Dieter Crisman**, Gordon College and **Mitchel T. Keller**, Washington and Lee University; Part A, Thursday, 1:00–3:00 pm, and Part B, Saturday, 1:00–3:00 pm. In this minicourse participants will learn how to effectively author online textbooks with the AIM-sponsored MathBook XML (MBX, `mathbook.pugetsound.edu/`), as well as to begin creating their materials such as lab manuals or formal course notes with this tool. The idea is to harness the power of embedded online interaction, including WeBWorK problems, Sage computational cells, and extensive hyperlinking to have online (and print) texts in subjects from Calculus to Abstract Algebra. After learning the basics, participants will try their hands at creating a small supplement to one of their own classes using MBX, experiencing the "write once, read anywhere" philosophy that creates output in print, pdf, web pages, and computational notebooks. In both cases, the presenters' own texts (one in discrete math, one in number theory) will be used as case studies of how to create a project like this or to convert an existing LaTeX or html project. No previous experience with any of these tools is necessary; you should be ready to try a few necessary command line tools. You will need to bring a wireless-enabled laptop, and will receive instructions regarding software in preworkshop correspondence.

MAA Contributed Papers

The MAA Committee on Contributed Paper Sessions solicits papers pertinent to the sessions listed below. Contributed Paper Session presentations are limited to fifteen minutes, except in the general session where they are limited to ten minutes. Each session room is equipped with a computer projector and a screen. Please note that the days and times scheduled for these sessions remain tentative. Several of these sessions have specific suggestions for the appropriateness of submissions. Potential submitters are advised to read the full descriptions of these sessions at `jointmathematicsmeetings.org/meetings/national/jmm2018/JMM2018_MAA_Call_for_Papers.pdf`.

The deadline for submission of abstracts is Tuesday, September 26, 2017

MAA Contributed Paper Sessions with Themes

The Advancement of Open Educational Resources, organized by **Benjamin Atchison**, Framingham State University; Friday morning. Sponsored by the MAA Committee on Technologies in Mathematics Education (CTIME) and the SIGMAA on Mathematics Instruction Using the WEB (WEB SIGMAA).

Arts and Mathematics: The Interface, organized by **Douglas Norton**, Villanova University; Wednesday morning and afternoon. Sponsored by the SIGMAA on Mathematics and the Arts (SIGMAA ARTS).

Attracting, Involving, and Retaining Women and Underrepresented Groups in Mathematics—Righting the Balance, organized by **Meghan De Witt**, St Thomas Aquinas College, **Semra Kiliç-Bahi**, Colby-Sawyer College and **Francesca Bernardi**, University of North Carolina at Chapel Hill; Saturday morning. Sponsored by the MAA Committee on the Participation of Women.

Discrete Mathematics in the Undergraduate Curriculum–Ideas and Innovations in Teaching, organized by **Elise Lockwood**, Oregon State University, **John Caughman**, Portland State University and **Art Duval**, University of Texas El Paso; Wednesday afternoon.

Environmental Modeling in the Classroom, organized by **Ellen Swanson**, Centre College and **Emek Kose**, St Mary's College of Maryland; Thursday morning. Sponsored by the SIGMAA for Environmental Mathematics (SIGMAA EM).

Flipped Classes: Implementation and Evaluation, organized by **Joel Kilty**, **Alex M. McAllister**, and **John H. Wilson**, Centre College; Wednesday afternoon.

Good Math from Bad: Crackpots, Cranks, and Progress, organized by **Samuel R. Kaplan**, University of North Carolina Asheville and **Elizabeth T. Brown**, James Madison University; Friday afternoon.

Humanistic Mathematics, organized by **Eric Marland**, Appalachian State University and **Gizem Karaali**, Pomona College; Thursday morning. Sponsored by MAA subcommittee on Curriculum Renewal Across the First Two Years (CRAFTY) and the Journal of Humanistic Mathematics.

Implementing Recommendations from the Curriculum Foundations Project, organized by **Susan Ganter**, Embry-Riddle Aeronautical University, **Mary Beisiegel**, Oregon State University, **Janet Bowers**, San Diego State University, **Tao Chen**, City University of New York - LaGuardia Community College and **Caroline Maher-Boulis**, Lee University; Wednesday afternoon. Sponsored by the MAA Committee for Curriculum Renewal Across the First Two Years (CRAFTY).

Innovative and Effective Online Teaching Techniques, organized by Sharon Mosgrove and **Doug Scheib**, Western Governors University; Friday afternoon.

Innovative and Effective Ways to Teach Linear Algebra, organized by **David Strong**, Pepperdine University; **Gil Strang**, Massachusetts Institute of Technology, **Megan Wawro**, Virginia Polytechic Institute and **Sepideh Stewart**, University of Oklahoma; Thursday morning.

Innovative Curricular Strategies for Increasing Mathematics Majors, organized by **Eric S. Marland**, Appalachian State University, **Stuart Boersma**, Central Washington University and **Victor Piercey**, Ferris State University; Wednesday morning. Sponsored by MAA subcommittee on Curriculum Renewal Across the First Two Years (CRAFTY).

Innovative Mathematical Outreach in Alternative Settings, organized by **Jennifer Switkes**, California State

Polytechnic University, Pomona, and **Hector Rosario**, University of North Carolina, Chapel Hill; Thursday afternoon.

Innovative Teaching Practices in Number Theory, organized by **Thomas Hagedorn**, The College of New Jersey, **Patrick Gault**, University of Arizona and **Mark Kozek**, Whittier College; Thursday afternoon.

Integrating Research into the Undergraduate Classroom, organized by **Shannon R. Lockard**, Bridgewater State University and **Timothy B. Flowers**, Indiana University of Pennsylvania; Wednesday afternoon.

Inquiry-Based Teaching and Learning, organized by **Brian P. Katz**, Augustana College, **Eric Kahn**, Bloomsburg University and **Victor Piercey**, Ferris State University; Friday morning and afternoon. Sponsored by the SIGMAA on Inquiry-Based Learning (IBL SIGMAA).

Lightning Talks and E-Posters: Me and My Gadgets, Teaching with Technology, organized by **Karl Schmitt**, Valparaiso University, **John Travis**, Mississippi College, **Michael B. Scott**, California State University and **Tom Hagedorn**, The College of New Jersey; Saturday morning. Sponsored by the Committee on Technology in Mathematics Education (CTiME) and the SIGMAA on Mathematics Instruction Using the WEB (WEB SIGMAA).

Math Circle Topics with Visual or Kinesthetic Components, organized by **Amanda Katharine Serenevy**, Riverbend Community; Thursday afternoon. Sponsored by the SIGMAA on Math Circles for Students and Teachers (SIGMAA MCST).

Mathematical Experiences and Projects in Business, Industry, and Government (BIG), organized by **Bill Fox**, Naval Postgraduate School, and **Allen Butler**, Wagner Associates; Friday morning. Sponsored by the SIGMAA on Business, Industry, and Government (BIG SIGMAA).

Mathematical Knowledge for Teaching Grades 6–12 Mathematics, organized by **Bonnie Gold**, Monmouth University, **David C. Carothers**, James Madison University, and **Yvonne Lai**, University of Nebraska—Lincoln; Thursday morning. Sponsored by the MAA Committee on the Mathematical Education of Teachers (COMET).

Mathematical Themes in a First-Year Seminar, organized by **Pamela Pierce** and **Jennifer Bowen**, The College of Wooster; Friday afternoon.

Mathematics and Sports, organized by **Drew Pasteur**, College of Wooster, and **John David**, Virginia Military Institute; Wednesday afternoon.

Meaningful Modeling in the First Two Years of College, organized by **Stuart Boersma**, Central Washington University, and **Jason Douma**, University of Sioux Falls; Saturday afternoon. Sponsored by MAA Mathematics Across the Disciplines (MAD) Subcommittee and the MAA Curriculum Renewal Across the First Two Years (CRAFTY) Subcommittee.

Philosophy of Mathematics as Actually Practiced, organized by **Bonnie Gold**, Monmouth University (emerita), **Sally Cockburn**, Hamilton College and **Thomas Drucker**, University of Wisconsin—Whitewater; Friday morning. Sponsored by the SIGMAA for the Philosophy of Mathematics (POM SIGMAA).

Quantitative Literacy Across the Curriculum, organized by **Andrew J. Miller**, Belmont University, **Victor Piercey**, Ferris State University, **Catherine Crockett**, Point Loma Nazarene University and **John Curran**, Eastern Michigan University; Saturday morning. Sponsored by the SIGMAA on Quantitative Literacy (SIGMAA QL).

Research in Undergraduate Mathematics Education (RUME), organized by **Megan Wawro**, Virginia Polytechnic Institute, **Aaron Weinberg**, Ithaca College and **Stacy Brown**, California State Polytechnic University; Thursday morning and afternoon. Sponsored by the SIGMAA on Research in Undergraduate Mathematics Education (SIGMAA RUME).

Revitalizing Complex Analysis, organized by **Russell W. Howell**, Westmont College; Saturday morning.

The Scholarship of Teaching and Learning in Collegiate Mathematics, organized by **Jacqueline Dewar**, Loyola Marymount University, **Tom Banchoff**, Brown University, **Curt Bennett**, Loyola Marymount University, Pam Crawford, Jacksonville University, **Edwin Herman**, University of Wisconsin—Stevens Point, and **Lew Ludwig**, Denison University; Wednesday morning and afternoon.

Scholarship on Teaching and Learning in Statistics Education, organized by **Stacey Hancock**, Montana State University, **Sue Schou**, Idaho State University, and **Soma Roy**, California Polytechnic State University; Saturday afternoon. Sponsored by the SIGMAA on Statistics Education (SIGMAA STAT ED).

Teaching Abstract Algebra: Topics and Techniques, organized by **Kristi Meyer**, Wisconsin Lutheran College, and **Jessie Lenarz**, St. Catherine University; Saturday morning.

The Teaching and Learning of Undergraduate Ordinary Differential Equations, organized by **Christopher S. Goodrich**, Creighton Preparatory School, and **Beverly H. West**, Cornell University; Friday afternoon. Sponsored by the Community of Ordinary Differential Equations Educators (CODEE).

Technology and Resources for Teaching Statistics, organized by **Karl Schmitt**, Valparaiso University, **Sue Schou**, Idaho State University, **Stacey Hancock**, Montana State University and **Soma Roy**, California Polytechnic State University; Friday afternoon. Sponsored by the SIGMAA on Statistics Education (SIGMAA STAT ED) and the MAA Committee on Technology in Mathematics Education (CTiME).

Trends in Undergraduate Mathematical Biology Education, organized by **Timothy D. Comar**, Benedictine University; Thursday morning. Sponsored by the SIGMAA on Mathematical and Computational Biology (BIO SIGMAA).

20th Anniversary—The EDGE (Enhancing Diversity in Graduate Education) Program: Pure and Applied Talks by Women, organized by **Shanise Walker**, Iowa State University, and **Laurel Ohm**, University of Minnesota; Thursday morning and afternoon.

Using Mathematics to Study Problems from the Social Sciences, organized by **Jason Douma**, University of Sioux Falls; Thursday afternoon. Sponsored by the MAA Mathematics Across the Disciplines (MAD) Subcommittee.

General Contributed Paper Sessions, organized by **Tim Comar**, Benedictine University, and **James Reid**, University of Mississippi; Wednesday, Thursday, Friday, and Saturday, mornings and afternoons. These sessions accept contributions in all areas of mathematics, curriculum, and pedagogy. When you submit your abstract you will be asked to classify it according to the following scheme: Assessment; History or Philosophy of Mathematics; Interdisciplinary Topics in Mathematics; Mathematics and Technology; Mentoring; Modeling and Applications; Outreach; Teaching and Learning Developmental Mathematics; Teaching and Learning Introductory Mathematics; Teaching and Learning Calculus; Teaching and Learning Advanced Mathematics; Algebra; Analysis; Applied Mathematics; Geometry; Graph Theory; Linear Algebra; Logic and Foundations; Number Theory; Probability and Statistics; Topology; and Other Topics.

See also the AMS-MAA-SIAM Special Session on *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs on* Wednesday morning, Thursday afternoon, Saturday morning and afternoon in the "AMS Special Session" listings. The organizers for this session are **Tamas Forgacs**, California State University Fresno, **Darren A. Narayan**, Rochester Institute of Technology, and **Mark David Ward**, Purdue University.

Submission Procedures for MAA Contributed Paper Abstracts

Abstracts may be submitted electronically at `jointmathematicsmeetings.org/meetings/abstracts/abstract.pl?type=jmm`. Simply fill in the number of authors, click "New Abstract," and then follow the step-by-step instructions. **The deadline for abstracts submission is Tuesday, September 26, 2017.**

Each participant may make at most one presentation in an MAA Contributed Paper Session, either a presentation in one of the themed sessions or a presentation in one of the general sessions. If your paper cannot be accommodated in the themed session for which it was submitted, it will automatically be considered for the general contributed paper sessions. The organizer(s) of your session will automatically receive a copy of the abstract, so it is not necessary for you to send it directly to the organizer. All accepted abstracts are published in a book that is available to registered participants at the meeting. Questions concerning the submission of abstracts should be addressed to `abs-coord@ams.org`.

MAA Panels, Posters, and Other Sessions

MAA Panel: How do we use assessment? What do we learn from it and how does it help us make related changes?, organized by **Beste Gucler**, University of Massachusetts Dartmouth, and **Gulden Karakok**, University of Northern Colorado; Wednesday, 8:00–9:20 am. The purpose of this panel is to inform the audience about recent research-based efforts on the development and use of assessments in undergraduate mathematics. The intended audience is mathematics and mathematics education faculty members. The session will focus on assessment of learning, teaching, and programs through the expertise of four panelists. Each panelist will present for 15 minutes; the remaining 20 minutes will consist of discussions between the panelists and audience. Dr. Marilyn Carlson will focus on the analysis of calculus final exams including what is known about the foundational ideas in precalculus needed for understanding key ideas of calculus. Dr. Pablo Mejia-Ramos will talk about the development and validation of reliable assessments for undergraduate students' comprehension of mathematical proofs that they read. Dr. Sandra Laursen will focus on methods for characterizing teaching in undergraduate mathematics classrooms based on recent research and program evaluation studies. She will discuss how the goals of such characterizations depend on the study goals. Dr. William Martin will talk about his experience on assessment in mathematics departments; development and implementation of assessment systems for units with programs in education. Panelists are **Marilyn Carlson**, Arizona State University, **Pablo Mejia-Ramos**, Rutgers University, **Sandra Laursen**, University of Colorado Boulder and **William Martin**, North Dakota State University

MAA-SIAM-AMS Hrabowski–Gates–Tapia–McBay Session, organized by **Ricardo Cortez,** Tulane University; Wednesday, 9:00–10:20 am. The Hrabowski–Gates–Tapia–McBay Session is named after four influential scientists of color: (1) Freeman Hrabowski, President of the University of Maryland at Baltimore County; (2) James S. Gates, University of Maryland, College Park; (3) Richard Tapia, Rice University; and (4) Shirley McBay, President of Quality Education for Minorities (QEM). Through multiple mechanisms, these Sessions expect to facilitate and accelerate the participation of scientists in the building of sustainable communities of mathematicians and mathematical scientists. In particular, the intention is to systematically recruit, welcome, encourage, mentor, and support individuals from underrepresented groups in the USA. This year the session will consist of a lecture at 9:00 am given by **Talithia Williams**, Harvey Mudd College, ***Mathematics for the Masses***, and a short panel discussion after the talk at 9:50 am. The 2018 panel will focus on ***Access to Quality Mathematics by All***. Panelists and attendees will discuss issues related to removing roadblocks in mathematics education (e.g., Tracking, placement, 'weed out' courses, etc) as well as hiring or award selection practices that tend to favor the majority groups that have influence. Panelists will also address the question: What are the roles and responsibilities do mathematicians and mathematics educators have in creating a just and accessible system? Panelists will include **Ron Buckmire**, National Science Foundation, **James Alvarez**, University of Texas at Arlington and **Talithia Williams**, Harvey Mudd College. This event is sponsored by the MAA Committee on Minority Participation in Mathematics, SIAM and the AMS.

MAA Panel: Mathematicians' Work in Creating Open Education Resources for K–12, organized by **William McCallum**, University of Arizona, Wednesday, 9:35–10:55 am.

Since the writing of the Common Core State Standards in Mathematics, mathematicians have played a central role in a number of projects dedicated to producing freely available curriculum for K–12 aligned to the standards, including Engage NY/Eureka Math, the Utah Middle School Math Project, and the Illustrative Mathematics middle school curriculum. Leads from each of these projects will address questions about the role of mathematicians in writing K–12 curriculum, such as: Do mathematicians bring a particular sensibility to this work that makes the end product distinctive? What is the nature of the collaboration between mathematicians and other experts, such as classroom teachers and mathematics education researchers? What general lessons can be drawn from mathematicians' experience in this work that can inform future collaborations? What are the implications for teacher preparation classes? What are the constraints and affordances of working with open licenses? Panelists are **Scott Baldridge**, Louisiana State University, **Hugo Rossi**, University of Utah and **Kristin Umland**, Illustrative Mathematics.

MAA Panel: What Every Student Should Know about the JMM, organized by **Violeta Vasilevska**, Utah Valley University; Wednesday, 9:35–10:55 am. Navigating a large conference can be overwhelming, even for those who have previously attended such an event. Panelists Joyati Debnath, Winona State University, Michael Dorff, Brigham Young University, and Frank Morgan, Williams College, will provide guidance for students attending the Joint Mathematics Meetings, including answers to some common questions: How do I get the most out of the program? What sessions are especially for students? What other events should I be on the lookout for? Will I understand any of the invited addresses or should I not bother attending them? If I am presenting a poster, where do I go to set it up? How can I get some cool, free math stuff? Students and their faculty mentors are encouraged to attend. Panelists are **Joyati Debnath,** Winona State University, **Michael Dorff**, Brigham Young University and **Frank Morgan**, Williams College. This panel is sponsored by the MAA Committee for Undergraduate Student Activities and Chapters (CUSAC).

MAA Panel: Ethics, Morality and Politics in the Quantitative Literacy Classroom, organized by **Ethan Bolker**, University of Massachusetts Boston, and **Maura Mast**, Fordham University; Wednesday, 2:15–3:35 pm. If you mine the daily news for examples to use in your Quantitative Literacy class you will soon need answers to pedagogical questions like these that rarely come up in Calculus or College Algebra:

- How do you navigate a discussion of topics that touch on politics without bringing in your personal views?
- When they do show (as they will), how do you prevent students from thinking that they should agree with you in order to get a good grade?
- How do you encourage reasoned answers when there are "facts"—alternative or otherwise—that students think they know?
- How do you avoid arbitrarily defined "balance" when controversies arise that numbers could resolve?
- How do you deal with anecdotal arguments based on personal experience that may not hold up to quantitative or statistical analysis, while still respecting students' views, perspectives and opinions?
- How do you address questions like "What is a fair tax policy?" that come with an implicit moral dimension?

The panelists will talk about their successes (and failures) dealing with classroom moments that prompt these questions. Members of the audience may submit their own examples and classroom situations for the panelists to discuss. Moderator for this panel will be **Ethan Bolker**, University of Massachusetts Boston. Panelists are **David Lavie Deville**, Northern Arizona University, **Kseija Simic-Muller**, Pacific Lutheran University, **Gizam Karaali**, Pomona College, **David Kung**, St. Mary's College of Maryland and **Rob Root**, Lafayette College. This panel is sponsored by SIGMAA QL

MAA Panel: NSF Funding Opportunities to Improve Learning and Teaching in the Mathematical Sciences, organized by **Ron Buckmire**, **Sandra Richardson**, and **Lee Zia**, Division of Undergraduate Education, NSF, **Karen King**, Division of Research on Learning, NSF, **Tara Smith**, Division of Graduate Education, NSF, and **Swatee Naik**, Division of Mathematical Sciences, NSF, Wednesday, 2:15–4:00 pm. A number of NSF divisions offer a variety of grant programs that support innovations in learning and teaching in the mathematical sciences. These programs will be discussed along with examples of successful projects. Anticipated budget highlights and other new initiatives for the next fiscal year, as appropriate, will also be presented. Panelists are **Ron Buckmire**, **Sandra Richardson**, and **Lee Zia**, Division of Undergraduate Education, NSF, **Karen King**, Division of Research on Learning, NSF, **Tara Smith**, Division of Graduate Education, NSF, and **Swatee Naik**, Division of Mathematical Sciences, NSF.

MAA Panel: A Mathematician Teaches Statistics: The Road Less Traveled, organized by **Stacey Hancock**, Montana State University; Wednesday, 3:10–5:10 pm. With the recent rapid growth in statistics programs and the large number of required statistics courses in other disciplines, many statistics instructors do not have a graduate degree in statistics. Especially at smaller institutions without separate statistics departments, trained mathematicians who may not have taken a data analysis course are commonly asked to teach applied statistics courses, either voluntarily or involuntarily. Our panel will host several members of the mathematics and statistics community from a variety of institutions that were trained in mathematics and transitioned to teaching statistics. Panelists will share their journey and experiences in successfully transitioning from teaching mathematics to statistics, including how teaching statistics differs from teaching mathematics and advice for other mathematicians that find themselves in the same situation. Panelists are **Patti Frazer Lock**, St. Lawrence College, **Chris Oehrlein**, Oklahoma City Community College, **Sue**

Schou, Idaho State University and **Charilaos Skiadas**, Hanover College. This panel is sponsored by the SIGMAA on Statistics Education.

Town Hall Meeting: National Changes in Education: 2018, a New World, Wednesday, 4:00–5:00 pm. The MAA Committee on the Mathematical Education of Teachers invites you to join us for informal discussions about changes in the national educational landscape. 2017 rocked the educational world and there are surely more changes to come as the current president continues to implement his vision. Bring your thoughts, ideas, and an open mind for a roundtable discussion. This session is sponsored by the MAA Committee on Faculty and Departments. This session is sponsored by the MAA Committee on the Mathematical Education of Teachers (COMET).

MAA Panel: Implicit Bias and Its Effects in Mathematics, organized by **Semra Kilic-Bahi**, Colby-Sawyer College, **Maura Mast**, Fordham College at Rose Hill, **Naomi Cameron**, Lewis & Clark College, **Andrew Cahoon**, Colby-Sawyer College and **Charles Doering**, University of Michigan; Wednesday, 4:15–5:35 pm. Implicit bias occurs when someone explicitly rejects stereotypes and prejudices, but unconsciously holds negative (mostly) associations. People are not hiding their prejudices, but rather, they just do not know they have these unconscious feelings or thoughts that affect their decision-making and behavior. Social scientists are identifying implicit biases as one of the most pervasive barriers to equal opportunities for minorities and women in today's society. This panel discussion addresses how implicit bias might manifest and affect our classrooms, departments, and campuses in terms of academic and scholarly opportunities and evaluations. Panelists are **Ron Buckmire**, National Science Foundation, **Jenna P. Carpenter**, Campbell University, **Lynn Garrioch**, Colby-Sawyer College, **Joanna Kania-Bartoszynska**, National Science Foundation and **Francis Edward Su**, Harvey Mudd College. This panel is sponsored by the MAA Committee on the Participation of Women in Mathematics; Committee on the Minority Participation in Mathematics; Association for Women in Mathematics; National Association of Mathematicians; and the Joint Committee on the Participation of Women in Mathematics.

MAA Panel: Communicating Mathematics to a Wider Audience, organized by **Joel Cohen**, University of Maryland and **Paul Zorn**, St. Olaf College; Thursday, 9:00–10:20 am. Panelists will address questions like the following: ow can we mathematicians better tell our stories? How can we speak to government decisionmakers and the general public about the importance, applicability, and beauty of our subject? What can we learn from social scientists about principles of effective communication to broad audiences? Panelists to be announced. This panel is sponsored by the MAA Science Policy Committee.

MAA Session for Chairs: Bridging the Gap, organized by **Catherine Murphy**, Purdue University Northwest, **Linda Braddy**, Tarrant County College Northeast Campus and **Daniel Maki**, Indiana University Bloomington; Thursday, 9:00–10:20 am. One of the major responsibilities of department chairs is serving as a communication link between faculty and dean/other academic administrators. In this time of significant change in higher education, this role is even more important. The four panelists are either current or recent chairs of mathematics departments who will share how they "bridge the gap," that is advocate for faculty as well as provide faculty with the information needed to understand and address issues/mandates from administration. About a third of this session will be devoted to conversations among attendees and with panelists. Attendees are encouraged to share their questions, concerns and expertise. Panelists are **Michael Dorff**, Brigham Young University, **Lewis Ludwig**, Denison University, **Alycia Marshall**, Anne Arundel Community College and **Karen Saxe**, Macalester College.

MAA Poster Session: Mathematical Outreach Programs, organized by **Betsy Yanik**, Emporia State University; Friday, 10:00 am–12 noon. This poster session is designed to highlight special programs which have been developed to encourage students to maintain an interest in and commitment to succeeding in mathematics. These programs might include such activities as after school clubs, weekend activities, one day conferences, mentoring opportunities, summer camps, etc. This poster session encompasses a wide variety of outreach efforts for a variety of age groups. For example, programs might be designed to reach out to underrepresented groups. The projects supported by MAA Tensor and Summa grants will find this an ideal venue in which to share the progress of their funded projects. Another possible type of outreach might involve mathematical enrichment programs. Other examples might include innovative programs to motivate undergraduates to study mathematics. We encourage everyone involved with offering mathematical outreach activities to consider submitting an abstract to the session organizer, Betsy Yanik, `eyanik@emporia.edu`. This session is sponsored by the Committee on the Participation of Women.

Town Hall Meeting: Revising MAA Guidelines on the Work of Faculty and Departments: Supporting Student Success, organized by **Tim Flowers**, Indiana University of Pennsylvania; Thursday, 10:35–11:55 am. The MAA Committee on Faculty and Departments (formerly called the Committee on the Status of the Profession) invites ideas and suggestions regarding ongoing updates and revisions to The Guidelines for Programs and Departments in Undergraduate Mathematical Sciences. These Guidelines are intended to be used by mathematical sciences programs in self-studies, planning, and assessment of their undergraduate programs, as well as by college and university administrators and external reviewers. In order to have the future online statements in the Guidelines be as complete and useful as possible, the committee is soliciting input from MAA members. In this session, panelists and committee members will take comments and questions from the audience regarding the statement on students. Specific topics will include guidelines related to the following: recruiting, retaining, and supporting a diverse student popu-

lation; evaluating the placement process for introductory courses; providing academic, career advice to students in mathematical sciences, including job placement; sponsoring co-curricular organizations and competitions; and leading undergraduate research projects. Moderator for this panel will be **Edward Aboufadel**, Grand Valley State University. Panelists are **Mary Beisiegel**, Oregon State University, **Suzeanne Dorée**, Augsburg College, **Tyler Jarvis**, Brigham Young University and **Benedict Nmah**, Morehouse College. This session is sponsored by the MAA Committee on Faculty and Departments.

MAA Panel: Effectively Chairing a Mathematical Sciences Department, organized by **Kevin Charlwood**, Washburn University, **Robert Buck**, Slippery Rock University and **Joanna Ellis-Monaghan**, Saint Michael's College; Thursday, 1:00–2:20 pm. We plan to host an 80-minute panel with 5 panelists from a variety of institutions, with two panelists having administrative experience outside the department. The target audience is those faculty who expect to Chair their units someday, but all are welcome to attend. Some talking points, used at the 2015 AMS Chair's workshop at the San Antonio JMM: 1. Why did you want to (or agree to) be Chair? 2. What are/were your goals as Chair: (A) Are there/were there new initiatives you/your colleagues wanted to see? (B) Problems needed fixing? (C) Existing programs to improve upon or grow? (D) Or, hoping to maintain status quo? 3. What is your main challenge/challenges in accomplishing these goals? Panelists are **Curtis Bennett**, Loyola Marymount University, **Karrolyne Fogel**, California Lutheran University, **Sergio Loch**, Grand View University and **Joe Yanik**, Emporia State University.

MAA Panel: Out in Mathematics: Professional Issues Facing LGBTQ Mathematicians, organized by **David Crombecque**, University of Southern California and **Christopher Goff**, University of the Pacific; Thursday, 1:00–2:20 pm. This panel, organized by SPECTRA, the Association of LGBTQ Mathematicians, will address issues of concern for LGBTQ mathematicians, professionals or students. Panelists will share their personal experiences as OUT LGBTQ mathematicians, addressing key questions for LGBTQ career mathematicians such as: Should I come out during the job interview? … on the CV? As a graduate student, should I be out to my advisor? If I am treated/evaluated differently at work because of my gender identity/sexual orientation, what is my recourse? How can I navigate changing my employment/academic records to reflect my gender identity? Our panelists will discuss these and many more questions relevant to the well-being and inclusion of current and future successful LGBTQ mathematicians. Moderator for this panel is Lily Khadjavi, Loyola Marymount University. Panelists are **Shelly Bouchat**, Indiana University of Pennsylvania, **DJ Bruce**, University of Wisconsin Madison, **Ron Buckmire**, National Science Foundation, **Frank Farris**, Santa Clara University and **Emily Riehl**, Johns Hopkins University.

MAA Poster Session: Projects Supported by the NSF Division of Undergraduate Education, organized by **Jon Scott**, Montgomery College; Friday, 2:00–4:00 pm. This session will feature principal investigators (PIs) presenting progress and outcomes from various NSF funded projects in the Division of Undergraduate Education. The poster session format will permit ample opportunity for attendees to engage in small group discussions with the PIs and to network with each other. Information about presenters and their projects will appear in the program.

Estimathon! organized by **Andy Niedermaier**, Jane Street Capital; Thursday, 2:30–4:15 pm. They're called Fermi problems…

- How heavy is the Eiffel Tower?
- How many prime numbers have distinct digits?
- How many calories would you be eating if you had "one of everything" at the Cheesecake Factory?

If you're looking for a mindbending mixture of math and trivia, look no further! Jane Street Capital presents The Estimathon contest: teams will have 30 minutes to work on 13 problems, ranging from totally trivial to positively Putnamesque. Can your team beat the all-time best score? The top teams will receive prizes!

We will run 2 contests. Feel free to show up to either one!

(Please show up 15 minutes before the start time of the contest you want to join.)

Our target schedule is as follows:

2:30 pm Welcome, overview of rules and scoring.

2:45 pm Estimathon contest #1

3:30 pm Estimathon contest #2

AMS-MAA Joint Committee on TAs and Part-Time Instructors Panel: Teaching-Focused Faculty at Research Institutions, organized by **Angela Kubena**, University of Michigan, **Jean Marie Linhart**, Central Washington University, **Tom Roby**, University of Connecticut and **Michael Weingart**, Rutgers University; Thursday, 2:30–3:55 pm. It is increasingly common that a portion of the teaching at research universities is done by full-time teaching-focused faculty (TFF). These faculty are not asked to do research but instead are asked to take on an expanded role in helping the department carry out its teaching. This session will discuss issues around this development, from how such faculty may be supported to issues of evaluating faculty whose primary role is teaching and integrating them into a department culture that is focussed on research. Moderator for this panel will be **Tom Roby**, University of Connecticut. Panelists are **Amy Cohen**, Rutgers University, **John Eggers**, University of California San Diego, **Ellen Golstein**, Boston College, **Robin Gottlieb**, Harvard University, and **Amit Savkar**, University of Connecticut. This panel is sponsored by the AMS-MAA Joint Committee on TAs and Part-Time Instructors.

The Dolciani Award: Mathematicians in K–16 Education, organized by **David Stone**, Georgia Southern University, **Will Abram**, Hillsdale College, **Ken Gross,** University of Vermont, **Bill Hawkins**, University of the District of Columbia**, Glenn Stevens**, Boston University, **Ann Watkins**, California State University, Northridge and **Susan Wildstrom**, Walt Whitman High School, Bethesda MD; Thursday,

2:35–3:55 pm. The MAA Mary P. Dolciani Award, funded by the Dolciani Halloran Foundation, recognizes a pure or applied mathematician who is making a distinguished contribution to the mathematical education of K–16 students in the United States or Canada. Established in 2012, it is one of the MAA's major awards. Its recipients form an impressive list of mathematicians who are widely recognized as having contributed to mathematics education:

2017 Tatiana Shubin, San Jose State University

2015 Sybilla Beckmann, University of Georgia

2014 Alan Schoenfeld, University of California at Berkeley

2013 Hyman Bass, University of Michigan

2012 William G. McCallum, University of Arizona.

The panel features two recipients of the award and one other distinguished mathematician who has been involved in mathematics education. The panelists will address why they believe it is important that research mathematicians become involved in K–16 mathematics education, can provide examples of positive engagement and provide a road map for others who wish to follow their lead. They will highlight the key issues, the roadblocks and rewards in such endeavors.

In an address at a previous JMM, Hy Bass said, "There are three issues in which every mathematician should be engaged: research, applications and education." This session is an opportunity to hear from mathematicians who have been leaders in all of these arenas.

The panel will conclude with an interactive Q&A session. Panelists are **Jim Lewis**, University of Nebraska, **Alan Schoenfeld**, University of California at Berkeley and **Tatiana Shubin**, San Jose State University. This panel is sponsored by the MAA Committee on the Mary P. Dolciani Award.

MAA Panel: What is a "Math Center" and What Can it do For Your Department?, organized by **Christina Lee**, Oxford College of Emory University, and **Jason Aubrey**, University of Arizona; Thursday, 2:35–3:55 pm. Many mathematics departments around the country are dedicating significant resources and personnel to the work of supporting the students in our courses, encouraging them to continue to take mathematics courses, and recruiting them into the major. This support goes beyond what is typically offered by campus tutoring centers, as it often includes mentoring and academic/career advising. At some schools, these activities have been organized into dedicated units (sometimes called "Math Centers"), led by mathematics faculty, often with dedicated staff support and budget. There are many benefits of having such units, such as increased interest in mathematics and the recruitment and retention of minority students. Panelists are comprised of leaders of such units and will discuss the implementation and outcomes of having such a dedicated support system for mathematics students. Panelists are **Jason Aubrey**, University of Arizona, **Christina Lee**, Oxford College of Emory University, **Rosalie Belanger-Rioux**, Harvard University, and **Kaitlyn Gingras**, Trinity College.

AMS-MAA-SIAM Panel on Multiple Paths to Mathematics Careers in Business, Industry and Government(BIG), organized by **Allen Butler**, Daniel H Wagner Associates, **Rachel Levy**, Harvey Mudd College, **Douglas Mupasiri**, University of Northern Iowa and **Suzanne Weekes**, Worcester Polytechnic Institute; Thursday, 2:35–3:55 pm. The proportion of new mathematics doctoral recipients who are taking jobs in business, industry and government (BIG) is growing. Still, many mathematics PhD programs do not include preparation for non-academic career options as part of their standard curriculum. At this panel, you will have the opportunity to hear about multiple career paths to employment in BIG. Panelists will share (a) what they wish they had known and done as graduate students/postdocs, (b) what you can do at your career stage if you are interested in making connections with business, industry or government, and (c) what suggestions they have for math doctoral programs to increase preparedness of their students for work in BIG. Co-sponsors for this panel are AMS, MAA, and SIAM.

MAA Panel: Teaching Mathematics Content to Prospective Elementary Teachers: Strategies and Opportunities, organized by **Lynn C. Hart**, Georgia State University; Friday, 8:00–9:20 am. This panel will discuss issues that mathematics faculty may encounter when teaching content courses to prospective elementary teachers, suggesting strategies for teaching future elementary teachers mathematics in ways that will have a lasting positive impact on how they will teach to future generations. Specifically, the panel will discuss the following questions.

1. What are the considerations for writing cognitively demanding mathematical tasks and enacting them in ways that maintain the demand?

2. How can exploring children's mathematical thinking support learning content by prospective elementary teachers?

3. What are mathematical habits of mind and why is it more important than ever for us to attend to them in content courses for prospective elementary teachers?

4. How does affect impact prospective elementary teachers learning in mathematics content courses?

5. How have institutions across 3 countries (US, Canada, Norway) developed curriculum approaches to address these challenges? Panelists are **Christine Browning**, Western Michigan University, **Ziv Feldman**, Boston University, **Lynn C. Hart**, Georgia State University, **Jennnifer Holm**, University of Alberta and **Susan Oesterle**, Douglas College.

MAA Panel: The New AP Calculus Curriculum —The First Round of Testing, organized by **James Sellers**, Pennsylvania State University; Friday, 9:35–10:55 am. In May of 2017, students across the country took the new AP Calculus AB and AP Calculus BC exams, the first that reflected the updated AP Calculus courses. This session will provide details on how the AP Calculus AB and AP Calculus BC courses have changed both in terms of course content and student expectations, and how students performed on these new examinations. The panel will include representatives from College Board, the col-

lege professor in charge of scoring these exams (aka, the Chief Reader), and some of the authors of the AP Calculus Curriculum Framework. There will be time in the session for the panelists to answer questions from the audience. Panelists are **Gail Burrill**, Michigan State University, **Stephen Davis**, Davidson College, **Ben Hedrick**, College Board and **James Sellers**, Pennsylvania State University.

MAA Panel: Pathways Through High School Mathematics: Building Focus and Coherence, organized by **Karen J. Graham**, University of New Hampshire; Friday, 1:00–2:20 pm. In Fall 2016, the NCTM Board of Directors appointed a task force whose members represent various constituencies from the larger mathematics education community including K–12 and post-secondary education. The task force was charged with addressing the purpose of high school mathematics and defining a set of curricular pathways that lead to college, career, and citizen readiness. This panel presentation will focus on the recommendations of the task force and the potential implications for post-secondary mathematics education. Members of the task force will discuss aspects of the document scheduled for release at the NCTM Annual Meeting & Exposition in Washington in April 2018 and engage the audience in a discussion of important themes and next steps. Panelists are **Gail Burrill**, Michigan State University, **Yvonne Lai**, University of Nebraska Lincoln, **Matt Larson**, National Council of Teachers of Mathematics, **Francis Su**, Harvey Mudd College and **Dan Teague**, North Carolina School of Science and Mathematics.

AMS-MAA Joint Committee on TAs and Part-Time Instructors Panel: Panel on The Experiences of Foreign Graduate Students as GTAs, organized by **John Boller**, University of Chicago, **Solomon Friedberg**, Boston College, and **Edward Richmond**, Oklahoma State University; Friday, 1:00–2:30 pm. Foreign graduate students make up a significant fraction of all math graduate students. When they serve as GTAs, these students must not only learn how to take on the role of teacher, but must do so in a system and culture that are unfamiliar to them. The goal of this session is to highlight the unique challenges that foreign graduate students encounter as GTAs so that the math community can better help them succeed. The panelists will draw from their own previous experiences as students living in the US for the first time as graduate students, and will offer their perspectives on what is most helpful in supporting similar students as they take on teaching responsibilities in the US. The moderator for this panel will be **Solomon Friedberg**, Boston College. Panelists will be composed of current graduate students and recent PhDs who lived in North America for the first time as graduate students. This panel is sponsored by the AMS-MAA Joint Committee on TAs and Part-Time Instructors

Town Hall Meeting: Creating Engaging, Meaningful Experiences for Teachers and Future Teachers, Friday, 1:00–2:00 pm. The MAA Committee on the Mathematical Education of Teachers (COMET) invites you to a networking event on creating experiences for pre-service and in-service math teachers. As we strive to actively engage teachers and pre-service teachers in meaningful and engaging mathematical activities, the sharing of ideas and what works across campuses is crucial. Please bring your thoughts, ideas, and your lunch for this roundtable discussion This session is sponsored by the MAA Committee on the Mathematical Education of Teachers (COMET).

MAA Panel: Career Trajectories Involving Administrative Roles: What You May Want to Consider, organized by **Ryan Zerr**, University of North Dakota, and **Edward Aboufadel**, Grand Valley State University; Friday, 2:35–3:55 pm. Because a move into administration can involve a major change in a mathematician's career trajectory, and require a variety of skills that may differ from those which have led to prior success, this panel discussion will solicit the advice and perspectives of mathematicians with administrative experience. What was their path to an administrative position? What are their responsibilities, and which new skills or abilities are required for success? Has their mathematical training helped them in their administrative roles? What impact has the move had on their teaching or research agendas? What can be expected upon a return to the non-administrative ranks? Topics such as these will be explored by the panelists. Panelists are **Edward Aboufadel**, Grand Valley State University, **Linda Braddy**, Tarrant County College, **Jenna Carpenter**, Campbell University, **Rick Gillman**, Valparaiso University and **Jennifer Quinn**, University of Washington Tacoma. This panel is sponsored by MAA Project NExT.

MAA Student Poster Session, organized by **Chasen Smith**, Georgia Southern University, and **Eric Ruggieri**, College of the Holy Cross; Friday, 4:30–6:00 pm. This session features research done by undergraduate students. First-year graduate students are eligible to present if their research was completed while they were still undergraduates. Research by high school students can be accepted if the research was conducted under the supervision of a faculty member at a post-secondary institution.

Appropriate content for a poster includes, but is not limited to, a new result, a new proof of a known result, a new mathematical model, an innovative solution to a Putnam problem, or a method of solution to an applied problem. Purely expository material is not appropriate for this session.

Participants should submit an abstract describing their research in 250 words or less by midnight, Friday, **October 6, 2017**. Notification of acceptance or rejection will be sent by **November 3, 2017**. See `www.maa.org/programs/students/undergraduate-research/jmm-student-poster-session` for further information on what should be included in the abstract and a link to the abstract submission form.

Posters will be judged during the session, and certificates will be mailed to presenters afterwards. Trifold, self-standing 48" by 36" tabletop poster boards will be provided. Additional materials and equipment are the responsibility of the presenters. Participants must set up posters between 2:30 and 3:30 pm and must be available at their posters from 3:30 to 6:00 pm Judging will begin at

3:30 pm, and general viewing will begin at 4:30 pm Judges' feedback will be available at the MAA Pavilion in the Exhibit Hall on Saturday. Questions regarding this session should be directed to Eric Ruggieri eruggier@holycross.edu and Chasen Smith csmith@georgiasouthern.edu. This session is sponsored by the MAA Committee on Undergraduate Student Activities and Chapters (CUSAC).

MAA Panel: the Evolving Career Outlook in Risk Management, organized by **Kevin Charlwood**, Washburn University, **Michelle Guan**, Indiana University Northwest, **Steve Paris**, Florida State University, **Barry Smith**, Lebanon Valley College, **Sue Staples**, Texas Christian University and **Rick Gorvett**, Casualty Actuary Society (CASACT); Friday, 5:00–7:00 pm. In recent years, many businesses have been hiring actuaries for data mining, predictive analytics, and many risk management tasks beyond the traditional financial or insurance based actuarial careers. Our panelists from the actuarial industry will examine possible directions where the actuarial profession may be headed and provide examples of new career options for actuarial students. For instance, opportunities in managing risk from cyber theft, from climate change, and from automated processes such as self-driving cars, may be discussed. As those in the audience are largely from academia, panelists from actuarial programs will then discuss how actuarial science programs at post-secondary institutions should respond in educating students to take positions in the future career climate. Representatives from the Society of Actuaries and the Casualty Actuary Society will also be present to discuss changes to the curriculum and associated professional exams. Panelists are **Paul Bailey**, Willis Towers Watson, **Raya Feldman**, University of California Santa Barbara, **Zoe Rico**, Aon and **Barry Smith**, Lebanon Valley College. This panel is sponsored by the MAA Committee on Actuarial Science Education.

Mathematically Bent Theater, featuring **Colin Adams** and the **Mobiusbandaid Players**; Friday, 6:00–7:00 pm. What does it mean when someone says to you, "You are such an asymptote?" Is the plural of squadron squadra? After Alice Silverberg's plenary talk at the Atlanta Joint Meetings, did you inadvertently walk off with my complimentary meeting bag containing my gummy bears and my entire worked out schedule for the meeting? These are just a few of the questions we will not answer in this theatrical presentation of several short mathematically inclined humorous pieces. The only prerequisite is a willingness to throw money rather than tomatoes.

Backgammon! organized by **Arthur Benjamin**, Harvey Mudd College; Friday, 8:00–10:00 pm. Learn to play backgammon from expert players. It's a fun and exciting game where players with a good mathematics background have a decisive advantage. Boards and free lessons will be provided by members of the US Backgammon Federation. Stop by anytime!

MAA Panel: Student Perspectives and Feedback on REUs, organized by **Gareth E. Roberts,** College of the Holy Cross, **Thomas P. Wakefield**, Youngstown State University; and **Aklilu Zeleke**, Michigan State University; Saturday, 9:00–10:20 am. REU (Research Experience for Undergraduates) programs provide an important opportunity for undergraduates to gain valuable experience conducting mathematical research. This panel will explore REUs from the student's viewpoint. Recent attendees of summer research programs in mathematics will share their experiences, offer feedback, and provide insight into these programs. Students will discuss the benefits of participating in a summer research program, the impact it had on their academics and career planning, the challenges that arose, particular aspects of their programs that worked well, and places for improvement. This panel discussion is pertinent to both students interested in participating in an REU as well as faculty who have worked in or led such programs.Panelists are **Alexander Durbin**, Virginia Polytechnic Institute; **Kathryn Leonard**, California State University Channel Islands and **Emily Winn**, Brown University. Sponsored by the MAA Subcommittee on Research by Undergraduates.

Interactive Lecture for Students and Teachers: Mathematics to the Rescue: How to Fold a Tie, organized by **Elgin Johnston**, Iowa State University; Saturday,10:00 –10:50 am Presenter, **James Tanton**, MAA Mathematician at Large, welcomes students of all ages, and teachers, parents, mathematicians, and math enthusiasts of all ages. James Tanton explains "I have a personal problem. I travel a great deal and often have to pack a tie in my suitcase. I can't lay the tie out flat in the case, nor can I fold the tie in half and lay out the folded tie, as the case is too short. Folding the tie into quarters leaves a crease mark later visible on my chest. Ideally, I should fold my tie into perfect thirds. How does one do that? Actually, years of careful data gathering shows that I tend to wear my ties with twenty-seven sixty-fourths of their length showing at front. Can I fold my tie at that positon? Fortunately, brilliant mathematics can solve my personal tie folding problem. Let me show you how! (And can this mathematics solve other problems in my life too?)" Sponsored by the MAA Council on Outreach.

MAA Panel: Tips and Tricks to Securing Funding for Undergraduate Research, organized by **James P. Solazzo**, Coastal Carolina University and **Pamela E. Harris**, Williams College; Saturday, 10:35–11:55 am. Undergraduate research in mathematics has gained immense popularity and support from math faculty and administrators across institutions in the last decade. This growth stems from the many benefits of undergraduate research, such as successful transitions into graduate programs and job preparation for non-academic careers in industry and government. Faculty in this panel share their experiences, offer feedback, and provide insight into the grant writing process needed to secure funding for undergraduate research. Funding opportunities as well as strategies for submitting competitive grant proposals will be discussed. This panel is pertinent to all faculty interested in learning about finding and obtaining funding for undergraduate research. Panelists include faculty members who have received grants to support undergraduate research and

includes faculty who have run successful undergraduate research programs. Panelists are **Michael Dorff**, Brigham Young University, **Tamas Forgacs**, California State University Fresno, **Rebecca Garcia**, Sam Houston State University, **Leslie Hogben**, Iowa State University and **Cindy Wyels**, California State University Channel Islands. This panel is sponsored by the MAA Subcommittee on Research by Undergraduates.

MAA Panel: The Impact of Software on Learning in Upper Division Mathematics Courses, organized by **Brittany Bannish**, **Liz Lane-Harvard** and **Sean Laverty**, University of Central Oklahoma; Saturday, 1:00–2:20 pm. Computer labs are used to enhance a variety of college mathematics courses, but effectively implementing computer activities can be difficult. This panel session will focus on using mathematical software to facilitate teaching and learning in upper division mathematics courses. In particular, the session will focus on the incorporation of computer labs in Differential Equations, Linear Algebra, and Numerical Methods. Panelists will address available software options, how to successfully manage a wide range of student programming backgrounds, how to implement a lab for credit (or not for credit), whether students are allowed to work in groups, and lab write-up requirements. Panelists may also share difficulties encountered while implementing and assessing computer activities, and provide suggestions for avoiding these issues in the future. Audience members should come away from the panel with concrete ideas for successfully including computer activities in upper division math courses. Panelists are **Robert Buchanan**, Millersville University, **Sean Laverty**, University of Central Oklahoma, **Steven Leon**, University of Massachusetts Dartmouth, **Frank Lynch**, Eastern Washington University and **Ann Stewart**, Hood College.

Math Circle Demonstration, organized by **Alessandra Pantano**, University of California Irvine and **Amanda Serenevy**, Riverbend Community Math Center; Saturday morning. A math circle is an enrichment experience that brings mathematics professionals in direct contact with pre-college students and/or their teachers. Circles foster passion and excitement for deep mathematics. This demonstration session offers the opportunity for conference attendees to observe and then discuss a math circle experience designed for local students. While students are engaged in a mathematical investigation, mathematicians will have a discussion focused on appreciating and better understanding the organic and creative process of learning that circles offer, and on the logistics and dynamics of running an effective circle. The sponsor for this demonstration is SIGMAA MCST.

Math Wrangle, organized by **Ed Keppelmann**, University of Nevada Reno and **Phil Yasskin**, Texas A&M University, Saturday afternoon. The Math Wrangle will pit teams of students against each other, the clock, and a slate of great math problems. The format of a Math Wrangle is designed to engage students in mathematical problem solving, promote effective teamwork, provide a venue for oral presentations, and develop critical listening skills. A Math Wrangle incorporates elements of team sports and debate, with a dose of strategy tossed in for good measure. The intention of the Math Wrangle demonstration at the Joint Math Meetings is to show how teachers, schools, circles, and clubs can get students started in this exciting combination of mathematical problem solving with careful argumentation via public speaking, strategy and rebuttal. Sponsors for this event is SIGMAA for Math Circles for Students and Teachers (SIGMAA-MCST).

Special Interest Groups of the MAA (SIGMAAs)

SIGMAAs will be hosting a number of activities, sessions, and guest lectures. There are currently fourteen such focus groups in the MAA offering members opportunities to interact, not only at meetings, but throughout the year, via newsletters and email-based communications. For more information visit `www.maa.org/community/sigmaas`.

SIGMAA Officers Meeting, Thursday, 10:30 am–noon; chaired by **Andrew Miller**, Belmont University.

SIGMAA on Mathematics and the Arts (SIGMAA ARTS)

Arts and Mathematics: The Interface, Wednesday morning and afternoon (see MAA Contributed Paper Sessions).

SIGMAA on Business, Industry, and Government (BIG SIGMAA)

MAA-AMS-SIAM Joint Panel on Multiple Paths to Mathematics Careers in Business, Industry and Government (BIG), Thursday, 2:35–3:55 pm (see MAA Panels).

Mathematics Experiences and Projects in Business, Industry, and Government, Friday morning (see MAA Contributed Paper Sessions).

Guest Lecture, Friday, 5:30–6:20 pm.

Reception, Friday 6:30–7:00 pm.

Business Meeting, Friday 7:00–7:30 pm.

SIGMAA on Mathematical and Computational Biology (BIO SIGMAA)

Business Meeting and Reception, Thursday, 6:00–7:00 pm.

Guest Lecture, Thursday, 7:00–7:50 pm, **Trey Ideker**, University of California San Diego, Towards construction of a siri of the cell.

Trends in Undergraduate Mathematical Biology Education, Thursday morning (see MAA Contributed Papers Section).

Trends in Mathematical and Computational Biology, Wednesday morning (see MAA Invited Paper Sessions).

SIGMAA on Environmental Mathematics (SIGMAA EM)

Modeling and Understanding Environmental Risks, Thursday morning (see MAA Contributed Paper Sessions).

SIGMAA on the History of Mathematics (HOM SIGMAA)

Reception and Business Meeting, Wednesday, 6:00–7:00 pm.

Guest Lecture, Wednesday, 7:00–7:50 pm, **Joseph W. Dauben**, Herbert H. Lehman College, *The history of Chinese mathematics: 60th anniversary of the founding of the IHNS (CAS), Beijing.*

MAA Minicourse: Teaching Undergraduate Mathematics via Primary Source Projects, Part A: Thursday

1:00–3:00 pm and Part B: Saturday 1:00–3:00 pm (see MAA Minicourses).

SIGMAA on Inquiry Based Learning (SIGMAA IBL)

Inquiry-Based Teaching and Learning, Friday morning and afternoon (see MAA Contributed Paper Sessions).

SIGMAA on Math Circles for Students and Teachers (SIGMAA MCST)

Math Circle Topics with Visual or Kinesthetic Components, Thursday afternoon (see MAA Contributed Paper Sessions).

Math Circle Demonstration, Saturday.

Math Wrangle, Saturday.

MAA Minicourse: How to Run Successful Math Circles for Students and Teachers, Part A: Wednesday 2:15–4:15 pm and Part B: Friday 1:00–3:00 pm (see MAA Minicourses).

SIGMAA on the Philosophy of Mathematics (POM SIGMAA)

Reception, Thursday, 5:30–6:00 pm.

Business Meeting, Thursday, 6:00–6:15 pm.

Guest Lecture, Thursday, 6:15–7:05 pm, **Rafael Núñez**, University of California San Diego, *Towards a philosophy of mathematics informed by the sciences of the mind.*

Philosophy of Mathematics as Actually Practiced, Friday morning (see MAA Contributed Paper Sessions).

SIGMAA on Quantitative Literacy (SIGMAA QL)

Quantitative Literacy Across the Curriculum, Saturday morning (see MAA Contributed Paper Sessions).

MAA Panel: Ethics, Morality and Politics in the Quantitative Literacy Classroom, Wednesday, 2:15–3:35 pm (see MAA Panels).

SIGMAA on Research in Undergraduate Mathematics Education (SIGMAA on RUME)

Research in Undergraduate Mathematics Education, Thursday morning and afternoon (see MAA Contributed Paper Sessions).

Research in Undergraduate Mathematics Education: Highlights from the Annual SIGMAA on RUME Conference, Saturday morning (see MAA Invited Paper Sessions).

SIGMAA on Statistics Education (SIGMAA Stat Ed)

A Mathematician Teaches Statistics: The Road Less Traveled, Wednesday, 3:50–5:10 pm (see MAA Panels).

MAA Minicourse: Teaching Introductory Statistics Using the Guidelines from the American Statistical Association, Part A: Wednesday 9:00–11:00 am and Part B: Friday 9:00–11:00 am (see MAA Minicourses).

MAA Minicourse: Teaching Statistics using R and RStudio, Part A: Thursday 9:00–11:00 am and Part B: Saturday 9:00 –11:00 am (see MAA Minicourses).

Incorporating Big Data Ideas in the Mathematics and Statistics Classroom, Thursday afternoon (see MAA Contributed Paper Sessions).

Technology and Resources for Teaching Statistics, Friday afternoon (see MAA Contributed Paper Sessions).

Reception, Friday, 5:30–6:00 pm.

Business Meeting, Friday, 6:00–6:45 pm.

Guest Lecture, Friday, 6:50–7:40 pm, **Robert Gould**, University of California Los Angeles, *We are all data scientists (or we should be).*

SIGMAA on Mathematics Instruction Using the Web (WEB SIGMAA)

Reception, Friday, 5:30–6:00 pm.

Guest Lecture, Friday, 6:00–6:50 pm, **Jim Fowler** and **Bart Snapp**, Ohio State University, *Using Ximera to build online interactive math activities.*

The Advancement of Open Educational Resources, Friday morning (see MAA Contributed Papers Section).

Lightning Talks and E-Posters: Me and My Gadgets, Teaching with Technology, Saturday morning (see MAA Contributed Paper Sessions).

MAA Sessions for Students

Radical Dash! organized by **Stacey Muir**, University of Scranton, and **Janine Janoski**, Kings College; **Radical Dash Kickoff Meeting:** Wednesday, 2:15–3:00 pm and **Radical Dash Prize Session:** Friday, 10:30–11:00 am. The Radical Dash is a multi-day scavenger hunt for teams of undergraduates filled with math challenges and creative activities. Clues will be released periodically via Instagram (follow us now @MAARadicalDash) tasking teams with doing things such as solving math problems, finding mathematical objects in everyday life, and hunting down locations throughout the conference. Team posts will be judged based on completion of tasks as well as creativity. Join us for the Radical Dash Kickoff on Wednesday, January 10, 2:15–3:00 pm where team sign ups take place and more details will be provided. Individuals are welcome and encouraged to participate; they will be formed into teams on site at our Kickoff. Winners and prizes will be announced at the Radical Dash Prize Session on Friday, January 12, 10:30–11:00 am. Questions? Email us at `MAARadicalDash@gmail.com`. Can't make the Kickoff? Email us by Tuesday, January 9. The Radical Dash! is sponsored by MAA Committee on Undergraduate Student Activities and Sections (CUSAC).

MAA Panel: What Every Student Should Know about the JMM, organized by **Violeta Vasilevska**, Utah Valley University; Wednesday, 9:35–10:55 am. Navigating a large conference can be overwhelming, even for those who have previously attended such an event. Panelists will provide guidance for students attending the Joint Mathematics Meetings, including answers to some common questions: How do I get the most out of the program? What sessions are especially for students? What other events should I be on the lookout for? Will I understand any of the invited addresses or should I not bother attending them? If I am presenting a poster, where do I go to set it up? How can I get some cool, free math stuff? Students and their faculty mentors are encouraged to attend. Panelists are **Joyati Debnath,** Winona State University, **Michael Dorff**, Brigham Young University and **Frank Morgan**, Williams College. This panel is sponsored by the MAA Committee for Undergraduate Student Activities and Chapters (CUSAC).

Estimathon!, organized by **Andy Niedermaier**, Jane Street Capital; Thursday, 2:30–4:15 pm. They're called Fermi problems...

- How heavy is the Eiffel Tower?

- How many prime numbers have distinct digits?
- How many calories would you be eating if you had "one of everything" at the Cheesecake Factory?

If you're looking for a mindbending mixture of math and trivia, look no further! Jane Street Capital presents The Estimathon contest: teams will have 30 minutes to work on 13 problems, ranging from totally trivial to positively Putnamesque. Can your team beat the all-time best score? The top teams will receive prizes!

We will run 2 contests. Feel free to show up to either one!

(Please show up 15 minutes before the start time of the contest you want to join.)

Our target schedule is as follows:

2:30 pm Welcome, overview of rules and scoring.

2:45 pm Estimathon contest #1

3:30 pm Estimathon contest #2

Grad School Fair, Friday, 8:30–10:30 am. Here is the opportunity for undergrads to meet representatives from mathematical sciences graduate programs from universities all over the country. January is a great time for juniors to learn more, and college seniors may still be able to refine their search. This is your chance for one-stop shopping in the graduate school market. At last year's meeting over 300 students met with representatives from 60 graduate programs. If your school has a graduate program and you are interested in participating, for US$125 a table will be provided for your posters and printed materials (**registration for this event must be made by a person already registered for the JMM**), and you are welcome to personally speak to interested students. Complimentary coffee will be served. Co-sponsored by the AMS and MAA.

MAA Lecture for Students, Friday, 1:00–1:50 pm, will be given by **James Tanton**, MAA Mathematician at Large, *HOW MANY DEGREES ARE IN A MARTIAN CIRCLE? And other human—and nonhuman—questions one should ask about everyday mathematics.*

MAA Student Poster Session, organized by **Chasen Smith**, Georgia Southern University and **Eric Ruggieri**, College of the Holy Cross; Friday, 4:30–6:00 pm. This session features research done by undergraduate students. First-year graduate students are eligible to present if their research was completed while they were still undergraduates. Research by high school students can be accepted if the research was conducted under the supervision of a faculty member at a post-secondary institution.

Appropriate content for a poster includes, but is not limited to, a new result, a new proof of a known result, a new mathematical model, an innovative solution to a Putnam problem, or a method of solution to an applied problem. Purely expository material is not appropriate for this session.

Participants should submit an abstract describing their research in 250 words or less by midnight, Friday, **October 6, 2017**. Notification of acceptance or rejection will be sent by **November 3, 2017**. See `www.maa.org/programs/students/undergraduate-research/jmm-student-poster-session` for further information on what should be included in the abstract and a link to the abstract submission form.

Posters will be judged during the session, and certificates will be mailed to presenters afterwards. Trifold, self-standing 48" by 36" tabletop poster boards will be provided. Additional materials and equipment are the responsibility of the presenters. Participants must set up posters between 2:30 and 3:30 pm and must be available at their posters from 3:30 to 6:00 pm. Judging will begin at 3:30 pm, and general viewing will begin at 4:30 pm. udges' feedback will be available at the MAA Pavilion in the Exhibit Hall on Saturday. Questions regarding this session should be directed to Eric Ruggieri `eruggier@holycross.edu` and Chasen Smith `csmith@georgiasouthern.edu`. This session is sponsored by the MAA Committee on Undergraduate Student Activities and Chapters (CUSAC).

Interactive Lecture for Students and Teachers: Mathematics to the Rescue: How to Fold a Tie, organized by **Elgin Johnston**, Iowa State University; Saturday,10:00–10:50 am. Presenter, **James Tanton**, MAA Mathematician at Large, welcomes students of all ages, and teachers, parents, mathematicians, and math enthusiasts of all ages. James Tanton explains: I have a personal problem. I travel a great deal and often have to pack a tie in my suitcase. I can't lay the tie out flat in the case, nor can I fold the tie in half and lay out the folded tie, as the case is too short. Folding the tie into quarters leaves a crease mark later visible on my chest. Ideally, I should fold my tie into perfect thirds. How does one do that? Actually, years of careful data gathering shows that I tend to wear my ties with twenty-seven sixty-fourths of their length showing at front. Can I fold my tie at that positon? Fortunately, brilliant mathematics can solve my personal tie folding problem. Let me show you how! (And can this mathematics solve other problems in my life too?) Sponsored by the MAA Council on Outreach.

Project NExT

Project NExT Workshop, Wednesday–Saturday, 8:00–6:00 pm.

Project NExT Lecture on Teaching, Thursday, 11:10–12 noon, will be given by **Jo Boaler,** Stanford University, *Changing mathematical relationships and mindsets: how all students can succeed in mathematics learning.*

See details about the reception on Friday in Social Events.

Other MAA Events

MAA Congress, Tuesday, 9:00 am–5:00 pm.

MAA Section Officers Meeting, Wednesday, 4:00–5:00 pm, chaired by **Betty Mayfield**, Hood College. Section officers will meet with members of the Committee on Sections and MAA staff to share information and discuss current initiatives.

SIGMAA Officers Meeting, Thursday, 10:30–12:00 noon, chaired by **Andrew Miller**, Belmont University.

MAA Business Meeting, Saturday, 11:10–11:40 am, chaired by MAA President **Deanna Hausperger**, Carleton College, and organized by MAA Secretary **Barbara Faires**, Westminster College.

MAA Workshops

Creating Interdisciplinary Activities for Mathematical Sciences Classrooms, presenters are **Eugene Fiorini** and **Linda McGuire**, Muhlenberg College; Wednesday, 9:35–10:55 am. Mathematics and science education research indicates that to actively engage students, instructors should encourage cooperative learning, present and discuss real-life applications, suggest open-ended questions, and provide higher-order thinking tasks [Verma & Dickerson, Technology and Engineering Teacher, 2011]. In a world with challenges that are complex, dynamic, riddled with uncertainty, and potentially massive in scale, the mathematical and computer sciences have a central role to play by providing tools for analyzing and interpreting massive data sets, models and simulations of complex systems, and designs for future systems that are more efficient and secure. Workshop participants will begin development of one-day modules at the undergraduate level that can then be implemented in their courses. The modules will either focus on topics participants brought with them or topics provided by workshop organizers from such areas related to sustainability, cyber-security, and forensics. The workshop, intended for the novice writer, will include small group writing sessions allowing participant teams to develop common modules.

Get to Know the National Science Foundation, organized by **Ron Buckmire**, **Sandra Richardson** and **Lee Zia**, Division of Undergraduate Education, National Science Foundation; Thursday, 9:00–10:20 am. Presenters will describe the general NSF grant proposal process and consider particular details relevant to programs in the Division of Undergraduate Education. This workshop is geared towards those who have not submitted a proposal to NSF and are unfamiliar with the organization. If you believe you have an idea, project or program worthy of federal support that will positively impact undergraduate education in mathematics you should attend this session. This workshop will provide information on the specific components of a NSF proposal, demonstrate the NSF peer review process, provide access to previously funded proposals and explicate the NSF merit review criteria by which proposals are evaluated. This is intended to be an interactive hands-on session where participants can have their individual questions answered and leave with more information about NSF than they had when they entered.

Hungarian Approach to Teaching Proof-Writing: Pósa's Discovery-Based Pedagogy, organized by **Péter Juhász**, MTA Rényi Institute and Budapest Semesters in Mathematics Education, **Réka Szász**, Budapest Semesters in Mathematics Education and **Ryota Matsuura**, St. Olaf College and Budapest Semesters in Mathematics Education; Thursday, 10:35–11:55 am. Lajos Pósa, a co-author of Erdos, is a Hungarian mathematician and educator. Pósa developed a method of teaching mathematics centered on the idea that students should learn to think like mathematicians. Pósa's pedagogy uses the task thread, or a series of tasks that build on each other and gradually guide students toward understanding. By engaging with these task threads, students discover mathematical concepts through their own work. While Pósa's method was initially intended for gifted students, it has also been successfully implemented in more general school settings. The workshop will begin with a brief introduction on Pósa and his work. Then participants will experience Pósa's method by working on several task threads (intended to introduce secondary students to proof-writing), followed by discussions of the tasks. We will share our experiences of using Pósa's method in Hungarian high school classrooms. Lastly, we will describe Budapest Semesters in Mathematics Education, a study abroad program (in Budapest) in which American students learn about the Hungarian approach to mathematics education, including Pósa's method. The workshop is intended for students and faculty members interested in the learning and teaching of secondary mathematics.

Using Problem Solving and Discussions in Mathematics Courses for Prospective Elementary Teachers, organized by **Ziv Feldman**, Boston University, **Ryota Matsuura**, St Olaf College, **Suzanne Chapin**, Boston University, **Lynsey Gibbons**, Boston University and **Laura Kyser Callis**, Boston University; Thursday, 1:00–2:20 pm. National reports and policy recommendations highlight the importance of deepening pre-service elementary teachers' (PSTs') mathematical understanding and focusing on mathematical knowledge for teaching. This workshop is intended for those who teach mathematics content courses for future elementary teachers. Participants will learn about instructional materials created by the Elementary Mathematics Project (EMP) and funded by NSF. In this curriculum, PSTs engage in recurring cycles of collaborative problem solving, group discussions, and presentations that support the development of mathematical practices such as generalization and justification. Units on whole number concepts/operations and geometry will be explored. Examples of how the curriculum connects mathematical concepts, helps PSTs understand why procedures work, uses mathematical structure and illustrates children's thinking to support learning will be provided. Attendees will examine and solve problems from the curriculum and link content to the Common Core State Standards. They will discuss how to implement the EMP materials using class discussions and presentations. Videos of how instructors enacted the tasks with PSTs will be shared. Opportunities for faculty members to field test materials will be discussed.

Writing Pedagogical and Expository Papers, organized by **Janet Beery**, University of Redlands, **Matt Boelkins**, Grand Valley State University, **Susan Jane Colley**, Oberlin College, **Joanna Ellis-Monaghan**, St Michael's College, **Brian Hopkins**, St. Peter's University, **Michael Jones**, Mathematical Reviews, **Gizem Karaali**, Pomona College,

Marjorie Senechal, Smith College and **Brigitte Servatius**, Worcester Polytechnic Institute; Thursday, 2:35–3:55 pm. This hands-on workshop will be an opportunity for prospective authors to learn directly from journal editors what they look for in papers on mathematical pedagogy and/or expository mathematics for a broad audience. It will be conducted by members of the editorial boards of several journals whose focus includes mathematical pedagogy and general audience exposition: the College Mathematics Journal, Convergence, the Journal of Humanistic Mathematics, Math Intelligencer, Mathematics Magazine, The American Mathematical Monthly, The Pi Mu Epsilon Journal, and PRIMUS (Problems Resources and Issues in Mathematics Undergraduate Studies). Workshop participants are encouraged to bring to the workshop ideas, titles, abstracts, or rough outlines of prospective papers concerned with some aspect of mathematics pedagogy or with expository mathematics for a broad audience. After brief overview presentations, there will be breakout groups where editors will briefly share some primary features of representative papers published in their various journals, and where authors may discuss the specifics of their work in progress. Attendees without specific papers in mind who want to learn more about publishing pedagogical or expository papers are also welcome.rkshop will be for you.

Championing Master's Programs in Mathematics: A Forum for Advocacy, Networking, and Innovation, organized by **Michael O'Sullivan**, San Diego State University, **Nigel Pitt**, University of Maine and **Virgil Pierce**, University of Texas Rio Grande Valley; Thursday, 2:15–4:15 pm. This workshop will give leaders of master's programs an opportunity to share challenges and successes and begin to plan for greater innovation and more robust advocacy for these programs. There is considerable attention given to undergraduate education and to doctoral programs in mathematics, but it seems to the organizers that the challenges facing departments that offer master's degrees are not adequately addressed. Yet, master's programs can be a great source of innovation. We will have a series of round-table discussions with reports backs in two phases. Phase 1 is oriented to assessment of the current status of programs in the country and will address the major challenges that master's programs face as well as successful innovations and ways to address these challenges. It will close by identifying pathways for strengthening master's programs, and set an agenda for the second phase, which will focus on advocacy. How can national mathematics societies and funding agencies provide more support for master's programs? How can we increase and strengthen ties between mathematics departments and business, industry and government? What sort of networking and cooperation among the master's degree institutions should we foster?

Activities of Other Organizations

This section includes scientific sessions. Several organizations or special groups are having receptions or other social events. Please see the "Social Events" section of this announcement for those details.

Association for Symbolic Logic (ASL)

This two-day program on Friday and Saturday will include sessions of contributed papers as well as Invited Addresses by **Cameron Hill**, Wesleyan University, **Antonina Kolokolova**, Memorial University of Newfoundland, **Aristotelis Panagiotopoulos**, California Institute of Technology, **Emily Riehl**, Johns Hopkins University, **Simon Thomas**, Rutgers University, **Sebastien Vasey**, Harvard University and **Keita Yokoyama**, JAIST, Japan.

See also the session cosponsored by ASL on *Set Theory, Logic and Ramsey Theory* on Wednesday morning, Thursday morning and afternoon in the "AMS Special Sessions" listings. Organizers for this session are **Andrés Caicedo**, Mathematical Reviews, and **José Mijares**, University of Colorado, Denver.

Association for Women in Mathematics (AWM)

Thirty-Ninth Annual Noether Lecture, Thursday, 10:05 am, will be given by **Jill Pipher,** Brown University, *Title to be announced.*

Association for Women in Mathematics Panel: Using Mathematics in Activism, organized by **Michelle Manes**, University of Hawaii at Manoa; Wednesday, 2:15–3:40 pm. There is a romantic notion that mathematics is somehow so pure that it is separate from the "real world" and untouched by it. However, mathematicians live in the world and are affected by it, and that in turn affects their work. Many mathematicians tackle problems and issues in their communities, in the country, and in the world. Activism can mean many things: engaging with the general public through social media or through traditional media via op ed pieces and letters to the editor; outreach with marginalized populations; advocacy work in professional organizations; and even mathematical research in the context of social and political justice. Our panelists will share their experiences as activist mathematicians and they will help lead a conversation about what we can each do to effect change around issues we care about. This session is open to all JMM attendees. Panelists include **Federico Ardila**, San Francisco State University, **Piper Harron**, University of Hawaii at Manoa, **Lily Khadjavi**, Loyola Marymount University, **Beth Malmskog**, Villanova University, **Karen Saxe**, American Mathematical Society and other panelists to be announced. `sites.google.com/site/awmpanel2018/`

Business Meeting, Wednesday, 3:45–4:15 pm. Chair, Ami Radunskaya, AWM President.

Association for Women in Mathematics Committee on Education Panel: Supporting, Evaluating and Rewarding Work in Mathematics Education in Mathematical Sciences Departments, organized by **Jacqueline Dewar**, **Pao-sheng Hsu** and **Harriet Pollatsek**, AWM Education Committee; Thursday, 10:30 am–12:00 pm. Many in the mathematical community in the US, in various capacities, are involved in mathematic education at all levels—from supporting K–12 teachers, improving learning of undergraduates to professional

development of graduate students. The panel will discuss the challenges of supporting, evaluating, and rewarding work in mathematics education in departments of mathematical sciences. Panels co-sponsored by AWM Education Committee at the last two JMM focused on highlighting the breadth of work in mathematics education in departments of mathematical sciences. This panel will expand on those discussions by focusing on how such work is valued by the mathematics community. Some panelists, as well as the moderator, will be able to speak from their own administrative experiences, and some from the faculty points of view. Moderator for this panel will be **Minerva Cordero**, University of Texas at Arlington. Panelists include **Jenna Carpenter**, Campbell University, **Rebecca Garcia,** Sam Houston State University, **W. James Lewis**, University of Nebraska—Lincoln and **Thomas Roby**, University of Connecticut.

Workshop Poster Presentations and Reception, Friday, 6:00–7:15 pm. AWM will conduct its workshop poster presentations by women graduate students. AWM seeks volunteers to serve as mentors for workshop participants. If you are interested, please contact the AWM office at awm@awm-math.org. This session is open to all JMM attendees. Organizers for these presentations are **Alina Bucur**, University of California, San Diego, **Matilde Lalin**, University of Montreal and **Radmila Sazdanovic**, North Carolina State University. The Poster Judging Coordinator is **Sylvia Wiegand**, University of Nebraska at Lincoln.

AWM Workshop: Special Session on Noncommutative Algebra and Representation Theory, Saturday, 8:00 am–5:00 pm, AWM will conduct its workshop with presentations by senior and junior women researchers. Updated information about the workshop is available at www.awm-math.org. All JMM attendees are invited to atend the program. Organizers for this workshop are **Anne Shepler**,

University of North Texas and **Sarah Witherspoon**, Texas A&M University.

Reception, Wednesday, 9:30–11:00 pm. See the listing in the "Social Events," section of the announcement.

See also the session cosponsored by the AWM on *Women in Symplectic and Contact Geometry and Topology* on Friday in the "AMS Special Sessions" listings. Organizers for this session are **Bahar Acu**, Northwestern University, **Ziva Myer**, Duke University, and **Yu Pan**, Massachusetts Institute of Technology.

See also the Joint Panel on Wednesday co-sponsored by AWM in the "MAA Panels" listings: ***MAA-JCW-AWM-NAM Panel: Implicit Bias and Its Effects in Mathematics***.

National Association of Mathematicians (NAM)

Granville–Brown–Haynes Session of Presentations by Recent Doctoral Recipients in the Mathematical Sciences, Friday, 1:00–4:00 pm. Organized by **Talitha Washington**, Howard University/NAM.

Cox–Talbot Address, to be given Friday after the banquet by **Erica Walker,** Teachers College, Columbia University, *Hidden in Plain Sight: Mathematics Teaching and Learning Through a Storytelling Lens*. See details about the banquet on Friday in the "Social Events" section.

Panel Discussion: ***Advising Our Students on the Transition to the 1st (or 0th) Year of Graduate School***, Saturday, 9:00–9:50 am. The moderator for this panel will be **Duane Cooper**, Morehouse. Panelists are **Julia Anderson–Lee**, Iowa State University, **Trachette Jackson**, University of Michigan, **Doug Mupasiri**, University of Northern Iowa and **Michael Young**, Iowa State University.

Business Meeting, Saturday, 10:00–10:50 am.

Claytor–Woodward Lecture, Saturday, 1:00 pm, **Ronald Mickens**, Clark Atlanta University, *Nonstandard Finite Different Schemes: Impact, Importnace, and Dynamical Consistency.* See also the Joint Panel on Wednesday co-sponsored by NAM in the "MAA Panels" listings: ***MAA-AWM-NAM-JCW Panel: Implicit Bias and Its Effects in Mathematics***.

National Science Foundation (NSF)

The NSF will be represented at a booth in the exhibit area. NSF staff members will be available to provide counsel and information on NSF programs of interest to mathematicians. The booth is open the same days as the exhibitis. Times that staff will be available will be posted at the booth.

NSF-EHR Grant Proposal Writing Workshop: ***Developing a Competitive Proposal for NSF-EHR***, Monday, 3:00–6:00 pm; advance registration required (see AMS Workshops). ***MAA Panel: NSF Funding Opportunities to Improve Learning and Teaching in the Mathematical Sciences***, Wednesday, 2:15–4:00 pm (See MAA Panels).

Get to Know the National Science Foundation, Thursday, 9:00–10:20 am (see MAA Workshops).

National Science Foundation: Update from the Division of Mathematical Sciences, Friday, 4:00–5:30pm, organized by **Henry Warchall**, Division of Mathematical Sciences, National Science Foundation.

Pi Mu Epsilon (PME)

Council Meeting, Thursday, 8:00–11:00 am.

Rocky Mountain Consortium

Board Meeting, Friday, 2:15–4:00 pm

Society for Industrial and Applied Mathematics (SIAM)

This program consists of an Invited Address, ***Tensor Decompositions: A Mathematical Tool for Data Analysis***, at 11:10 am on Thursday given by **Tamara G. Kolda**, Sandia National Laboratories, and a series of Minisymposia to include ***Data Science in the Mathematics Curriculum***, **Suzanne Weekes**, Worcester Polytechnic Institute; ***Numerical Linear Algebra***, **Daniel B. Szyld**, Temple University and Eugene Vecharynski, **Lawrence Berkeley National Laboratory**; ***Advances in Imaging Science***, **Misha Kilmer,** Tufts University, **Eric de Sturler**, Virginia Polytechnic Institute, **Eric Miller**, Tufts University, and **Avind Saibaba**, North Carolina State University; ***Tensors! Mathematical Challenges and Opportunities***, **David Gleich**, Purdue University, **Tamara G. Kolda**, Sandia National Laboratories,

and **Luke Oeding**, Auburne University; ***Advances in Finite Element Approximation***, **Constantin Bacuta**, University of Delaware, and **Ana Maria Soane**, United States Naval Academy; ***Mimetic Multiphase Subsurface and Oceanic Transport***, **Jose Castillo**, San Diego State University and **Chris Paolini**, San Diego State University; ***Recent advances in modeling, analysis, and control in epidemiology, spatial ecology and evolution***, **Aijun Zhang**, **Vrushali Bokil** and **Patrick Deleenheer**, Oregon State University, and **Carrie Manore**, Los Alamos National Labs; and ***Problems in Quasilinear Dispersive PDE***, **David Ambrose**, Drexel University, **Jeremy Marzuola**, The University of North Carolina at Chapel Hill.

MAA-SIAM-AMS Hrabowski–Gates–Tapia–McBay Session, organized by **Ricardo Cortez**, Tulane University; Wednesday, 9:00–10:20 am. The Hrabowski–Gates–Tapia–McBay Session is named after four influential scientists of color: (1) Freeman Hrabowski, President of the University of Maryland at Baltimore County; (2) James S. Gates, University of Maryland, College Park; (3) Richard Tapia, Rice University; and (4) Shirley McBay, President of Quality Education for Minorities (QEM). Through multiple mechanisms, these Sessions expect to facilitate and accelerate the participation of scientists in the building of sustainable communities of mathematicians and mathematical scientists. In particular, the intention is to systematically recruit, welcome, encourage, mentor, and support individuals from underrepresented groups in the USA. This year the session will consist of a lecture at 9:00 am given by **Talithia Williams**, Harvey Mudd College, ***Mathematics for the Masses***, and a short panel discussion after the talk at 9:50 am. The 2018 panel will focus on ***Access to Quality Mathematics by All***. Panelists and attendees will discuss issues related to removing roadblocks in mathematics education (e.g. Tracking, placement, 'weed out' courses, etc) as well as hiring or award selection practices that tend to favor the majority groups that have influence. Panelists will also address the question: What are the roles and responsibilities do mathematicians and mathematics educators have in creating a just and accessible system? Panelists will include **Ron Buckmire**, NSF, **James Alvarez**, University of Texas at Arlington, and **Talithia Williams**, Harvey Mudd College. This event is sponsored by the MAA Committee on Minority Participation in Mathematics, SIAM and the AMS.

AMS-MAA-SIAM Panel on Multiple Paths to Mathematics Careers in Business, Industry and Government(BIG), organized by **Allen Butler**, Daniel H Wagner Associates, **Rachel Levy**, Harvey Mudd College, **Douglas Mupasiri**, University of Northern Iowa and **Suzanne Weekes**, Worcester Polytechnic Institute; Thursday, 2:35–3:55 pm. The proportion of new mathematics doctoral recipients who are taking jobs in business, industry and government (BIG) is growing. Still, many mathematics PhD programs do not include preparation for non-academic career options as part of their standard curriculum. At this panel, you will have the opportunity to hear about multiple career paths to employment in BIG. Panelists will share (a) what they wish they had known and done as graduate students/postdocs, (b) what you can do at your career stage if you are interested in making connections with business, industry or government, and (c) what suggestions they have for math doctoral programs to increase preparedness of their students for work in BIG. Co-sponsors for this panel are AMS, MAA, and SIAM.

See also the AMS-MAA-SIAM Special Session on *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs on* Wednesday morning, Thursday afternoon, Saturday morning and afternoon in the "AMS Special Session" listings. The organizers for this session are **Tamas Forgacs**, CSU Fresno, **Darren A. Narayan**, Rochester Institute of Technology, and **Mark David Ward**, Purdue University.

Other events

MAA-JCW-AWM-NAM Panel: Implicit Bias and Its Effects in Mathematics, organized by **Semra Kilic-Bahi**, Colby-Sawyer College, **Maura Mast**, Fordham College at Rose Hill, **Naomi Cameron**, Lewis & Clark College, **Andrew Cahoon**, Colby-Sawyer College, and **Charles Doering**, University of Michigan; Wednesday, 4:15–5:35 pm. Implicit bias occurs when someone explicitly rejects stereotypes and prejudices, but unconsciously holds negative (mostly) associations. People are not hiding their prejudices, but rather, they just do not know they have these unconscious feelings or thoughts that affect their decision-making and behavior. Social scientists are identifying implicit biases as one of the most pervasive barriers to equal opportunities for minorities and women in today's society. This panel discussion addresses how implicit bias might manifest and affect our classrooms, departments, and campuses in terms of academic and scholarly opportunities and evaluations. Panelists are **Ron Buckmire**, National Science Foundation, **Jenna P. Carpenter**, Campbell University, **Lynn Garrioch**, Colby-Sawyer College, **Joanna Kania-Bartoszynska**, National Science Foundation, and **Francis Edward Su**, Harvey Mudd College. This panel is sponsored by the MAA Committee on the Participation of Women in Mathematics; Committee on the Minority Participation in Mathematics; Association for Women in Mathematics; National Association of Mathematicians; and the Joint Committee on the Participation of Women in Mathematics.

Mathematical Art Exhibition, organized by **Robert Fathauer**, Tessellations Company, **Nathan Selikoff**, Digital Awakening Studios, and **Elizabeth Whiteley**, studio artist, Washington, DC, and supported by the Special Interest Group of the MAA for Mathematics and the Arts, and the Bridges Organization. A popular feature at the Joint Mathematics Meetings, this exhibition provides a break in your day. On display are works in various media by artists who are inspired by mathematics and by mathematicians who use visual art to express their findings. Topology, fractals, polyhedra, and tiling are some of the ideas at play here. Do not miss this unique opportunity for a different perspective on mathematics. The exhibition will be located

inside the Joint Mathematics Exhibits and open during the same exhibit hours.

Summer Program for Women in Mathematics (SPWM) Reunion, organized by **Murli M. Gupta**, George Washington University; Thursday, 1:00–3:00 pm. This is a reunion of the summer program participants from all 19 years (1995–2013) who are in various states of their mathematical careers: some are students and, others are in various jobs, both in academia as well as government and industry. The participants will describe their experiences relating to all aspects of their careers. There will also be a discussion on the increasing participation of women in mathematics over the past two decades and the national impact of SPWM and similar programs. See `www.gwu.edu/~spwm`.

Mathemati-Con

Events will take place on Saturday, January 13 between 9:00 am and 4:00 pm in a variety of locations at the JMM.

Some special presentations slated to be included in this program are the Who Wants to Be a Mathematician Championship, demonstrations of both Math Circles and Math Wrangles provided by the MAA SIGMAA on Math Circles for Students and Teachers, an Interactive Lecture for Teachers and Students presented by James Tanton, the 2018 Mathematical Art Exhibition, and much more, concluding with the MAA-AMS-SIAM Gerald and Judith Porter Public Lecture "Political Geometry: Voting Districts, 'Compactness,' and Ideas About Fairness," by Moon Duchin, Tufts University. All events on the Mathemati-Con program are open to the public.

Mathematical Art Exhibition, organized by **Robert Fathauer**, Tessellations Company; **Nathan Selikoff**, Digital Awakening Studios, and **Elizabeth Whiteley**, studio artist, Washington, DC, and supported by the Special Interest Group of the MAA for Mathematics and the Arts, and the Bridges Organization. A popular feature at the Joint Mathematics Meetings, this exhibition provides a break in your day. On display are works in various media by artists who are inspired by mathematics and by mathematicians who use visual art to express their findings. Topology, fractals, polyhedra, and tiling are some of the ideas at play here. Do not miss this unique opportunity for a different perspective on mathematics. The exhibition will be located inside the Joint Mathematics Exhibits and open during the same exhibit hours.

Interactive Lecture for Students and Teachers: Mathematics to the Rescue: How to Fold a Tie, organized by **Elgin Johnston**, Iowa State University; Saturday,10:00 –10:50 am. Presenter, **James Tanton**, MAA Mathematician at Large, welcomes students of all ages, and teachers, parents, mathematicians, and math enthusiasts of all ages. James Tanton explains: I have a personal problem. I travel a great deal and often have to pack a tie in my suitcase. I can't lay the tie out flat in the case, nor can I fold the tie in half and lay out the folded tie, as the case is too short. Folding the tie into quarters leaves a crease mark later visible on my chest. Ideally, I should fold my tie into perfect thirds. How does one do that? Actually, years of careful data gathering shows that I tend to wear my ties with twenty-seven sixty-fourths of their length showing at front. Can I fold my tie at that positon? Fortunately, brilliant mathematics can solve my personal tie folding problem. Let me show you how! (And can this mathematics solve other problems in my life too?) Sponsored by the MAA Council on Outreach.

Who Wants to Be a Mathematician Championship, organized by **Michael A. Breen**, American Mathematical Society, and **William T. Butterworth**, DePaul University; Saturday, 1:00 pm–2:45 pm. Show your support for top high school students from the US, Canada, and the UK in the first international Who Wants to Be a Mathematician as they compete for a US$5,000 first prize for themselves and US$5,000 for their school's math department. Semifinals are at 1:00 pm and finals are at 2:00 pm. Come match wits with the contestants and support their mathematical achievement.

Math Circle Demonstration, organized by **Alessandra Pantano**, University of California Irvine, and **Amanda Serenevy**, Riverbend Community Math Center; Saturday-morning. A math circle is an enrichment experience that brings mathematics professionals in direct contact with pre-college students and/or their teachers. Circles foster passion and excitement for deep mathematics. This demonstration session offers the opportunity for conference attendees to observe and then discuss a math circle experience designed for local students. While students are engaged in a mathematical investigation, mathematicians will have a discussion focused on appreciating and better understanding the organic and creative process of learning that circles offer, and on the logistics and dynamics of running an effective circle. The sponsor for this demonstration is SIGMAA MCST.

Math Wrangle, organized by **Ed Keppelmann**, University of Nevada Reno, and **Phil Yasskin**, Texas A&M University, Saturday afternoon. The Math Wrangle will pit teams of students against each other, the clock, and a slate of great math problems. The format of a Math Wrangle is designed to engage students in mathematical problem solving, promote effective teamwork, provide a venue for oral presentations, and develop critical listening skills. A Math Wrangle incorporates elements of team sports and debate, with a dose of strategy tossed in for good measure. The intention of the Math Wrangle demonstration at the Joint Math Meetings is to show how teachers, schools, circles, and clubs can get students started in this exciting combination of mathematical problem solving with careful argumentation via public speaking, strategy and rebuttal. Sponsors for this event is SIGMAA for Math Circles for Students and Teachers (SIGMAA-MCST).

Moon Duchin, Tufts University, *Political Geometry: Voting districts, "compactness," and ideas about fairness,* (MAA-AMS-SIAM Gerald and Judith Porter Public Lecture); Saturday, 3:00 pm.

Welcoming Environment Policy

The AMS and MAA strive to ensure that participants in the Joint Mathematics Meetings (JMM) enjoy a welcoming environment. In all JMM activities, the two organizations

seek to foster an atmosphere that encourages the free expression and exchange of ideas. The AMS and MAA support equality of opportunity and treatment for all participants, regardless of gender, gender identity or expression, race, color, national or ethnic origin, religion or religious belief, age, marital status, sexual orientation, disabilities, or veteran status.

Harassment is a form of misconduct that undermines the integrity of JMM activities as well as the AMS and MAA missions. The AMS and MAA will make every effort to maintain an environment that is free of harassment, even though they do not control the behavior of third parties. A commitment to a welcoming environment is expected of all attendees at JMM activities, including mathematicians, students, guests, staff, contractors and exhibitors, and participants in scientific sessions and social events. To this end, the AMS and MAA will include a statement concerning their expectations toward maintaining a welcoming environment in registration materials, and have put in place a mechanism for reporting violations. Violations may be reported confidentially and anonymously to 855-282-5703 or at `www.mathsociety.ethicspoint.com`. The reporting mechanism ensures the respect of privacy while alerting the AMS and MAA to the situation.

Exhibits

The Joint Mathematics Meetings Exhibits include the country's leading scientific publishers, professional organizations, companies that offer mathematics-enrichment products and services, computer hardware and software companies, and the Mathematical Art Exhibit. It will be open to all registered participants on Wednesday (starting with the Grand Opening) 12:15 pm–5:30 pm, on Thursday and Friday 9:30 am–5:30 pm and on Saturday 9:00 a–noon. See more details at `jointmathematicsmeetings.org`.

AMS Book Sales and Membership: The American Mathematical Society booth, located in the Exhibit Hall, is where attendees will find the latest AMS titles, fun giveaways, mathematics awareness materials, and information about programs available to the mathematical community. Make sure to visit the booth to track your Mathematical Geneaology or attend a demonstration of MathSciNet, both offered daily throughout the meeting.

If you join the AMS or renew your membership during the meeting, you will receive a complimentary gift and will be able to start using your member discount on AMS titles right away. Make sure to ask about our new membership benefit, free shipping on all purchases, not just at meetings but also on orders placed online, phoned in, faxed, or sent via postal mail. This year, as an exclusive member benefit, the AMS Membership Department has arranged for a photographer to take professional portraits that will be available electronically within minutes. Visit `amermathsoc.simplybook.me` to schedule an appointment.

Attendees are invited to the booth to see the unveiling of the AMS's new logo. While you're there, take advantage of the special exhibit discounts that will be offered on most AMS titles, 40% off list price for members and 25% off for all other attendees. All orders that are purchased on-site are eligible for free shipping.

MAA Book Sales and Membership: Join fellow mathematicians in the exhibit hall at the Mathematical Association of America Pavillion, Booth 120. Take a break in our lounge, find your dream job with the MAA Career Resource Center, talk to staff about programs and resources for your research and classroom, renew your membership, and learn how **MAA advances the understanding of mathematics and its impact on our world.**

Mathematical Art Exhibit: This exhibit is organized by **Robert Fathauer**, Tessellations Company, **Nathan Selikoff**, Digital Awakening Studios, and **Elizabeth Whiteley**, studio artist, Washington, DC, and supported by the Special Interest Group of the MAA for Mathematics and the Arts, and the Bridges Organization. A popular feature at the Joint Mathematics Meetings, this exhibition provides a break in your day. On display are works in various media by artists who are inspired by mathematics and by mathematicians who use visual art to express their findings. Topology, fractals, polyhedra, and tiling are some of the ideas at play here. Do not miss this unique opportunity for a different perspective on mathematics. The exhibition will be located inside the Joint Mathematics Exhibits and open during the same exhibit hours.

Joint Mathematics Meetings

January 10-13, 2018
San Diego Convention Center

HOTELS

1. Marriott Marquis San Diego Marina
2. Embassy Suites San Diego Bay - Downtown
3. Manchester Grand Hyatt San Diego
4. Omni San Diego Hotel
5. Hilton San Diego Gaslamp Quarter
6. Hard Rock Hotel San Diego
7. Best Western Plus Bayside Inn
8. Hotel Solamar
9. Hotel Palomar San Diego
10. Horton Grand Hotel
11. Porto Vista Hotel

1.25 in. approx. = 1500 ft
2 cm approx. = 288 meters

Hotel Accomodations

The importance of reserving a hotel room at one of the official Joint Mathematics Meetings (JMM) hotels cannot be stressed enough. The AMS and the MAA make every effort to keep participants expenses at the meeting, registration fees, and hotel rooms for the meeting as low as possible. They work hard to negotiate the best hotel rates and to make the best use of your registration dollars to keep the meetings affordable. The AMS and MAA encourage all participants to register for the meeting. When anyone pays the registration fee and reserves a room with an official JMM hotel, he or she is helping to support not only the JMM in 2018, but also future meetings.

General: Participants are encouraged to register for the JMM in order to reserve hotel rooms at the contracted JMM rates. If a participant needs to reserve a hotel room before they are registered for the JMM, he or she must contact the Mathematics Meetings Services Bureau (MMSB) at mmsb@ams.org or 1-800-321-4267 ext. 4137 or ext. 4144 for further instructions.

Special rates have been negotiated exclusively for this meeting at the following hotels:
Marriott Marquis San Diego Marina, Embassy Suites Hotel San Diego Bay, Manchester Grand Hyatt San Diego, Omni Hotel San Diego, Hilton Gaslamp San Diego, Hard Rock Hotel San Diego, Best Western Plus Bayside Inn, Solamar Hotel San Diego, Palomar Hotel San Diego, Horton Grand Hotel, and Porto Vista Hotel. (See details on these hotels below.)

To receive the JMM rates, reservations for these hotels must be made through the MMSB. The hotels will not be able to accept reservations directly until after **December 15, 2017**, and at that time, rooms and rates will be based on availability. Any rooms reserved directly with the hotels after **December 15, 2017** are subject to rates higher than the JMM rates.

A link to the 2018 JMM housing site will be included in the email confirmations of all registrations. If a participant needs to have the link emailed to him or her, please send the request to mmsb@ams.org. If anyone is having problems reserving a hotel room, please send email to mmsb@ams.org.

Any participant who needs to reserve a hotel room and does not have a credit card, he or she should contact the MMSB at mmsb@ams.org for further instructions. If a check is being used to reserve a hotel room, the reservation and check must be received by the MMSB no later than **December 5, 2017**.

ADA Accessibility: We strive to take the appropriate steps required to ensure that no individual with a disability is excluded, denied services, segregated, or otherwise treated differently. If special assistance, auxiliary aids, or other reasonable accommodations to fully participate in this meeting is required, it should be indicated in the appropriate section on the Registration and Housing Form or emailed to the MMSB at mmsb@ams.org. Requests for ADA-accessible rooms should also be clearly indicated when making hotel reservations. All requests for special accommodations under the Americans with Disabilities Act of 1990 (ADA) must be made allowing enough time for evaluation and appropriate action by the AMS and MAA. Any information obtained about any disability will remain confidential.

Cancellation Policies: All of the official 2018 JMM hotels have a 72-hour cancellation policy.

Check-in/Check-out: Check-in at 3:00 pm and check-out at 11:00 am: Porto Vista Hotel

- Check-in at 3:00 pm and check-out at noon: Omni Hotel San Diego, Hilton Gaslamp San Diego, Best Western Plus Bayside Inn, and Horton Grand Hotel
- Check-in at 4:00 pm and check-out at 11:00 am: Marriott Marquis San Diego Marina, Embassy Suites Hotel San Diego Bay, Hard Rock Hotel San Diego, Solamar Hotel San Diego, and Palomar Hotel San Diego
- Check-in at 4:00 pm and check-out at noon: Manchester Grand Hyatt San Diego

Confirmations: An email confirmation number will be provided for each hotel reservation made online. This confirmation number will give participants direct access to edit their reservations up to **December 15, 2017**. Those who did not receive a confirmation number or who have any questions about the reservation process should contact the MMSB at mmsb@ams.org or 1-800-321-4267, ext. 4137 or 4144.

Complimentary Room Drawing: Participants who register and reserve a hotel room by **October 31, 2017**, will be included in a lottery for complimentary hotel room nights during the meeting. Rooms with multiple occupants will be included. The winners will be notified by phone and/or email prior to **December 19, 2017**.

Deadlines:

- Chance to win complimentary hotel nights: **October 31**
- In time to have badge/program mailed in December: **November 22**
- Hotel Reservation Changes, and Cancellations through the MMSB: **December 6**

Environmental Policies: All of the hotels listed have environmental-friendly programs in place.

Internet Access/Wireless:

- Complimentary wireless internet in all public areas, the lobby, and all sleeping rooms: Embassy Suites Hotel San Diego Bay, Manchester Grand Hyatt San Diego, Omni Hotel San Diego, Hard Rock Hotel San Diego, Best Western Plus Bayside Inn, Solamar Hotel San Diego, Palomar Hotel San Diego, Horton Grand Hotel, and Porto Vista Hotel
- Complimentary wireless is all public places and the lobby. A daily charge of US$12.95 for wired or wireless internet in the sleeping rooms: Hilton Gaslamp San Diego
- Complimentary wireless in all public places and the lobby. All JMM participants who are Marriott Rewards Members and who provide their Marriott Rewards Number on their reservations will receive complimentary "essential" wireless access in their guest

rooms during the JMM at the Marriott Marquis San Diego Marina. Any JMM participants who do not have a Marriott Rewards number will be charged US$1.00 per day for "essential" wireless access in their guest rooms during the JMM. To sign up for a free membership to Marriott Rewards, visit www.marriott.com/rewards/createAccount/createAccountPage1.mi?segmentId=elite.nonrewards. Note that "essential" wireless access will be high speed internet access that is good for checking emails and smaller tasks. It will not be good for streaming.

Location: The Marriott Marquis San Diego Marina will be the headquarter hotel for this meeting. The JMM Registration Desk, exhibits, poster sessions, scientific sessions, and AMS Employment Center will be located in the San Diego Convention Center. Committee meetings, social events and affiliate events will be held in both the Marriott Marquis San Diego and the San Diego Convention Center. These properties are located approximately 500 feet from each other.

Marriott Marquis San Diego Marina (headquarter),333 West Harbor Drive, San Diego, CA 92101. Room Rates are US$207 for a city view single/double; US$222 for a bay view single/double and US$147 for a city view student rate single/double room. This property is a smoke-free hotel. Restaurants located on-site include Marina Kitchen Restaurant & Bar; Tequila Bar & Grille; Roy's; Exchange and Starbucks. Amenities at this property include an outdoor pool, fitness center open limited hours and a 24-hour business center available to registered guests. Full amenities are available in guest rooms including laptop-sized safes and some rooms with windows that open. Children under 17 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are available for use only in king-bedded rooms. No pets are allowed at this property. Valet parking is available for a charge of US$35 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Embassy Suites Hotel San Diego Bay, 601 Pacific Highway, San Diego, CA 92101. Room Rates for this property are US$180 for a single/double and US$160 for a student rate single/double room. This property is a smoke-free hotel. Restaurants located on-site include the Lobby Restaurant & Bar and Dunkin Donuts. Amenities at this property include a fitness center, indoor pool and a 24-hour business center available to registered guests. Full amenities are available in guest rooms including laptop-sized safes and some rooms with windows that open. Children under 18 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are not available. No pets are allowed at this property. Valet parking is available for a charge of US$46 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Manchester Grand Hyatt San Diego, One Market Place, San Diego, CA 92101. Room Rates at this property are US$179 for a single, US$189 for a double and US$147 for a student rate single/double room. This property is a smoke-free hotel. Restaurants located on-site include the Seaview Breakfast Buffet Restaurant, Market One, Sally Fish House & Bar, the Grand Lobby Bar, Redfield's Sports Bar, and the Top of the Hyatt. Amenities at this property include a fitness center, outdoor pool and 24-hour business center available to registered guests. Full amenities are available in guest rooms including laptop-sized safes and some rooms with windows that open. Children under 18 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are available only in king-bedded rooms. Pets are allowed at this property; pets are restricted to 50 pounds or under for one pet, or 75 pounds or under for 2 pets. There will be a US$100 fee assessed for pet cleaning per stay (up to 6 nights). Valet parking is availble for a charge of US$49 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Omni Hotel San Diego, 675 L Street, San Diego, CA 92101. Room Rates are US$179 for a single, US$189 for a double and US$147 for a student rate single/double room.This property is a smoke-free hotel. Restaurants located on-site include McCormick & Schmick's and Zumbido. Amenities at this property include a fitness center, outdoor pool and 24-hour business center available to registered guests. Full amenities are available in guest rooms including laptop-sized safes andsome rooms with windows that open. Children under 17 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are available only in king-bedded rooms.This property allows cats only, not exceeding 25 pounds, with a US$50 non-refundable cleaning deposit fee due upon check-in. Valet parking is available for a charge of US$47 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Hilton Gaslamp San Diego, 401 K Street,San Diego, CA 92101. Room Rates are US$176 for a single/double and US$158 for a student rate single/double room. This property is a smoke-free hotel. On-site restaurant at this property is New Leaf Restaurant. Amenities available at this property include a fitness center, outdoor pool and 24-hour business center available to registered guests. Full amenitiesare available in guest rooms including laptop-sized safes and some rooms with windows that open. Children under 18 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are available only in king-bedded rooms. Pets are allowed at this property with a US$75 non-refundable deposit plus a US$75 per day fee. Valet parking is available for a charge of US$49 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Hard Rock Hotel San Diego, 207 Fifth Avenue, San Diego, CA 92101. Room Rates are US$170 for a single/double and US$159 for a student rate single/double room.

This property is a smoke-free hotel. Restaurants located onsite include Float Rooftop Pool & Lounge, 207 Bar, Mary Jane's Diner, and Nobu. Amenities at this property include a fitness center, outdoor pool and 24-hour business center available to registered guests. Full amenities are available in guest rooms including laptop-sized safes and some rooms with windows that open. Children under 18 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are available only in king-bedded rooms. No pets are allowed at this property. Valet parking is available for a charge of US$49 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Best Western Plus Bayside Inn, 555 West Ash Street, San Diego, CA 92101. Room Rates are US$165 for a single/double and US$155 for a student rate single/double room. This property is a smoke-free hotel. On-site restaurant is the Bayside Bar & Grill. Amenities at this property include a fitness center, outdoor pool and a 24-hour business center available to registered guests. Full amenities are available in guest rooms including laptop-sized safes and a balcony in each room. Children under 18 are free in room with an adult and cribs are available upon request at no additional charge. Rollaways are available only in king-bedded rooms.No pets are allowed at this property. Self-parking only is available for a charge of US$18 per day with in/out privileges. Parking rates are subject to change. This hotel offers a courtesy airport shuttle. Confirmations will be sent by email only.

Solamar Hotel San Diego, 435 Sixth Avenue, San Diego, CA 92101. Room Rates are US$165 for a single/double and US$149 for a student rate single/double. This property is a smoke-free hotel. Restaurants located on-site include Jsix and Upper East. Amenities at this property include a fitness center and outdoor pool. All front desk agents are available to assist with business center needs. Full amenities are available in guest rooms including laptop-sized safes and windows that open in all rooms. Children under 18 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are available only in king-bedded rooms. Pets are allowed at this property. Valet parking is available for a charge of US$47 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Palomar Hotel San Diego, 1047 Fifth Avenue, San Diego, CA 92101. Room Rates are US$160 for a single/double and US$149 for a student rate single/double room. This property is a smoke-free hotel. The on-site restaurant at this hotel is Curedero. Amenities at this property include a fitness center, outdoor pool and a 24-hour business center available to registered guests. Full amenities are available in guest rooms including laptop-sized safes in guest roomsand some rooms with windows that open. Children under 18 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are not available. Pets are allowed at this property. Valet parking is available for a charge of US$45 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Horton Grand Hotel, 311 Island Avenue, San Diego, CA, 92101. Room Rates are US$159 for a single/double and US$139 for a student rate single/double room. This property is a smoke-free hotel. The on-site restaurant at this hotel isIda Bailey's. Amenities at this property include a fitness center and a 24-hour business center available to registered guests. Full amenities are available in guest rooms. Safes are available behind the front desk. Windows in guest rooms do not open. Children under 18 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are not available Pets are not allowed at this property. Valet parking is available at a charge of US$42 per day with in/out privileges. Parking rates are subject to change. This hotel does not offer an airport shuttle. Confirmations will be sent by email only.

Porto Vista Hotel, 1835 Columbia Street, San Diego, CA, 92101. Room Rates are US$125 for a single/double room. This property is a smoke-free hotel. The on-site restaurant at this hotel is the Glass Door. Amenities at this property include a fitness center, outdoor pool and a 24-hour business center available to registered guests. Full amenities are available in guest rooms including laptop-sized safes and windows that open in all rooms. Children under 18 are free in a room with an adult and cribs are available upon request at no additional charge. Rollaways are not available. Pets, up to 40 lbs in weight, are allowed with a US$25 per day fee. Pets are not allowed to stay in a room unattended. Valet parking is available for a charge of US$25 per day with in/out privileges. Parking rates are subject to change. This hotel offers an airport shuttle from 7:00 am to 8:00 pm. Confirmations will be sent by email only.

Parking: Please see the *Parking* section under "Travel" for any additional parking options. Parking information for each hotel is listed below.

Rates: All rates are subject to applicable local and state taxes in effect at the time of check-in; currently 10.5% state tax, the San Diego Tourism Marketing District assessment 2% tax, and the CA Tourism fee of US$0.77 per night.

Miscellaneous

Audio-Visual Equipment: AMS Special Sessions and Contributed Papers, and MAA Invited and Contributed Paper Sessions, are provided with a screen and a LCD projector for projecting presentation slides. Blackboards, white boards, and transparency projectors are not available. Session rooms do not include an Internet connection or sound connection for videos or sound clips. For presentations using MAC computers, speakers are advised to bring the proper adaptors and equipment needed. LCD projectors are equipped with adapters to accept both VGA & HDMI cables

Invited address talks (50-minutes long) are provided with a lectern, PC Laptop with Microsoft Office Suite including PowerPoint, wireless microphone, laser pointer, wireless slide advancer "clicker," document camera (for

print materials and transparencies), and LCD projector for projecting presentation slides on large stage flanking screens. For presentations using MAC materials, speakers are advised to bring the proper adaptors and equipment needed. The Invited Address room does not include an Internet connection. Speakers that are planning to show videos should save them to their computers or USB drives prior to the meeting.

Overhead projectors are no longer provided as part of the standard audio-visual setup in any room. Any request for additional equipment should be sent to meet@ams.org and received by November 1.

Child Care: The AMS and the MAA will provide a limited number of reimbursement grants of US$250 per family to help with the cost of child care for registered participants at JMM 2018. The funds may be used for child care that frees a parent to participate more fully in JMM. Registration for the JMM as well as membership in the AMS or MAA is required to apply for this program.

Information about applying for child care grants will be available prior to the opening of advance registration in September; watch the JMM website for details. Applications will be accepted on a first-come, first-served basis until **November 7, 2017**. Final decisions on recipients will be made on or before **November 28, 2017**. All grant funds will provided in the form a check which will be issued at the JMM.

Email Services: Limited email access for all Joint Meetings participants will be available in an email center located in Exhibit Hall B1, on the ground level of the San Diego Convention Center. The hours of operation will be published in the program. Participants should be aware that **complimentary wireless internet access** will also be available in specific, designated areas of the Convention Center. These locations will be identified in the program.

Information Distribution: Tables are set up in the exhibit area for dissemination of general information of possible interest to the members and for the dissemination of information of a mathematical nature not promoting a product or program for sale. Information must be approved by the AMS Director of Meetings and Conferences prior to being placed on these tables.

If a person or group wishes to display information of a mathematical nature promoting a product or program for sale, they may do so in the exhibit area at the Joint Books, Journals, and Promotional Materials exhibit for a fee of US$50 (posters are slightly higher) per item. Please contact the exhibits coordinator, MMSB, PO Box 6887, Providence, RI 02940, or by email at cpd@ams.org for further details.

The administration of these tables is in the hands of the AMS-MAA Joint Meetings Committee, as are all arrangements for Joint Mathematics Meetings.

Local Information: For information about the city, see visitsandiego.com

Broadcasting, Photographing, and Videotaping Policy: Each invited address (50+minutes long) that takes place in the Invited Address room will be recorded, with the permission of the speaker, and posted online on a webpage hosted by the Joint Mathematics Meetings. These recordings will be taken by a professional videographer hired by the Joint Mathematics Meetings.

The recording or broadcasting of any AMS or joint-sponsored event, talk, and session by any other party is strictly forbidden without the explicit written permission of the AMS Executive Director or AMS Director of Meetings and Conferences. To obtain permission, send your request by email to meet@ams.org to the attention of the AMS Director of Meetings and Conferences. Having submitted a request form does not constitute temporary authority, and approval will not be given orally. Please allow sufficient time for the approval process to be completed. Allow at least two weeks from time of receipt of request by the AMS.

The recording or broadcasting of any MAA sponsored event by any other party is strictly forbidden without the explicit written permission of the Mathematical Association of America. To obtain permission to record and/or broadcast an MAA event or activity, complete the information requested in the Request to Record or Broadcast form on maa.org and send your request to the MAA Executive Director. You must have received a signed form granting approval for recording and/or broadcasting an MAA event before the event takes place. Having submitted a request form does not constitute temporary authority, and approval will not be given orally. Please allow sufficient time for the approval process to be completed. Allow at least two weeks from time of receipt of request by the MAA office.

Photographs and videos of meeting interactions will be taken by professional photographers hired by the Joint Mathematics Meetings or by AMS and MAA staff. These photographs and videos may occasionally be used for publicity purposes. By participating in the Joint Mathematics Meetings, participants acknowledge that their photograph or a video that includes them may be published in material produced by the Joint Mathematics Meetings, AMS or MAA. AMS and MAA are not responsible for unauthorized photographs, videos, or other images not taken by professional photographers hired by the Joint Mathematics Meetings or AMS and MAA staff.

Under no circumstances will anyone be permitted to take pictures of an exhibitor's product without permission of the exhibitor.

Telephone Messages: It will be possible to leave a message for any registered participant at the meetings registration desk from January 10 through 13 during the hours that the desk is open. These messages will be posted on the Mathematics Meetings Message Board in the networking center; however, staff at the desk will try to locate a participant in the event of a bona fide emergency. The telephone number will be published in the program and daily newsletter.

Registration

The importance of registering for the meeting cannot be overemphasized. Advanced registration fees are considerably lower than on-site registration fees. The AMS and the MAA encourage all participants to register for the meeting. When a participant pays a registration fee, he or she

is helping to support a wide range of activities associated with planning, organizing, and executing the meetings.

All participants who wish to attend sessions are expected to register and should be prepared to show their badges, if so requested. Badges are required to enter the Joint Mathematics Meetings (JMM) Exhibits, the Employment Center, to obtain discounts at the AMS and MAA Book Sales, and to cash a check with the Joint Meetings cashier.

All JMM registrations are processed by the Mathematics Meetings Service Bureau (MMSB). Participants who register by **November 22, 2017**, may receive their badges, programs, and tickets (where applicable) in advance by US mail, approximately three weeks before the meetings. Those who do not want their materials mailed should check the appropriate box on the Registration and Housing Form. Materials cannot be mailed to Canada, Mexico, or other countries outside of the US Participants from these countries must pick up their materials at the Joint Meetings Registration Desk, which will be located inside exhibit hall B of the San Diego Convention Center. Please note that a replacement fee of US$5 will be charged for badges that were mailed but not brought to the meeting.

Online Registration: To register and reserve a hotel room online, visit `www.jointmathematicsmeetings.org/register`. VISA, MasterCard, Discover, and American Express are the only methods of payment accepted for online registrations, and charges to credit cards will be made in US funds. Registration acknowledgments will be sent by email to the email addresses provided.

Paper Form Registration: For the convenience of those who do not have access to the internet or who prefer to not use the internet to register and reserve a hotel room, a paper copy of the registration form is located at the back of this issue. It is also located at `www.jointmathematicsmeetings.org/meetings/national/jmm2018/JMM18_regform.pdf`. If you are using this method to register for the meeting and do not have a credit card, please contact the MMSB at `mmsb@ams.org` for further instructions. If you are using a check to reserve your hotel room, your reservation and check must be received by the MMSB no later than **December 1, 2017** to ensure that your check is validated and reaches the hotel in time to hold your room.

Forms must be mailed or faxed to the MMSB at MMSB, PO Box 6887, Providence, RI 02940 or 401-455-4004. For security reasons, credit card numbers by postal mail, email or fax cannot be accepted. If a participant is registering by paper form and would like to pay for his or her registration via credit card, he or she should indicate this on the form. MMSB staff will then contact that person.

Programs: NEW! In an effort to make the JMM more environmentally friendly as well as save on printing expenses to the meeting, the JMM program books will **now only be distributed to participants who ask for them.**

Updates and corrections received too late for the printed program will be reflected in the online program on the JMM website and in the JMM mobile app. Therefore, participants will be encouraged to explore the features and functionality available to them through these digital options, which give them easier access to the most up-to-date program as well as other meeting information.

To receive a program book, please check the "yes" button in the appropriate section on the Registration and Housing Form. If you do not want to receive a program booklet, please check the "no" button. Note that extra copies of the program book will be available onsite at the meeting for those that inadvertently checked the wrong button, while supplies last.

Badges: All registered participants (including guests) for the meeting will receive a badge. Each badge of a registered mathematician will include an embedded vCard (electronic business card) in the form of a QR Code; placed on the back of the badge. This code will include name, postal address, phone number, email address, and subject classification code (if given). It will enable exhibitors to retrieve the same information they would retrieve from a business card, but with one quick scan. Any participant may choose to not have an exhibitor scan his or her badge.

Participant Lists and Mailing Lists: If a participant would like to opt-out of any mailing lists or participant lists that are generated for the meeting, he or she should check the appropriate box on the Registration and Housing Form. All participants who do not opt-out will be included in all mailing lists and participant lists that are generated and distributed for the meeting.

Cancellation Policy: Participants who cancel their registrations for the meetings, minicourses, short course, or banquet tickets by **January 4, 2018**, will be eligible to receive a 50% refund of fees paid. No refunds will be issued after this date.

Joint Mathematics Meetings Registration Fees

	Advanced (by Dec. 20)	**At Meeting**
Member of AMS, ASL, CMS, MAA, SIAM	US$329	US$433
Non-member	522	666
Graduate Student Member of AMS, ASL, CMS, MAA, SIAM	74	86
Graduate Student Non-member	118	130
Undergraduate Student Member of AMS, ASL, CMS, MAA, PME, KME, SIAM	74	86
Undergraduate Student Non-member	118	130
Temporarily Employed	268	307
Emeritus Member of AMS, MAA; Unemployed; High School Teacher; Developing Countries; Librarian	74	86
High School Student	7	14
One-Day Member of AMS, ASL, CMS, MAA, SIAM	N/A	235
One-Day Non-member	N/A	367
Non-mathematician Guest	21	21
Commercial Exhibitor	0	0
MAA Minicourses	100	100
Grad School Fair Table	125	125

AMS Short Course:		
Member of AMS	114	148
Non-member	175	205
Student/Unemployed/Emeritus	62	83

Registration Category Definitions

Full-Time Students: Any person who is currently working toward a degree or diploma is eligible for this category. Students are asked to determine whether their status can be described as a graduate (working toward a degree beyond the bachelor's), an undergraduate (working toward a bachelor's degree), or high school (working toward a high school diploma) and to mark the Registration and Housing Form accordingly. See membership distinctions below.

Graduate Student Member: Any graduate student who is a member of the AMS, ASL, CMS, MAA, or SIAM is eligible for this category. Students should check with their department administrator to check their membership status.

Undergraduate Student Member: Any undergraduate student who is a member of the AMS, ASL, CMS, MAA, SIAM, PME, or KME is eligible for this category. Students should check with their department administrator to check their membership status.

Emeritus: Any person who has been a member of the AMS for twenty years or more and who retired because of age or long-term disability from his or her latest position is eligible for this category. Anyone person who has been a member of the MAA for 25 years and who is 70+ years of age is eligible for this category.

Librarian: Any librarian who is not a professional mathematician is eligible for this category.

Unemployed: Any person who is currently unemployed, actively seeking employment, and is not a student is eligible for this category. This category is not intended to include any person who has voluntarily resigned or retired from his or her latest position.

Developing Country Participant: Any person employed in developing countries where salary levels are radically not commensurate with those in the US is eligible for this category.

Temporarily Employed: Any person currently employed but who will become unemployed by June 1, 2018, and who is actively seeking employment is eligible for this category.

Non-mathematician Guest: Any family member or friend, who is not a mathematician, and who is accompanied by a participant in the meetings is eligible for this category. Guests will receive a badge and may accompany a mathematician to any session or talk and may also enter the exhibit area.

Commercial Exhibitor: Any person exhibiting in the Joint Mathematics Meetings Exhibits is eligible for this category. This does not include anyone participating in any poster sessions. Any exhibitor who is a mathematician and is participating in the scientific program and/or wants to attend sessions, talks, etc. is expected to register separately for the meeting.

Art Exhibitor: Any person exhibiting in the Mathematical Art Exhibition is eligible for this category. This does not include anyone participating in any poster sessions. Any exhibitor who is a mathematician and is participating in the scientific program and/or wants to attend sessions, talks, etc. is expected to register separately for the meeting.

Registration Deadlines

There are three registration deadlines, each with its own benefits:

EARLY meeting registration (complimentary room lottery deadline)—**October 31**

ORDINARY meeting registration (registration materials mailed)—**November 22**

FINAL meeting registration (advanced registration, short course, minicourses, banquets)—**December 20**

Early Registration: Participants who register by the early deadline of October 31 will be included in a random drawing to select winners of complimentary hotel room nights during the meeting. Rooms with multiple occupants will be included in the drawing. The location of these rooms will be based on the number of complimentary room nights earned in the various hotels. Therefore, a free room will not necessarily be in winner's first-choice hotel. All winners will be notified by phone and email prior to **December 19**, so register early!

Ordinary Registration: Participants who register by **November 22** can choose to receive their materials before the meeting by mail.

Final Registration: Participants who register after **November 22** and by **December 20** must pick up their badges, programs, and any tickets for social events at the meeting.

Social Events

All events listed are open to all registered participants. It is strongly recommended that for any event requiring a ticket, tickets should be purchased through advance registration. Only a very limited number of tickets, if any, will be available for sale on site. If you must cancel your participation in a ticketed event, you may request a 50% refund by returning your tickets to the Mathematics Meetings Service Bureau (MMSB) by **January 4, 2018**. After that date, no refunds can be made. Special meals are available at banquets upon advance request, but this must be indicated on the Advanced Registration/Housing Form.

AMS Dinner, The AMS Connects and Supports! Join your colleagues on this special occasion of celebration in the mathematical community. Enjoy delicious meals from gourmet food stations, take pictures at the photo booth, and enter to win fun prizes at the raffle table! Each guest will also receive a special gift from the AMS.

This evening of celebration will be held on Saturday, January 13 with a reception at 6:30 pm and doors opening at 7:30 pm. Purchase your tickets when registering for the Joint Mathematics Meetings. Tickets are US$75 and a limited number of tickets will be available at the special student rate of US$30.

Annual Spectra Reception, Thursday, 6:00–8:00 pm. Annual Spectra reception for lesbian, gay, bisexual, and

transgender mathematicians. We are affiliated with NOGLSTP, the National Organization of Gay and Lesbian Scientists and Technical Professionals, Inc.

Association of Christians in the Mathematical Sciences (ACMS) Reception and Lecture, Thursday, 5:30–7:30 pm. The reception will take place between 5:30 and 6:30 pm, followed by a short program and 20 minute talk at 6:30 pm. Students are encouraged to attend, and opportunity will be provided afterwards for delegates to go to dinner at local restaurants. The talk will be given by **Francis Su**.

Association for Women in Mathematics Reception and Awards Presentation, the AWM Reception which is open to all JMM participants will be held on Wednesday at 9:30 pm after the AMS Gibbs Lecture. The AWM President at 10:00 pm will recognize all of the honorees of the AWM Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman, the recipients of the AWM Dissertation Prize and the AWM Service Awards.

Backgammon! organized by **Arthur Benjamin**, Harvey Mudd College; Friday, 8:00–10:00 pm. Learn to play backgammon from expert players. It's a fun and exciting game where players with a good mathematics background have a decisive advantage. Boards and free lessons will be provided by members of the US Backgammon Federation. Stop by anytime!

Budapest Semesters in Mathematics Annual Alumni Reunion, Thursday, 5:30–6:30 pm.

Budapest Semesters in Mathematics Education Informational Session, Friday, 12:00–1:00 pm. BSME is a semester-long program in Budapest, Hungary, designed for American and Canadian undergraduates (and recent graduates) interested in teaching middle school or high school mathematics. Participants will study the *Hungarian approach* to learning and teaching, in which a strong and explicit emphasis is placed on problem solving, mathematical creativity, and communication. Come learn more about this exciting new program.

University of California, San Diego Reception, Thursday, 6:00–7:30 pm. Reception for Mathematics alumni.

University of Chicago Mathematics Alumni Reception, Thursday, 6:00–7:00 pm.

Reception for Graduate Students and First-Time Participants, Wednesday, 5:30–6:30 pm. The AMS and MAA cosponsor this social hour. Graduate students and first-timers are especially encouraged to come and meet some old-timers to pick up a few tips on how to survive the environment of a large meeting. Light refreshments will be served.

University of Illinois at Urbana—Champaign, Friday, 5:30–7:30 pm. Department of Mathematics, Math Reception. Everyone ever connected with the Department is encouraged to get together for conversation and to hear about mathematics at the University of Illinois.

Joint Prize Reception,Thursday 5:30–6:30 pm.

University of Kansas Reception, Thursday, 6:00–7:00 pm. University of Kansas alumni and friends reception.

Knitting Circle, Thursday, 8:15–9:45 pm. Bring a project (knitting/crochet/tatting/beading/etc.) and chat with other mathematical crafters!

MAA/Project NExT Reception, Friday, 8:00–10:00 pm. All Project NExT Fellows, consultants, and other friends of MAA Project NExT are invited. Organizers: **Julia Barnes**, West Carolina University, **Alissa Crans**, Loyola Marymount University, **Matt DeLong**, Taylor University and **David Kung**, St Mary's College of Maryland.

MAA Two-Year College Reception, Wednesday, 5:45–7:00 pm, is open to all meeting participants, particularly two-year faculty members. This is a great opportunity to meet old friends and make some new ones.

Mathematical Reviews Reception, Friday, 6:00–7:00 pm. All friends of the Mathematical Reviews (MathSciNet) are invited to join reviewers and MR editors and staff (past and present) for a reception in honor of all of the efforts that go into the creation and publication of the Mathematical Reviews database. Refreshments will be served.

Mathematical Institutes Open House, Wednesday, 5:30–8:00 pm. Members of the AMS and MAA who are attending the Joint Mathematics Meetings are warmly invited to come to the Mathematical Institutes Open House reception, co-sponsored by several of the mathematical sciences institutes in North America. This reception precedes the Gibbs Lecture. We hope to see you there! `icerm.brown.edu/events/mioh/2018`

MathILY, MathILy-Er Yearly Gather, Wednesday, 7:00–8:30 pm. Come one, come all, and play a recently created mathematical game or solve a new puzzle! And learn about the MathILy, MathILy-Er summer programs for high-school students, then hang out with MathILy, MathILy-Er alumns and instructors.

MSRI Reception for Current and Future Donors, Thursday, 6:30–8:00 pm. MSRI invites current and prospective donors to an informal reception with appetizers and drinks. Directors **David Eisenbud** and **Helene Barcelo** will speak about present and upcoming events and programs, as well as the impact of private support on the Institute.

MSRI thanks and acknowledges mathematicians who support MSRI's programs and workshops through membership in the Archimedes Society or the Gauss Society. Archimedes Society members support MSRI with annual gifts. Gauss Society members support MSRI with a planned gift through arrangements in their wills and estates.

For more information about the event and how to join the Archimedes or Gauss Societies, please contact, James Sotiros, Director of Development, `j.sotiros@msri.org`; 510.643-6056. `www.msri.org`

National Association of Mathematicians Banquet, Friday, 6:00–8:40 pm. A cash bar reception will be held at 6:00 pm, and dinner will be served at 6:30 pm. Tickets are US$75 each, including tax and gratuity. The Cox–Talbot Invited Address will be given after the dinner.

NSA Women in Mathematics Society Networking Session, Thursday, 6:00–8:00 pm.

Penn State Mathematics Department Reception, Thursday, 5:30–7:30 pm. Reception for alumni, students and faculty. Join us for this event.

PROMYS and Ross Reception for Alumni and Friends, Thursday, 7:30–9:30 pm. There will be hors d'oeuvres, a

cash bar, and interesting conversation with friends old and new!

Texas A&M University Mathematics Department Reception for Alumni, Students, and Faculty, Friday, 5:30–7:30 pm. All alumni, current students, faculty, and current and former post-docs are invited to join us for this reception.

Reception for Undergraduates, Wednesday, 4:30–5:30 pm.

YP17 HCSSiM Reunion Breakfast, Friday, 7:34 am.

Travel/Transportation

The 2018 Joint Mathematics Meetings will be held in San Diego, CA, at the San Diego Convention Center and the **Marriott Marquis San Diego Marina**. The San Diego Convention Center is located at 111 West Harbor Drive, San Diego, CA 92101, and the **Marriott Marquis San Diego Marina** is located at 333 West Harbor Drive, San Diego, CA 92101. San Diego is on Pacific Standard Time.

Air Transportation

The principal airport in San Diego is San Diego Airport (SAN), www.san.org. SAN is served by all major airlines and is located slightly over three miles from the downtown area and the Convention Center. For reference, an interactive terminal map can be found here: sanmap.san.org.

Ground Transportation

Car Rental: All major rental car companies have offices at San Diego Airport. There is a separate rental car facility. Car rental pick-ups and drop-offs from the San Diego Airport are done at the Rental Car Center at 3355 Admiral Boland Way, San Diego, CA 92101. Free dedicated shuttle buses run continually to bring customers between the airport terminals and the rental car center.

Hertz is the official car rental company for the meeting. To access the JMM special meeting rates at www.hertz.com, please click the box that says "Enter a discount or Promo code" on the reservation screen, and type in the JMM convention number (CV): **04N30008**. At the time of the reservation, meeting rates will be automatically compared to other Hertz rates and the best rate will be applied.

Reservations can also be made by calling Hertz directly at 800-654-2240 (US and Canada) or 1-405-749-4434. Meeting rates include unlimited mileage and are subject to availability. Advance reservations are recommended and blackout dates may apply. Government surcharges, taxes, tax reimbursement, airport-related fees, vehicle licensing fees and optional items are extra. Standard rental conditions and qualifications apply. Minimum rental age is 20 (age differential charge for 20-24 applies).

Shuttles: Shuttle service in a shared van is available from the airport to downtown hotels for approximately US$10–13 per person one way, and US$20–24 per person round trip. From Terminal 1, cross the skybridge, and take either the escalators or the elevators to street level. From Terminal 2, use the pedestrian crosswalk located outside the baggage claim area to access the Transportation Plaza. A customer service representative will place you with the first available shuttle, unless you specify a particular shuttle company. There is a list of shuttle companies available at www.san.org/Parking-Transportation/Shuttles. Two of the companies listed are Advanced Shuttle (www.advancedshuttle.com/), 800-719-3499 and Cloud 9/Supershuttle (www.supershuttle.com/), 800-9-SHUTTLE (800-974-8885). Supershuttle also offers private van service at a higher price.

The Best Western Bayside Inn has a courtesy shuttle available from 7:00 am to 11:00 pm daily. The **Porto Vista Hotel** offers a complimentary airport shuttle from 7:30 am to 7:30 pm. For these hotels, please call upon your arrival at the San Diego Airport and pick up your baggage. They will then send a shuttle. For the return trip, please make a reservation in advance with the front desk of your hotel.

The concierge services at many of the hotels will assist you with a return shuttle if you do not book a round trip.

Taxi: From the baggage claim area, follow the signs leading to the Transportation Plaza, and a customer service representative will place you with the first available taxi. Taxi fare to the downtown area is approximately US$18 one way.

Public Transportation: The Metropolitan Transit System Bus Route No. 992 (Airport via Harbor Drive/Cruise Ship Terminal) stops at airport Terminals 1 and 2 and travels to downtown San Diego. Ask a customer service representative outside baggage claim for directions to the bus stop. The 992 runs every 15 minutes between 5:00 am and 11:30 pm on weekdays and every 30 minutes on weekends. Maps, schedules and a helpful online trip planner (www.sdmts.com/schedules-real-time/trip-planner) for San Diego's bus and trolley routes are available at the website of the San Diego Metropolitan Transit System, www.sdmts.com/.

To go to the Convention Center, take the 992 to Broadway and Kettner Boulevard, and cross the street to Santa Fe Station. Take the Green Line trolley with the sign "12th and Imperial" and get off at the Convention Center stop. For alternate routes and destinations, please check the trip planner or call 1-619-233-3004. To take the 992 bus, the price is currently US$2.25 one way, cash and exact fare is required. For the trolley, exact fare is US$2.50, but credit cards are accepted as well as cash. The SMTS also has an app called "Compass Cloud" which will help you purchase fares. Please see www.sdmts.com/fares-passes/compass-cloud for details.

Train: The San Diego Station, Santa Fe Depot (also called Union Station), is located at 1050 Kettner Boulevard. For additional information on Amtrak service to San Diego, call 1-800-USA-RAIL, or visit Amtrak (www.amtrak.com) or Amtrak California (www.amtrakcalifornia.com/).

Parking: On-site private vehicle parking is available at the San Diego Convention Center's 1,950-vehicle underground garage which is located below the building. The entrance to the parking garage is on Harbor Drive between First Avenue and Fifth Avenue. Parking rates may range from US$15 to US$35 on days when there is a special event

activity at PETCO Park or other downtown events. Payment is due upon entry and there are no in and out privileges. For questions about the parking garage, call Ace Parking at 619-237-0399. No overnight or RV parking is permitted. The garage has 31 ADA compliant parking spots with elevator access to the convention center.

There is also a 2,000-space parking structure located directly across the street from the Convention Center, on the corner of Harbor and 8th Avenue. Off-site parking is also available at other nearby parking lots and garages in downtown San Diego. Many are within walking distance. Helpful local parking information may also be found on the Gaslamp District's website at www.gaslamp.org/parking/.

Information about parking at the hotels is listed under "Hotel Information."

Driving Directions from the airport to the Convention Center: The San Diego Convention Center is located at 111 W. Harbor Drive, San Diego, CA 92101, and is approximately 3 miles away from the airport. Upon leaving the airport, drive out of parking lot, and follow signs to Interstate 5/Downtown. The ramp will put you on Harbor Drive going south. Follow signage to the parking entrance for the San Diego Convention Center. For driving directions from other points, see visitsandiego.com/location/directions.

Columbus, Ohio

Ohio State University

March 17–18, 2018

Saturday–Sunday

Meeting #1136

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: December 2017
Program first available on AMS website: January 31, 2018
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 39, Issue 2

Deadlines

For organizers: Expired
For abstracts: January 22, 2018

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

Invited Addresses

Aaron Brown, University of Chicago, *Title to be announced.*

Tullia Dymarz, University of Wisconsin—Madison, *Title to be announced.*

June Huh, Institute for Advanced Study, *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 Integral and Differential Equations (Code: SS 26A), **Jeffrey T. Neugebauer**, Eastern Kentucky University, and **Min Wang**, Rowan University.

Algebraic Coding Theory and Applications (Code: SS 27A), **Heide Gluesing-Luerssen**, University of Kentucky, **Christine A. Kelley**, University of Nebraska—Lincoln, and **Steve Szabo**, Eastern Kentucky University.

Algebraic Combinatorics: Association Schemes, Finite Geometry, and Related Topics (Code: SS 15A), **Sung Y. Song**, Iowa State University, and **Bangteng Xu**, Eastern Kentucky University.

Algebraic Curves and Their Applications (Code: SS 17A), **Artur Elezi**, American University, **Monika Polak**, Maria Curie-Sklodowska University (Poland) and University of Information Science and Technology (Mac, and **Tony Shaska**, Oakland University.

Algebraic and Combinatorial Aspects of Tropical Geometry (Code: SS 11A), **Maria Angelica Cueto**, Ohio State University, **Yoav Len**, University of Waterloo, and **Martin Ulirsch**, University of Michigan.

Algebraic, Combinatorial, and Quantum Invariants of Knots and Manifolds (Code: SS 6A), **Cody Armond**, Ohio State University, Mansfield, **Micah Chrisman**, Monmouth University, and **Heather Dye**, McKendree University.

Analytical and Computational Advances in Mathematical Biology Across Scales (Code: SS 30A), **Veronica Ciocanel** and **Alexandria Volkening**, Mathematical Biosciences Institute.

Categorical, Homological and Combinatorial Methods in Algebra (Celebrating the 80th birthday of S. K. Jain) (Code: SS 28A), **Pedro A. Guil Asensio**, University of Murcia, **Ivo Herzog**, Ohio State University, **Andre Leroy**, University of Artois, and **Ashish K. Srivastava**, Saint Louis University.

Coherent Structures in Interfacial Flows (Code: SS 14A), **Benjamin Akers** and **Jonah Reeger**, Air Force Institute of Technology.

Commutative and Combinatorial Algebra (Code: SS 18A), **Jennifer Biermann**, Hobart and William Smith Colleges, and **Kuei-Nuan Lin**, Penn State University, Greater Allegheny.

Convex Bodies in Algebraic Geometry and Representation Theory (Code: SS 20A), **Dave Anderson**, Ohio State University, and **Kiumars Kaveh**, University of Pittsburgh.

Differential Equations and Applications (Code: SS 8A), **King-Yeung Lam** and **Yuan Lou**, Ohio State University, and **Qiliang Wu**, Michigan State University.

Function Spaces, Operator Theory, and Non-Linear Differential Operators (Code: SS 21A), **David Cruz-Uribe**, University of Alabama, and **Osvaldo Mendez**, University of Texas.

Geometric Methods in Shape Analysis (Code: SS 10A), **Sebastian Kurtek** and **Tom Needham**, Ohio State University.

Graph Theory (Code: SS 5A), **John Maharry**, Ohio State University, **Yue Zhao**, University of Central Florida, and **Xiangqian Zhou**, Wright State University.

Homological Algebra (Code: SS 4A), **Ela Celikbas** and **Olgur Celikbas**, West Virginia University.

Homotopy Theory (Code: SS 29A), **Ernest Fontes**, **John E. Harper**, **Crichton Ogle**, and **Gabriel Valenzuela**, Ohio State University.

Lefschetz Properties (Code: SS 24A), **Juan Migliore**, University of Notre Dame, and **Uwe Nagel**, University of Kentucky.

Mathematical Modeling of Neuronal Networks (Code: SS 36A), **Janet Best**, Ohio State University, **Alicia Prieto Langarica**, Youngstown State University, and **Pamela B. Pyzza**, Ohio Wesleyan University.

Multiplicative Ideal Theory and Factorization (in honor of Tom Lucas retirement) (Code: SS 7A), **Evan Houston**, University of North Carolina, Charlotte, and **Alan Loper**, Ohio State University.

Noncommutative Algebra and Noncommutative Algebraic Geometry (Code: SS 16A), **Jason Gaddis**, Miami University, and **Robert Won**, Wake Forest University.

Nonlinear Evolution Equations (Code: SS 9A), **John Holmes** and **Feride Tiglay**, Ohio State University.

Nonlinear Waves and Patterns (Code: SS 19A), **Anna Ghazaryan**, Miami University, **Stephane Lafortune**, College of Charleston, and **Vahagn Manukian** and **Alin Pogan**, Miami University.

Parameter Analysis and Estimation in Applied Dynamical Systems (Code: SS 35A), **Adriana Dawes**, The Ohio State University, and **Reginald L. McGee**, Mathematical Biosciences Institute.

Probabilistic and Extremal Graph Theory (Code: SS 32A), **Louis DeBiasio** and **Tao Jiang**, Miami 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.

Recent Advances in Finite Element Methods for Partial Differential Equations (Code: SS 31A), **Ching-shan Chou**, **Yukun Li**, and **Yulong Xing**, The Ohio State University.

Recent Advances in Packing (Code: SS 23A), **Joseph W. Iverson**, University of Maryland, **John Jasper**, South Dakota State University, and **Dustin G. Mixon**, The Ohio State University.

Recent Development of Nonlinear Geometric PDEs (Code: SS 12A), **Bo Guan**, Ohio State University, **Qun Li**, Wright State University, **Xiangwen Zhang**, University of California, Irvine, and **Fangyang Zheng**, Ohio State University.

Several Complex Variables (Code: SS 13A), **Liwei Chen**, **Kenneth Koenig**, and **Liz Vivas**, Ohio State University.

Stochastic Analysis in Infinite Dimensions (Code: SS 22A), **Parisa Fatheddin**, Air Force Institute of Technology, and **Arnab Ganguly**, Louisiana State University.

Structure and Representation Theory of Finite Groups (Code: SS 33A), **Justin Lynd**, University of Louisiana at Lafayette, and **Hung Ngoc Nguyen**, University of Akron.

Symmetry in Differential Geometry (Code: SS 34A), **Samuel Lin**, Dartmouth College, **Barry Minemyer**, Bloomsburg University, and **Ben Schmidt**, Michigan State University.

The Mathematics of Phylogenetics (Code: SS 25A), **Colby Long**, Mathematical Biosciences Institute.

Topology and Geometry in Data Analysis (Code: SS 37A), **Sanjeevi Krishnan** and **Facundo Memoli**, Ohio State University.

Portland, Oregon

Portland State University

April 14–15, 2018

Saturday–Sunday

Meeting #1137

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: January 2018
Program first available on AMS website: February 15, 2018
Program issue of electronic *Notices*: To be announced
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`.

Algebraic and Combinatorial Structures in Knot Theory (Code: SS 3A), **Allison Henrich**, Seattle University, **Inga Johnson**, Willamette University, and **Sam Nelson**, Claremont McKenna College.

Biomathematics—Progress and Future Directions (Code: SS 4A), **Hannah Callender Highlander**, University of Portland, **Peter Hinow**, University of Wisconsin—Milwaukee, and **Deena Schmidt**, University of Nevada, Reno.

Commutative Algebra (Code: SS 5A), **Adam Boocher**, University of Utah, and **Irena Swanson**, Reed College.

Inverse Problems (Code: SS 2A), **Hanna Makaruk**, Los Alamos National Laboratory (LANL), and **Robert Owczarek**, University of New Mexico, Albuquerque & Los Alamos.

Motivic homotopy theory (Code: SS 6A), **Daniel Dugger**, University of Oregon, and **Kyle Ormsby**, Reed College.

Nonsmooth Optimization and Applications(Dedicated to Prof. B. S. Mordukhovich on the occasion of his 70th birthday) (Code: SS 7A), **Mau Nam Nguyen**, Portland State University, **Hung M. Phan**, University of Massachusetts Lowell, and **Shawn Xianfu Wang**, University of British Columbia.

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.

Spectral Theory (Code: SS 8A), **Jake Fillman**, Virginia Tech, **Milivoe Lukic**, Rice University.

Nashville, Tennessee

Vanderbilt University

April 14–15, 2018

Saturday–Sunday

Meeting #1138

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: January 2018
Program first available on AMS website: February 22, 2018
Program issue of electronic *Notices*: To be announced
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, *Title to be announced* (Erdős Memorial Lecture).

J. M. Landsberg, Texas A & M University, *Title to be announced.*

Jennifer Morse, University of Virginia, *Title to be announced.*

Kirsten Wickelgren, Georgia Institute of Technology, *Title to be announced.*

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at `www.ams.org/cgi-bin/abstracts/abstract.pl`.

Advances in Operator Algebras (Code: SS 7A), **Scott Atkinson**, **Dietmar Bisch**, **Vaughan Jones**, and **Jesse Peterson**, Vanderbilt University.

Difference Equations and Applications (Code: SS 2A), **Michael A. Radin**, Rochester Institute of Technology, and **Youssef Raffoul**, University of Dayton, Ohio.

Matroids and Related Structures (Code: SS 5A), **Carolyn Chun**, United States Naval Academy, **Deborah Chun** and **Tyler Moss**, West Virginia University Institute of Technology, and **Jakayla Robbins**, Vanderbilt University.

Probabilistic Models in Mathematical Physics (Code: SS 6A), **Robert Buckingham**, University of Cincinnati, **Seung-Yeop Lee**, University of South Florida, and **Karl Liechty**, DePaul University.

Quantization for Probability Distributions and Dynamical Systems (Code: SS 1A), **Mrinal Kanti Roychowdhury**, University of Texas Rio Grande Valley.

Selected Topics in Graph Theory (Code: SS 3A), **Songling Shan**, Vanderbilt University, and **David Chris Stephens** and **Dong Ye**, Middle Tennessee State University.

Structural Graph Theory (Code: SS 4A), **Joshua Fallon**, Louisiana State University, and **Emily Marshall**, Arcadia University.

Boston, Massachusetts

Northeastern University

April 21–22, 2018

Saturday–Sunday

Meeting #1139

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2018
Program first available on AMS website: March 1, 2018
Program issue of electronic *Notices*: To be announced
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`.

Invited Addresses

Jian Ding, University of Chicago, *Title to be announced.*

Edward Frenkel, University of California, Berkeley, *Title to be announced* (Einstein Public Lecture in Mathematics).

Valentino Tosatti, Northwestern University, *Title to be announced.*

Maryna Viazovska, École Polytechnique Fédérale de Lausanne, *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`.

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 **Joseph H. Silverman**, Brown University.

Arrangements of Hypersurfaces (Code: SS 2A), **Graham Denham**, University of Western Ontario, and **Alexander I. Suciu**, Northeastern University.

Combinatorial Aspects of Nilpotent Orbits (Code: SS 15A), **Anthony Iarrobino**, Northeastern University, **Leila Khatami**, Union College, and **Juliana Tymoczko**, Smith College.

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.

Extremal Graph Theory and Quantum Walks on Graphs (Code: SS 13A), **Sebastian Cioabă**, University of Delaware, **Mark Kempton**, Harvard University, **Gabor Lippner**, Northeastern University, and **Michael Tait**, Carnegie Mellon University.

Facets of Symplectic Geometry and Topology (Code: SS 3A), **Tara Holm**, Cornell University, **Jo Nelson**, Columbia University, and **Jonathan Weitsman**, Northeastern University.

Geometry of Moduli Spaces (Code: SS 10A), **Ana-Marie Castravet** and **Emanuele Macrí**, Northeastern University, **Benjamin Schmidt**, University of Texas, and **Xiaolei Zhao**, Northeastern University.

Homological Commutative Algebra (Code: SS 11A), **Sean Sather-Wagstaff**, Clemson University, and **Oana Veliche**, Northeastern University.

Hopf Algebras, Tensor Categories, and Homological Algebra (Code: SS 8A), **Cris Negron**, Massachusetts Institute of Technology, **Julia Plavnik**, Texas A&M, and **Sarah Witherspoon**, Texas A&M University.

New Developments in Inverse Problems and Imaging (Code: SS 9A), **Ru-Yu Lai**, University of Minnesota, and **Ting Zhou**, Northeastern University.

Nonlinear and Stochastic Partial Differential Equations and Applications (Code: SS 19A), **Nathan Glatt-Holtz** and **Vincent Martinez**, Tulane University, and **Cecilia Mondaini**, Texas A&M University.

Numerical Methods and Applications (Code: SS 16A), **Vera Babenko**, Ithaca College.

Polytopes and Discrete Geometry (Code: SS 6A), **Gabriel Cunningham**, University of Massachusetts, Boston, **Mark Mixer**, Wentworth Institute of Technology, and **Egon Schulte**, Northeastern University.

Regularity of PDEs on Rough Domains (Code: SS 14A), **Murat Akman**, University of Connecticut, and **Max Engelstein**, Massachusetts Institute of Technology.

Relations Between the History and Pedagogy of Mathematics (Code: SS 20A), **Amy Ackerberg-Hastings**, and **David L. Roberts**, Prince George's Community College.

Singularities of Spaces and Maps (Code: SS 4A), **Terence Gaffney** and **David Massey**, Northeastern University.

The Gaussian Free Field and Random Geometry (Code: SS 12A), **Jian Ding**, University of Chicago, and **Vadim Gorin**, Massachusetts Institute of Technology.

Topics in Toric Geometry (Code: SS 17A), **Ivan Martino**, Northeastern University, and **Emanuele Ventura**, Texas A&M University.

Topology of Biopolymers (Code: SS 18A), **Erica Flapan**, Pomona College, and **Helen Wong**, Carleton College.

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*: April 2018
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced
For abstracts: To be announced

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

Invited Addresses

Yu-Hong Dai, Academy of Mathematics and System Sciences, *Title to be announced.*

Kenneth A. Ribet, University of California, Berkeley, *Title to be announced.*

Richard M. Schoen, University of California, Irvine, *Title to be announced.*

Sijue Wu, University of Michigan, *Title to be announced.*

Chenyang Xu, Peking University, *Title to be announced.*

Jiangong You, Nankai University, *Title 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*: June 2018
Program first available on AMS website: August 9, 2018
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 39, Issue 3

Deadlines
For organizers: February 28, 2018
For abstracts: July 31, 2018

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

Invited Addresses
Leslie Greengard, New York University, *Title to be announced.*
Elisenda Grigsby, Boston College, *Title to be announced.*
Davesh Maulik, Massachusetts Institute of Technology, *Title to be announced.*

Fayetteville, Arkansas

University of Arkansas

October 6–7, 2018
Saturday–Sunday

Meeting #1142
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: July 2018
Program first available on AMS website: August 16, 2018
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 39, Issue 3

Deadlines
For organizers: March 6, 2018
For abstracts: August 7, 2018

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

Invited Addresses
Mihalis Dafermos, Princeton University, *Title to be announced.*
Jonathan Hauenstein, University of Notre Dame, *Title to be announced.*
Kathryn Mann, University of California Berkeley, *Title to be announced.*

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*: July 2018
Program first available on AMS website: August 30, 2018
Program issue of electronic *Notices*: To be announced
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.

Invited Addresses
Elena Fuchs, University of Illinois at Urbana—Champaign, *Title to be announced.*
Andrew Putman, University of Notre Dame, *Title to be announced.*
Charles Smart, University of Chicago, *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.

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.

Interactions between Algebra, Machine Learning and Data Privacy (Code: SS 3A), **Jonathan Gryak**, University of Michigan, **Kelsey Horan**, CUNY Graduate Center, **Delaram Kahrobaei**, CUNY Graduate Center and New York Univer-

sity, **Kayvan Najarian** and **Reza Soroushmehr**, University of Michigan, and **Alexander Wood**, CUNY Graduate Center.

Random Matrix Theory Beyond Wigner and Wishart (Code: SS 2A), **Elizabeth Meckes** and **Mark Meckes**, Case Western Reserve University, and **Mark Rudelson**, University of Michigan.

Self-similarity and Long-range Dependence in Stochastic Processes (Code: SS 4A), **Takashi Owada**, Purdue University, **Yi Shen**, University of Waterloo, and **Yizao Wang**, University of Cincinnati.

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*: July 2018
Program first available on AMS website: September 6, 2018
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Volume 39, Issue 4

Deadlines

For organizers: March 27, 2018
For abstracts: August 28, 2018

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

Invited Addresses

Srikanth B. Iyengar, University of Utah, *Title to be announced.*

Sarah Witherspoon, Texas A&M University, *Title to be announced.*

Abdul-Aziz Yakubu, Howard 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`.

Mathematcial Biology with a focus on Moeling Analysis and Simulation (Code: SS 1A), **Jim Cushing**, University of Arizona, **Saber Elaydi**, Trinity University, **Suzanne Sindi**, University of California, Merced, and **Abdul-Aziz Yakulou**, Howard University.

Homological Aspects of Noncommutative Algebra ad Geometry (Code: SS 2A), **Dan Rogalski**, University of California, San Diego, **Sarah Witherspoon**, Texas A&M University, and **James Zhang**, University of Washington, Seattle.

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel

January 16–19, 2019

Wednesday–Saturday

Meeting #1145

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
Program issue of electronic *Notices*: 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

Meeting #1146

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: 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

Meeting #1147

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
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: May 15, 2018
For abstracts: January 22, 2019

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

Invited Addresses

Barry Mazur, Harvard University, *Title to be announced* (Einstein Public Lecture in Mathematics).

Aaron Naber, Northwestern University, *Title to be announced.*

Deanna Needell, University of California, Los Angeles, *Title to be announced.*

Katherine Stange, University of Colorado, Boulder, *Title to be announced.*

Andrew Suk, University of Illinois at Chicago, *Title to be announced.*

Call for Special Session Proposals

The AMS solicits proposals for Special Sessions at the 2019 Joint AMS Central and Western Sectional Meeting to be held Friday March 22 through Sunday March 24, 2019 at the University of Hawaii at Manoa, Honolulu, Hawaii. Each proposal must include:

1. the name, affiliation, and email address of each organizer, with one organizer designated as the contact person for all communication about the session;

2. the title and a brief description (no longer than one or two paragraphs) of the topic of the proposed Special Session;

3. the primary two-digit MSC (Mathematics Subject Classification) number for the topic—see www.ams.org/mathscinet/msc/msc2010.html;

4. a sample list of the names of up to ten speakers and their institutions, whom the organizers plan to invite. (It is not necessary to have received confirmed commitments from these potential speakers.)

Organizers are strongly encouraged to consult the AMS Manual for Special Session Organizers at: www.ams.org/meetings/specialsessionmanual.html.

Proposals for Special Sessions should be sent by email to AMS Associate Secretary, Michel Lapidus (lapidus@math.ucr.edu), by May 15, 2018. The contact organizer of the proposal will be notified whether their proposal has been accepted after the May 15, 2018 deadline for proposals has passed, but no later than June 15, 2018.

Special Sessions will be allotted between five and fifteen hours in which to schedule speakers. Additional instructions and the session's schedule will be sent to the contact organizer of the accepted sessions by July 1, 2018.

Quy Nhon City, Vietnam

Quy Nhon University

June 10–13, 2019

Monday–Thursday
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: 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*: October 2019
Program first available on AMS website: November 1, 2019
Program issue of electronic *Notices*: To be announced
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
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2020
For abstracts: To be announced

JOINT MATHEMATICS MEETINGS
SAN DIEGO • JAN 10–13, 2018
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

Program at a Glance

This document provides a thumbnail sketch of all scientific and social events so you can easily see which events may overlap and better plan your time. **For the most up-to-date scheduling information, see:** jointmathematicsmeetings.org/meetings/national/jmm2018/2197_timetable.html

Monday, January 08

9:00 am–4:30 pm	**AMS SHORT COURSE ON DISCRETE DIFFERENTIAL GEOMETRY, PART I**
3:00 pm–6:00 pm	**NSF-EHR GRANT PROPOSAL WRITING WORKSHOP**

Tuesday, January 09

8:00 am–6:30 pm	**AMS DEPARTMENT CHAIRS WORKSHOP**
9:00 am–4:30 pm	**AMS SHORT COURSE ON DISCRETE DIFFERENTIAL GEOMETRY, PART II**
9:00 am–5:00 pm	**MAA CONGRESS**
1:30 pm–10:00 pm	**AMS COUNCIL**
3:00 pm–7:00 pm	**JOINT MEETINGS REGISTRATION** *Advanced registration will remain open until 7:30 pm*

Wednesday, January 10

7:00 am–8:45 am	**MAA MINORITY CHAIRS MEETING**
7:30 am–6:00 pm	**JOINT MEETINGS REGISTRATION**
7:30 am–5:30 pm	**EMAIL CENTER**
	AMS SPECIAL SESSIONS
8:00 am–10:50 am	*Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, I (AMS-MAA-SIAM)*
8:00 am–10:50 am	*Set Theory, Logic and Ramsey Theory, I (AMS-ASL)*
8:00 am–10:50 am	*Modeling in Differential Equations—High School, Two-Year College, Four-Year Institution, I*
8:00 am–10:50 am	*Structure and Representations of Hopf Algebras: a Session in Honor of Susan Montgomery, I*
8:00 am–10:50 am	*Network Science, I*

8:00 am–10:50 am *Nilpotent and Solvable Geometry,I*
8:00 am–10:50 am *Mathematical Analysis and Nonlinear Partial Differential Equations, I*
8:00 am–10:50 am *Mathematical Fluid Mechanics: Analysis and Applications, I*
8:00 am–10:50 am *Topological Graph Theory: Structure and Symmetry, I*
8:00 am–10:50 am *Mathematics of Gravitational Wave Science, I*
8:00 am–10:50 am *Arithmetic Dynamics, I*
8:00 am–10:50 am *Operators on Function Spaces in One and Several Variables, I*
8:00 am–10:50 am *Financial Mathematics, Actuarial Sciences, and Related Fields, I*
8:00 am–10:50 am *Mathematical Methods in Genomics, I*
8:00 am–10:50 am *History of Mathematics, I*
8:00 am–10:50 am *Discrete Dynamical Systems and Applications, I*
8:00 am–10:50 am *Geometric Analysis and Geometric Flows, I*
8:00 am–10:50 am *Applied and Computational Combinatorics, I*
8:00 am–10:50 am *Advances in Applications of Differential Equations to Disease Modeling, I*
8:00 am–10:50 am *Research by Postdocs of the Alliance for Diversity in Mathematics, I*
8:00 am–10:50 am *Mathematical Information in the Digital Age of Science, I*
8:00 am–10:50 am *Special Functions and Combinatorics (in honor of Dennis Stanton's 65th birthday), I*

8:00 am–10:55 am **AMS CONTRIBUTED PAPER SESSIONS**

MAA INVITED PAPER SESSIONS
8:00 am–10:50 am *Trends in Mathematical and Computational Biology*

MAA CONTRIBUTED PAPER SESSIONS
8:00 am–10:55 am *The Scholarship of Teaching and Learning in Collegiate Mathematics*
8:00 am–10:55 am *Innovative Curricular Strategies for Increasing Mathematics Majors*
8:00 am–10:55 am *Arts and Mathematics: The Interface, I*

8:00 am–10:55 am **MAA GENERAL CONTRIBUTED PAPER SESSIONS**

8:00 am–10:55 am **SIAM MINISYMPOSIUM ON DATA SCIENCE IN THE MATHEMATICS CURRICULUM**
8:00 am– 9:20 am **MAA PANEL** *How do we use assessment? What do we learn from it and how does it help us make related changes?*
8:00 am– 5:30 pm **EMPLOYMENT CENTER**
9:00 am–11:00 am **MAA MINICOURSE #1: PART A** *Introduction to Process Oriented Guided Inquiry Learning (POGIL) in Mathematics Courses*
9:00 am–11:00 am **MAA MINICOURSE #2: PART A** *Teaching Introductory Statistics Using the Guidelines from the American Statistical Association*
9:00 am–10:20 am **MAA-SIAM-AMS HRABOWSKI-GATES-TAPIA-MCBAY SESSION**
9:00 am– 9:50 am **MAA-SIAM-AMS HRABOWSKI-GATES-TAPIA-MCBAY SESSION: LECTURE**
9:00 am–10:30 am **AMS DIRECTORS OF UNDERGRADUATE STUDIES**
9:35 am–10:55 am **MAA PANEL** *What Every Student Should Know about the JMM*
9:35 am–10:55 am **MAA PANEL** *Mathematicians' Work in Creating Open Education Resources for K–12*
9:35 am–10:55 am **MAA WORKSHOP** *Creating Interdisciplinary Activities for Mathematical Sciences Classrooms*
9:50 am–10:30 am **MAA-SIAM-AMS HRABOWSKI-GATES-TAPIA-MCBAY PANEL** *Access to Quality Mathematics by All.*
10:05 am–10:55 am **AMS INVITED ADDRESS** *Title to be announced.* **Edriss Titi**
11:10 am–12:00 pm **AMS-MAA INVITED ADDRESS** *Topological Modeling of Complex Data.* **Gunnar Carlsson**
12:15 pm– 5:30 pm **EXHIBITS AND BOOK SALES**
1:00 pm– 1:50 pm **AMS COLLOQUIUM LECTURES: LECTURE I** *Title to be announced.* **Avi Wigderson**

2:00 pm–3:30 pm **AMS COMMITTEE ON MEETINGS AND CONFERENCES PANEL DISCUSSION** *Collaborative Research Communities in Mathematics*

2:15 pm–3:05 pm **MAA INVITED ADDRESS** *Quintessential quandle queries.* **Alissa Crans**

AMS SPECIAL SESSIONS

2:15 pm–6:05 pm *Orthogonal Polynomials and Applications, I*
2:15 pm–6:05 pm *Combinatorial Commutative Algebra and Polytopes, I*
2:15 pm–6:05 pm *Modeling in Differential Equations—High School, Two-Year College, Four-Year Institution, II*
2:15 pm–6:05 pm *Quaternions, I*
2:15 pm–6:05 pm *Differential Geometry, I*
2:15 pm–6:05 pm *Structure and Representations of Hopf Algebras: a Session in Honor of Susan Montgomery, II*
2:15 pm–6:05 pm *Nilpotent and Solvable Geometry,II*
2:15 pm–6:05 pm *Mathematical Fluid Mechanics: Analysis and Applications, II*
2:15 pm–6:05 pm *Operators on Function Spaces in One and Several Variables, II*
2:15 pm–6:05 pm *Financial Mathematics, Actuarial Sciences, and Related Fields, II*
2:15 pm–6:05 pm *Mathematical Methods in Genomics, II*
2:15 pm–6:05 pm *History of Mathematics, II*
2:15 pm–6:05 pm *A Showcase of Number Theory at Liberal Arts Colleges, I*
2:15 pm–6:05 pm *Geometric Analysis and Geometric Flows, II*
2:15 pm–6:05 pm *Applied and Computational Combinatorics, II*
2:15 pm–6:05 pm *Mathematical Modeling and Analysis of Infectious Diseases, I*
2:15 pm–6:05 pm *Ergodic Theory and Dynamical Systems–to Celebrate the Work of Jane Hawkins, I*
2:15 pm–6:05 pm *Algebraic, Analytic, and Geometric Aspects of Integrable Systems, Painlevé Equations, and Random Matrices, I*
2:15 pm–6:05 pm *Topological Data Analysis, I*
2:15 pm–6:05 pm *Analysis of Nonlinear Partial Differential Equations and Applications, I*

2:15 pm–5:55 pm **AMS CONTRIBUTED PAPER SESSIONS**

MAA INVITED PAPER SESSIONS

2:15 pm–5:35 pm *Teaching for Equity and Broader Participation in the Mathematical Sciences*
2:15 pm–4:15 pm **MAA MINICOURSE #3: PART A** *Flipping your Mathematics Course using Open Educational Resources*
2:15 pm–4:15 pm **MAA MINICOURSE #4: PART A** *How to Run Successful Math Circles for Students and Teachers*
2:15 pm–4:15 pm **MAA MINICOURSE #5: PART A** *Reach the World: Writing Math Op-Eds for a Post-Truth Culture*

MAA CONTRIBUTED PAPER SESSIONS

2:15 pm–5:35 pm *Implementing Recommendations from the Curriculum Foundations Project*
2:15 pm–6:00 pm *Discrete Mathematics in the Undergraduate Curriculum – Ideas and Innovations in Teaching*
2:15 pm–6:00 pm *Mathematics and Sports*
2:15 pm–6:00 pm *Integrating Research into the Undergraduate Classroom*
2:15 pm–6:00 pm *Flipped Classes: Implementation and Evaluation*
2:15 pm–6:05 pm *Arts and Mathematics: The Interface, II*

2:15 pm–5:55 pm **MAA GENERAL CONTRIBUTED PAPER SESSIONS**

2:15 pm–5:40 pm **SIAM MINISYMPOSIUM ON NUMERICAL LINEAR ALGEBRA**

2:15 pm–3:35 pm **MAA PANEL** *Ethics, Morality and Politics in the Quantitative Literacy Classroom*

2:15 pm–4:00 pm **MAA PANEL** *NSF Funding Opportunities to Improve Learning and Teaching in the Mathematical*

2:15 pm–3:00 pm **RADICAL DASH KICKOFF MEETING** *A daily scavenger hunt filled with math challenges and creativity for teams of undergraduates. Individuals are welcome and encouraged to participate;they will be formed into teams.*

2:15 pm–3:35 pm	**MAA WORKSHOP** *Championing Master's Programs in Mathematics: A forum for advocacy, networking, and innovation*
2:15 pm–3:40 pm	**ASSOCIATION FOR WOMEN IN MATHEMATICS PANEL DISCUSSION** *Using Mathematics in Activism.*
3:20 pm–4:10 pm	**MAA INVITED ADDRESS** *Groups, graphs, algorithms: The Graph Isomorphism problem.* **László Babai**
3:45 pm–4:15 pm	**AWM BUSINESS MEETING**
3:50 pm–5:10 pm	**MAA PANEL** *A Mathematician Teaches Statistics: The Road Less Traveled*
4:00 pm–5:00 pm	**TOWN HALL MEETING** *National Changes in Education—2018, a New World*
4:00 pm–5:00 pm	**MAA SECTION OFFICERS**
4:15 pm–5:35 pm	**MAA-JCW-AWM-NAM PANEL** *Implicit Bias and Its Effects in Mathematics*
4:30 pm–5:30 pm	**RECEPTION FOR UNDERGRADUATE STUDENTS**
5:30 pm–6:30 pm	**RECEPTION FOR GRADUATE STUDENTS AND FIRST-TIME PARTICIPANTS**
5:30 pm–8:00 pm	**MATHEMATICAL INSTITUTES OPEN HOUSE**
6:00 pm–7:30 pm	**AMS EDUCATION AND DIVERSITY DEPARTMENT PANEL** *Strategies for Diversifying Graduate Mathematics Programs*
6:00 pm–7:00 pm	**SIGMAA ON THE HISTORY OF MATHEMATICS (HOM SIGMAA) RECEPTION AND BUSINESS MEETING**
7:00 pm–7:50 pm	**SIGMAA ON THE HISTORY OF MATHEMATICS (HOM SIGMAA) GUEST LECTURE**
7:00 pm–8:30 pm	**MATHILY, MATHILY-ER YEARLY GATHER** *Come one, come all, and play a recently created mathematical game or solve a new puzzle!*
8:30 pm–9:30 pm	**AMS JOSIAH WILLARD GIBBS LECTURE** *Title to be announced.* **Cynthia Dwork**
9:30 pm–11:00 pm	**ASSOCIATION FOR WOMEN IN MATHEMATICS RECEPTION AND AWARDS PRESENTATION**

Thursday, January 11

7:30 am–4:00 pm	**JOINT MEETINGS REGISTRATION**
7:30 am–5:30 pm	**EMAIL CENTER**
	AMS SPECIAL SESSIONS
8:00 am–11:50 am	*Set Theory, Logic and Ramsey Theory, II (AMS-ASL)*
8:00 am–11:50 am	*Accelerated Advances in Mathematical Fractional Programming, I*
8:00 am–11:50 am	*Homotopy Type Theory (a Mathematics Research Communities Session), I*
8:00 am–11:50 am	*Beyond Planarity: Crossing Numbers of Graphs (a Mathematics Research Communities Session), I*
8:00 am–11:50 am	*Dynamical Systems: Smooth, Symbolic, and Measurable (a Mathematics Research Communities Session), I*
8:00 am–11:50 am	*Open and Accessible Problems for Undergraduate Research, I*
8:00 am–11:50 am	*Mathematics of Quantum Computing and Topological Phases of Matter, I*
8:00 am–11:50 am	*Mathematical Analysis and Nonlinear Partial Differential Equations, II*
8:00 am–11:50 am	*Novel Methods of Enhancing Success in Mathematics Classes, I*
8:00 am–11:50 am	*Multi-scale Modeling with PDEs in Computational Science and Engineering:Algorithms, Simulations, Analysis, and Applications, I*
8:00 am–11:50 am	*Advances in Operator Theory, Operator Algebras, and Operator Semigroups, I*
8:00 am–11:50 am	*Discrete Dynamical Systems and Applications, II*
8:00 am–11:50 am	*A Showcase of Number Theory at Liberal Arts Colleges, II*
8:00 am–11:50 am	*Research by Postdocs of the Alliance for Diversity in Mathematics, II*
8:00 am–11:50 am	*Algebraic, Discrete, Topological and Stochastic Approaches to Modeling in Mathematical Biology, I*
8:00 am–11:50 am	*Commutative Algebra in All Characteristics, I*
8:00 am–11:50 am	*Combinatorics and Geometry, I*

8:00 am–11:50 am	*Stochastic Processes, Stochastic Optimization and Control, Numerics and Applications, I*
8:00 am–11:50 am	*Boundaries for Groups and Spaces, I*
8:00 am–11:50 am	*Analysis of Nonlinear Partial Differential Equations and Applications, II*
8:00 am–11:50 am	*Special Functions and Combinatorics (in honor of Dennis Stanton's 65th birthday), II*
8:00 am–11:55 am	**AMS CONTRIBUTED PAPER SESSIONS**
	MAA INVITED PAPER SESSIONS
8:00 am–10:50 am	*MAA Instructional Practices Guide*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 am–12:00 pm	*Research in Undergraduate Mathematics Education (RUME), I*
8:00 am–12:00 pm	*Mathematical Knowledge for Teaching Grades 6–12 Mathematics*
8:00 am–10:55 am	*Trends in Undergraduate Mathematical Biology Education*
8:00 am–12:00 pm	*Humanistic Mathematics*
8:00 am–12:00 pm	*Environmental Modeling in the Classroom*
8:00 am–12:00 pm	*20th Anniversary—The EDGE (Enhancing Diversity in Graduate Education) Program: Pure and Applied Talks by Women, I*
8:00 am–12:00 pm	*Innovative and Effective Ways to Teach Linear Algebra*
8:00 am–12:00 pm	**MAA GENERAL CONTRIBUTED PAPER SESSIONS**
8:00 am–10:50 am	**SIAM MINISYMPOSIUM ON ADVANCES IN IMAGING SCIENCE**
8:00 am–11:00 am	**PME COUNCIL MEETING**
8:00 am– 5:30 pm	**EMPLOYMENT CENTER**
9:00 am– 9:50 am	**MAA INVITED ADDRESS** *Information, computation, optimization: connecting the dots in the traveling salesman problem.* **William Cook**
9:00 am–11:00 am	**MAA MINICOURSE #6: PART A** *Directing Undergraduate Research*
9:00 am–11:00 am	**MAA MINICOURSE #7: PART A** *Starter Kit for Teaching Modeling—First Differential Equations Course*
9:00 am–11:00 am	**MAA MINICOURSE #8: PART A** *Teaching Statistics using R and R Studio*
9:00 am–10:20 am	**MAA PANEL** *MAA Session for Chairs: Bridging the Gap*
9:00 am–10:20 am	**MAA PANEL** *Communicating Mathematics to a Wider Audience*
9:00 am–10:20 am	**MAA WORKSHOP** *Get to Know the National Science Foundation*
9:30 am– 5:30 pm	**EXHIBITS AND BOOK SALES**
10:00 am–12:00 pm	**MAA POSTER SESSION**
10:05 am–10:55 am	**AWM-AMS NOETHER LECTURE** *To be announced.* **Jill Pipher**
10:30 am–12:00 pm	**SIGMAA OFFICERS MEETING**
10:30 am–12:00 pm	**AWM COMMITTEE ON EDUCATION PANEL** *Supporting, Evaluating and Rewarding Work in Mathematics Education in Mathematical Sciences Departments*
10:35 am–11:55 am	**MAA WORKSHOP** *Hungarian Approach to Teaching Proof-writing Pósa's Discovery-Based Pedagogy*
10:35 am–11:55 am	**TOWN HALL MEETING** *Revising MAA Guidelines on the Work of Faculty and Departments: Supporting Student Success*
11:00 am–11:50 am	**PROJECT NEXT LECTURE ON TEACHING**
11:00 am–12:00 pm	**AMS INFORMATIONAL SESSION** *Report on the findings of the 2015 CBMS survey of undergraduate mathematical and statistical sciences in the U.S.*
11:10 am–12:00 pm	**SIAM INVITED ADDRESS** *Tensor Decompositions: A Mathematical Tool for Data Analysis.* **Tamara G. Kolda**

1:00 pm–1:50 pm **AMS COLLOQUIUM LECTURES: LECTURE II** *Title to be announced.* **Avi Wigderson**

AMS SPECIAL SESSIONS

1:00 pm–3:50 pm *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, II (AMS-MAA-SIAM)*
1:00 pm–3:50 pm *Set Theory, Logic and Ramsey Theory, III (AMS-ASL)*
1:00 pm–3:50 pm *New Trends in Celestial Mechanics, I*
1:00 pm–3:50 pm *Homotopy Type Theory (a Mathematics Research Communities Session), II*
1:00 pm–3:50 pm *Beyond Planarity: Crossing Numbers of Graphs (a Mathematics Research Communities Session), II*
1:00 pm–3:50 pm *Dynamical Systems: Smooth, Symbolic, and Measurable (a Mathematics Research Communities Session), II*
1:00 pm–3:50 pm *Open and Accessible Problems for Undergraduate Research, II*
1:00 pm–3:50 pm *Quaternions, II*
1:00 pm–3:50 pm *Recent Trends in Analysis of Numerical Methods of Partial Differential Equations, I*
1:00 pm–3:50 pm *Structure and Representations of Hopf Algebras: a Session in Honor of Susan Montgomery, III*
1:00 pm–3:50 pm *Interactions of Inverse Problems, Signal Processing, and Imaging, I*
1:00 pm–3:50 pm *Advances in Operator Theory, Operator Algebras, and Operator Semigroups, II*
1:00 pm–3:50 pm *Mathematical Modeling, Analysis and Applications in Population Biology, I*
1:00 pm–3:50 pm *History of Mathematics, III*
1:00 pm–3:50 pm *Spectral Theory, Disorder and Quantum Physics, I*
1:00 pm–3:50 pm *Theory, Practice, and Applications of Graph Clustering, I*
1:00 pm–3:50 pm *Mathematical Modeling and Analysis of Infectious Diseases, II*
1:00 pm–3:50 pm *Commutative Algebra in All Characteristics, II*
1:00 pm–3:50 pm *Discrete Neural Networking and Applications, I*
1:00 pm–3:50 pm *Algebraic, Analytic, and Geometric Aspects of Integrable Systems, Painlevé Equations, and Random Matrices, II*
1:00 pm–3:50 pm *Metric Geometry and Topology, I*
1:00 pm–3:50 pm *Mathematical Information in the Digital Age of Science, II*
1:00 pm–3:50 pm *Analysis of Nonlinear Partial Differential Equations and Applications, III*

1:00 pm– 3:50pm **AMS CONTRIBUTED PAPER SESSIONS**

MAA INVITED PAPER SESSIONS

1:00 pm–4:20 pm *Quandle Questions*
1:00 pm–3:00 pm **MAA MINICOURSE #10: PART A** *Incorporating Mathematical and Statistical Forensics Activities into the Undergraduate Mathematics Classroom*
1:00 pm–3:00 pm **MAA MINICOURSE #11: PART A** *Authoring Integrated Online Textbooks with MathBook XML*
1:00 pm–3:00 pm **MAA MINICOURSE #9: PART A** *Teaching Undergraduate Mathematics via Primary Source Projects*

MAA CONTRIBUTED PAPER SESSIONS

1:00 pm–4:10 pm *Research in Undergraduate Mathematics Education (RUME), II*
1:00 pm–4:10 pm *Using Mathematics to Study Problems from the Social Sciences*
1:00 pm–6:00 pm *Innovative Teaching Practices in Number Theory*
1:00 pm–4:10 pm *20th Anniversary—The EDGE (Enhancing Diversity in Graduate Education) Program: Pure and Applied Talks by Women, II*
1:00 pm–4:10 pm *Innovative Mathematical Outreach in Alternative Settings*
1:00 pm–4:10 pm *Math Circle Topics with Visual or Kinesthetic Components*

1:00 pm–4:10 pm **MAA GENERAL CONTRIBUTED PAPER SESSIONS**

1:00 pm–4:00 pm **SIAM MINISYMPOSIUM ON TENSORS! MATHEMATICAL CHALLENGES AND OPPORTUNITES**

1:00 pm–2:30 pm	**AMS COMMITTEE ON EDUCATION PANEL DISCUSSION** *Preparing mathematics students for non-academic careers*
1:00 pm–2:20 pm	**MAA PANEL** *Effectively Chairing a Mathematical Sciences Department*
1:00 pm–2:20 pm	**MAA PANEL** *Out in Mathematics: Professional Issues Facing LGBTQ Mathematicians*
1:00 pm–2:20 pm	**MAA WORKSHOP** *Using Problem Solving and Discussions in Mathematics Courses for Prospective Elementary Teachers*
1:00 pm–3:00 pm	**SUMMER PROGRAM FOR WOMEN IN MATHEMATICS (SPWM) REUNION**
2:00 pm–4:00 pm	**MAA POSTER SESSION: PROJECTS SUPPORTED BY THE NSF DIVISION OF UNDERGRADUATE EDUCATION**
2:15 pm–3:05 pm	**AMS INVITED ADDRESS** *Algebraic structures on polytopes.* **Federico Ardila**
2:30 pm–4:15 pm	**ESTIMATHON!** *A mindbending mixture of math and trivia.*
2:30 pm–3:55 pm	**AMS-MAA JOINT COMMITTEE ON TAS AND PART-TIME INSTRUCTORS PANEL** *Teaching-Focused Faculty at Research Institutions*
2:35 pm–3:55 pm	**MAA PANEL** *What is a "Math Center" and What Can it do For Your Department?*
2:35 pm–3:55 pm	**MAA PANEL** *The Dolciani Award: Mathematicians in K–16 Education*
2:35 pm–3:55 pm	**MAA WORKSHOP** *Writing Pedagogical and Expository Papers*
2:35 pm–3:55 pm	**SIAM-MAA-AMS PANEL** *Multiple Paths to Mathematics Careers in Business, Industry and Government (BIG)*
3:20 pm–4:10 pm	**AMS INVITED ADDRESS** *Searching for Hyperbolicity.* **Ruth Charney**
4:25 pm–5:25 pm	**JOINT PRIZE SESSION**
5:30 pm–7:30 pm	**ASSOCIATION OF CHRISTIANS IN THE MATHEMATICAL SCIENCES RECEPTION AND LECTURE**
5:30 pm–6:30 pm	**BUDAPEST SEMESTERS IN MATHEMATICS ALUMNI REUNION**
5:30 pm–6:30 pm	**JOINT PRIZE SESSION RECEPTION**
5:30 pm–7:00 pm	**MAA TWO-YEAR COLLEGE RECEPTION**
5:30 pm–7:30 pm	**PENN STATE MATHEMATICS DEPARTMENT RECEPTION**
5:30 pm–6:00 pm	**SIGMAA ON THE PHILOSOPHY OF MATHEMATICS (POM SIGMAA) RECEPTION**
6:00 pm–7:00 pm	**SIGMAA ON MATHEMATICAL AND COMPUTATIONAL BIOLOGY RECEPTION AND BUSINESS MEETING**
6:00 pm–6:15 pm	**SIGMAA ON THE PHILOSOPHY OF MATHEMATICS (POM SIGMAA) BUSINESS MEETING**
6:00 pm–8:00 pm	**ANNUAL SPECTRA RECEPTION FOR LESBIAN, GAY, BISEXUAL, AND TRANSGENDERED MATHEMATICIANS**
6:00 pm–8:00 pm	**NSA'S WOMEN IN MATHEMATICS SOCIETY NETWORKING SESSION**
6:00 pm–7:30 pm	**UNIVERSITY OF CALIFORNIA, SAN DIEGO RECEPTION**
6:00 pm–7:00 pm	**UNIVERSITY OF KANSAS RECEPTION**
6:15 pm–7:05 pm	**SIGMAA ON THE PHILOSOPHY OF MATHEMATICS (POM SIGMAA) GUEST LECTURE**
6:30 pm–8:00 pm	**MSRI RECEPTION FOR CURRENT AND FUTURE DONORS**
7:00 pm–8:00 pm	**SIGMAA ON MATHEMATICAL AND COMPUTATIONAL BIOLOGY GUEST LECTURE**
7:30 pm–8:30 pm	**AMS FORUM, SPONSORED BY THE U.S. NATIONAL COMMITTEE FOR MATHEMATICS** *2018 International Congress of Mathematicians*
7:30 pm–9:30 pm	**PROMYS AND ROSS GATHERING FOR ALUMNI AND FRIENDS**
8:15 pm–9:45 pm	**KNITTING CIRCLE** *Knitting Circle: Bring a project (knitting/crochet/tatting/beading/etc.) and chat with other mathematical crafters*

Friday, January 12

7:30 am–4:00 pm	**JOINT MEETINGS REGISTRATION**
7:30 am–5:30 pm	**EMAIL CENTER**
	AMS SPECIAL SESSIONS
8:00 am–10:50 am	*Women in Symplectic and Contact Geometry and Topology, I (AMS-AWM)*
8:00 am–10:50 am	*Free Convexity and Free Analysis, I*
8:00 am–10:50 am	*Noncommutative Algebras and Noncommutative Invariant Theory, I*
8:00 am–10:50 am	*If You Build It They Will Come: Presentations by Scholars in the National Alliance for Doctoral Studies in the Mathematical Sciences, I*
8:00 am–10:50 am	*Recent Trends in Analysis of Numerical Methods of Partial Differential Equations, II*
8:00 am–10:50 am	*Nonlinear Evolution Equations of Quantum Physics and Their Topological Solutions, I*
8:00 am–10:50 am	*Mathematical Modeling of Natural Resources, I*
8:00 am–10:50 am	*History of Mathematics, IV*
8:00 am–10:50 am	*Visualization in Mathematics: Perspectives of Mathematicians and Mathematics Educators, I*
8:00 am–10:50 am	*Advances in Applications of Differential Equations to Disease Modeling, II*
8:00 am–10:50 am	*Quantum Link Invariants, Khovanov Homology, and Low-dimensional Manifolds, I*
8:00 am–10:50 am	*Algebraic, Discrete, Topological and Stochastic Approaches to Modeling in Mathematical Biology, II*
8:00 am–10:50 am	*Dynamical Algebraic Combinatorics, I*
8:00 am–10:50 am	*Discrete Neural Networking and Applications, II*
8:00 am–10:50 am	*Combinatorics and Geometry, II*
8:00 am–10:50 am	*Ergodic Theory and Dynamical Systems–to Celebrate the Work of Jane Hawkins, II*
8:00 am–10:50 am	*Mathematical Relativity and Geometric Analysis, I*
8:00 am–10:50 am	*Stochastic Processes, Stochastic Optimization and Control, Numerics and Applications, II*
8:00 am–10:50 am	*Boundaries for Groups and Spaces, II*
8:00 am–10:50 am	*Mathematical Information in the Digital Age of Science, III*
8:00 am–10:50 am	*Topological Data Analysis, II*
8:00 am–10:55 am	**AMS CONTRIBUTED PAPER SESSIONS**
8:00 am–10:55 am	**ASL INVITED ADDRESSES**
	MAA INVITED PAPER SESSIONS
8:00 am–10:50 am	*Research in Improving Undergraduate Mathematical Sciences Education: Examples Supported by the National Science Foundation's IUSE: EHR Program*
	MAA CONTRIBUTED PAPER SESSIONS
8:00 am–10:55 am	*The Advancement of Open Educational Resources*
8:00 am–10:55 am	*Mathematical Experiences and Projects in Business, Industry, and Government (BIG)*
8:00 am–10:55 am	*Philosophy of Mathematics as Actually Practiced*
8:00 am–10:55 am	*Inquiry-Based Teaching and Learning, I*
8:00 am–10:55 am	**MAA GENERAL CONTRIBUTED PAPER SESSIONS**
8:00 am–10:55 am	**SIAM MINISYMPOSIUM ON ADVANCES IN FINITE ELEMENT APPROXIMATION**
8:00 am–9:20 am	**MAA PANEL** *Teaching Mathematics Content to Prospective Elementary Teachers: Strategies and Opportunities*
8:00 am–5:30 pm	**EMPLOYMENT CENTER**
8:30 am–10:30 am	**AMS-MAA GRAD SCHOOL FAIR** *Undergrads! Take this opportunity to meet representatives from mathematical science graduate programs.*
9:00 am–9:50 am	**MAA INVITED ADDRESS** *Toy models.* **Tadashi Tokieda**

9:00 am–11:00 am	**MAA MINICOURSE #1: PART B** *Introduction to Process Oriented Guided Inquiry Learning (POGIL) in Mathematics Courses*
9:00 am–11:00 am	**MAA MINICOURSE #2: PART B** *Teaching Introductory Statistics Using the Guidelines from the American Statistical Association*
9:00 am–10:30 am	**AMS PANEL** *Historical Chief Editors of the Notices*
9:30 am– 5:30 pm	**EXHIBITS AND BOOK SALES**
9:35 am–10:55 am	**MAA PANEL** *The New AP Calculus Curriculum—The First Round of Testing*
10:05 am–10:55 am	**AMS INVITED ADDRESS** *Emergent phenomena in random structures and algorithms.* **Dana Randall**
10:30 am–11:00 am	**RADICAL DASH PRIZE SESSION**
11:10 am–12:00 pm	**AMS-MAA INVITED ADDRESS** *Minimal surfaces, volume spectrum, and Morse index.* **André Neves**
12:00 pm– 1:00 pm	**BUDAPEST SEMESTERS IN MATHEMATICS EDUCATION INFORMATIONAL SESSION**
1:00 pm– 1:50 pm	**AMS COLLOQUIUM LECTURES: LECTURE III** *Title to be announced.* **Avi Wigderson**
1:00 pm– 1:50 pm	**MAA LECTURE FOR STUDENTS** *HOW MANY DEGREES ARE IN A MARTIAN CIRCLE? And other human (and non-human) questions one should ask about everyday mathematics.* **James Tanton**
1:00 pm– 4:45 pm	**CURRENT EVENTS BULLETIN**
	AMS SPECIAL SESSIONS
1:00 pm– 5:50 pm	*Women in Symplectic and Contact Geometry and Topology, II (AMS-AWM)*
1:00 pm– 5:50 pm	*Combinatorial Commutative Algebra and Polytopes, II*
1:00 pm– 5:50 pm	*Noncommutative Algebras and Noncommutative Invariant Theory, II*
1:00 pm– 5:50 pm	*If You Build It They Will Come: Presentations by Scholars in the National Alliance for Doctoral Studies in the Mathematical Sciences, II*
1:00 pm– 5:50 pm	*Markov Chains, Markov Processes and Applications, I*
1:00 pm– 5:50 pm	*Diophantine Approximation and Analytic Number Theory in Honor of Jeffrey Vaaler, I*
1:00 pm– 5:50 pm	*Network Science, II*
1:00 pm– 5:50 pm	*Nonlinear Evolution Equations of Quantum Physics and Their Topological Solutions, II*
1:00 pm– 5:50 pm	*Mathematical Modeling of Natural Resources, II*
1:00 pm– 5:50 pm	*Topological Graph Theory: Structure and Symmetry, II*
1:00 pm– 5:50 pm	*Mathematics of Gravitational Wave Science, II*
1:00 pm– 5:50 pm	*Arithmetic Dynamics, II*
1:00 pm– 5:50 pm	*Advances in Operator Algebras, I*
1:00 pm– 5:50 pm	*Research from the Rocky Mountain—Great Plains Graduate Research Workshop in Combinatorics, I*
1:00 pm– 5:50 pm	*Mathematical Relativity and Geometric Analysis, II*
1:00 pm– 5:50 pm	*Strengthening Infrastructures to Increase Capacity Around K–20 Mathematics, I*
1:00 pm– 5:50 pm	*Emergent Phenomena in Discrete Models, I*
1:00 pm– 5:50 pm	*Geometric Analysis, I*
1:00 pm– 5:55 pm	**AMS CONTRIBUTED PAPER SESSIONS**
1:00 pm– 5:55 pm	**ASL INVITED ADDRESSES**
	MAA INVITED PAPER SESSIONS
1:00 pm– 3:50 pm	*Polyhedra, Commemorating Magnus J. Wenninger*
1:00 pm– 3:00 pm	**MAA MINICOURSE #3: PART B** *Flipping your Mathematics Course using Open Educational Resources*
1:00 pm– 3:00 pm	**MAA MINICOURSE #4: PART B** *How to Run Successful Math Circles for Students and Teachers*
1:00 pm– 3:00 pm	**MAA MINICOURSE #5: PART B** *Reach the World: Writing Math Op-Eds for a Post-Truth Culture*

MAA CONTRIBUTED PAPER SESSIONS

1:00 pm–6:00 pm *Mathematical Themes in a First-Year Seminar*
1:00 pm–6:00 pm *Good Math from Bad: Crackpots, Cranks, and Progress*
1:00 pm–5:55 pm *The Teaching and Learning of Undergraduate Ordinary Differential Equations*
1:00 pm–6:00 pm *Technology and Resources for Teaching Statistics*
1:00 pm–5:50 pm *Inquiry-Based Teaching and Learning, II*
1:00 pm–6:00 pm *Innovative and Effective Online Teaching Techniques*

1:00 pm–6:00 pm. **MAA GENERAL CONTRIBUTED PAPER SESSIONS**
1:00 pm–6:10 pm **SIAM MINISYMPOSIUM ON MIMETIC MULTIPHASE SUBSURFACE AND OCEANIC TRANSPORT**
1:00 pm–3:50 pm **NAM GRANVILLE-BROWN-HAYNES SESSION OF PRESENTATIONS BY RECENT DOCTORAL RECIPIENTS IN THE MATHEMATICAL SCIENCES**
1:00 pm–2:20 pm **MAA PANEL** *Pathways Through High School Mathematics: Building Focus and Coherence*
1:00 pm–2:30 pm **PANEL ON THE EXPERIENCES OF FOREIGN GRADUATE STUDENTS AS GTAS**
1:00 pm–2:00 pm **TOWN HALL MEETING** *Creating Engaging, Meaningful Experiences for Teachers and Future Teachers*
2:00 pm–3:30 pm **AMS DIRECTORS OF GRADUATE STUDIES**
2:15 pm–4:00 pm **ROCKY MOUNTAIN MATHEMATICS CONSORTIUM BOARD OF DIRECTORS MEETING**
2:30 pm–3:50 pm **PRESENTATIONS BY MAA TEACHING AWARD RECIPIENTS**
2:30 pm–4:00 pm **AMS COMMITTEE ON SCIENCE POLICY PANEL DISCUSSION** *Funding at federal agencies & advocacy for grassroots support*
2:35 pm–3:55 pm **MAA PANEL** *Career Trajectories Involving Administrative Roles: What You May Want to Consider*
4:00 pm–5:30 pm **NATIONAL SCIENCE FOUNDATION: UPDATE FROM THE DIVISION OF MATHEMATICAL SCIENCES**
4:30 pm–6:00 pm **MAA STUDENT POSTER SESSION**
4:30 pm–6:30 pm **AMS CONGRESSIONAL FELLOWSHIP SESSION**
5:00 pm–7:00 pm **MAA PANEL** *The Evolving Career Outlook in Risk Management*
5:30 pm–6:20 pm **SIGMAA ON BUSINESS, INDUSTRY, AND GOVERNMENT (BIG SIGMAA)GUEST LECTURE**
5:30 pm–6:00 pm **SIGMAA ON STATISTICS EDUCATION BUSINESS MEETING**
5:30 pm–7:30 pm **TEXAS A & M UNIVERSITY MATHEMATICS DEPARTMENT ALUMNI, STUDENT, AND FACULTY RECEPTION**
5:30 pm–7:30 pm **UNIVERSITY OF ILLINOIS AT URBANA—CHAMPAIGN DEPARTMENT OF MATHEMATICS ALUMNI RECEPTION**
5:30 pm–6:00 pm **SIGMAA ON MATHEMATICS INSTRUCTION USING THE WEB (WEB SIGMAA)RECEPTION**
6:00 pm–6:50 pm **SIGMAA ON MATHEMATICS INSTRUCTION USING THE WEB (WEB SIGMAA) GUEST LECTURE**
6:00 pm–7:15 pm **AWM WORKSHOP: POSTER PRESENTATIONS BY WOMEN GRADUATE STUDENTS AND RECEPTION**
6:00 pm–7:00 pm **MATHEMATICALLY BENT THEATER** *Performed by Colin Adams and the Mobiusbandaid Players.*
6:00 pm–6:45 pm **SIGMAA ON STATISTICS EDUCATION BUSINESS MEETING**
6:00 pm–7:00 pm **AMS *MATHEMATICAL REVIEWS* RECEPTION**
6:00 pm–8:40 pm **NAM RECEPTION AND BANQUET**
6:30 pm–7:00 pm **SIGMAA ON BUSINESS, INDUSTRY, AND GOVERNMENT (BIG SIGMAA) RECEPTION**
6:50 pm–7:40 pm **SIGMAA ON STATISTICS EDUCATION GUEST LECTURE**
7:00 pm–7:30 pm **SIGMAA ON BUSINESS, INDUSTRY, AND GOVERNMENT (BIG SIGMAA) BUSINESS MEETING**
7:30 pm–9:00 pm **AMS FELLOWS RECEPTION**

7:45 pm– 8:35 am	**NAM COX–TALBOT ADDRESS** *To be announced.* **Erica Walker**
8:00 pm–10:00 pm	**PROJECT NEXT RECEPTION** *All Project NExT Fellows, consultants, and other friends of Project NExT are invited.*
8:00 pm–10:00 pm	**BACKGAMMON!** *Learn to play backgammon from expert players.*

Saturday, January 13

7:30 am– 2:00 pm	**JOINT MEETINGS REGISTRATION**
7:30 am– 2:00 pm	**EMAIL CENTER**
	AMS SPECIAL SESSIONS
8:00 am–11:50 am	*Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, III (AMS-MAA-SIAM)*
8:00 am–12:00 pm	*Alternative Proofs in Mathematical Practice, I*
8:00 am–12:00 pm	*Analysis of Fractional, Stochastic, and Hybrid Dynamic Systems, I*
8:00 am–12:00 pm	*Mathematics of Quantum Computing and Topological Phases of Matter, II*
8:00 am–12:00 pm	*Differential Geometry, II*
8:00 am–12:00 pm	*Diophantine Approximation and Analytic Number Theory in Honor of Jeffrey Vaaler, II*
8:00 am–12:00 pm	*Multi-scale Modeling with PDEs in Computational Science and Engineering:Algorithms, Simulations, Analysis, and Applications, II*
8:00 am–12:00 pm	*Set-theoretic Topology (Dedicated to Jack Porter in Honor of 50 Years of Dedicated Research), I*
8:00 am–12:00 pm	*Mathematical Modeling, Analysis and Applications in Population Biology, II*
8:00 am–12:00 pm	*Visualization in Mathematics: Perspectives of Mathematicians and Mathematics Educators, II*
8:00 am–12:00 pm	*Advances in Operator Algebras, II*
8:00 am–12:00 pm	*Fractional Difference Operators and Their Application, I*
8:00 am–12:00 pm	*Emerging Topics in Graphs and Matrices, I*
8:00 am–12:00 pm	*Bifurcations of Difference Equations and Discrete Dynamical Systems, I*
8:00 am–12:00 pm	*Mathematics Research from the SMALL Undergraduate Research Program, I*
8:00 am–12:00 pm	*Boundaries for Groups and Spaces, III*
8:00 am–12:00 pm	*Topological Data Analysis, III*
8:00 am–12:00 pm	*Special Functions and Combinatorics (in honor of Dennis Stanton's 65th birthday), III*
8:00 am–12:00 pm	**AMS CONTRIBUTED PAPER SESSIONS**
8:00 am–12:00 pm	**ASL INVITED ADDRESSES**
	MAA CONTRIBUTED PAPER SESSIONS
8:00 am–12:00 pm	*Attracting, Involving, and Retaining Women and Underrepresented Groups in Mathematics – Righting the Balance*
8:00 am–12:00 pm	*Quantitative Literacy Across the Curriculum*
8:00 am–12:00 pm	*Lightning Talks and E-Posters: Me and My Gadgets, Teaching with Technology*
8:00 am–12:00 pm	*Revitalizing Complex Analysis*
8:00 am–12:00 pm	*Teaching Abstract Algebra: Topics and Techniques*
8:00 am–12:00 pm	**MAA GENERAL CONTRIBUTED PAPER SESSIONS**
8:00 am–11:55 am	**SIAM MINISYMPOSIUM ON RECENT ADVANCES IN MODELING, ANALYSIS, AND CONTROL IN EPIDEMIOLOGY, SPATIAL ECOLOGY AND EVOLUTION**
8:00 am– 5:00 pm	**AWM WORKSHOP: SPECIAL SESSION ON NONCOMMUTATIVE ALGEBRA AND REPRESENTATION THEORY**

MAA INVITED PAPER SESSIONS

8:30 am–10:50 am *Research in Undergraduate Mathematics Education: Highlights from the Annual SIGMAA on RUME Conference*

9:00 am– 9:50 am **AMS RETIRING PRESIDENTIAL ADDRESS** *Title to be announced* **Robert L. Bryant**

MAA INVITED PAPER SESSIONS

9:00 am–11:50 am *Accessible Problems in Modern Number Theory*

9:00 am–11:00 am **MAA MINICOURSE #6: PART B** *Directing Undergraduate Research*

9:00 am–11:00 am **MAA MINICOURSE #7: PART B** *Starter Kit for Teaching Modeling—First Differential Equations Course*

9:00 am–11:00 am **MAA MINICOURSE #8: PART B** *Teaching Statistics using R and R Studio*

9:00 am–10:20 am **MAA PANEL** *MAA Committee on Actuarial Science Education*

9:00 am– 9:50 am **NAM PANEL DISCUSSION** *Advising Our Students on the Transition to the 1st (or 0th) Year of Graduate School*

9:00 am–12:00 pm **EMPLOYMENT CENTER**

9:30 am–12:00 pm **EXHIBITS AND BOOK SALES**

10:00 am–10:50 am **MAA INTERACTIVE LECTURE FOR STUDENTS AND TEACHERS** *Mathematics to the rescue—how to fold a tie.*

10:00 am–10:50 am **NAM BUSINESS MEETING**

10:05 am–10:55 am **MAA INVITED ADDRESS** *Transforming learning: building confidence and community to engage students with rigor.* **Maria Klawe**

10:35 am–11:55 am **MAA PANEL** *Tips and Tricks to Securing Funding for Undergraduate Research*

11:10 am–11:40 am **MAA BUSINESS MEETING**

11:45 am–12:15 pm **AMS BUSINESS MEETING**

1:00 pm– 1:50 pm **NAM CLAYTOR-WOODARD LECTURE** *To be announced.* **Ronald Mickens**

AMS SPECIAL SESSIONS

1:00 pm– 5:50 pm *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, IV (AMS-MAA-SIAM)*

1:00 pm– 5:50 pm *New Trends in Celestial Mechanics, II*

1:00 pm– 5:50 pm *Advances in Difference, Differential, and Dynamic Equations with Applications, I*

1:00 pm– 5:50 pm *Free Convexity and Free Analysis, II*

1:00 pm– 5:50 pm *Interactions of Inverse Problems, Signal Processing, and Imaging, II*

1:00 pm– 5:50 pm *Set-theoretic Topology (Dedicated to Jack Porter in Honor of 50 Years of Dedicated Research), II*

1:00 pm– 5:50 pm *Research in Mathematics by Early Career Graduate Students, I*

1:00 pm– 5:50 pm *Mathematical Problems in Ocean Wave Modeling and Fluid Mechanics, I*

1:00 pm– 5:50 pm *Spectral Theory, Disorder and Quantum Physics, II*

1:00 pm– 5:50 pm *Emerging Topics in Graphs and Matrices, II*

1:00 pm– 5:50 pm *Theory, Practice, and Applications of Graph Clustering, II*

1:00 pm– 5:50 pm *Quantum Link Invariants, Khovanov Homology, and Low-dimensional Manifolds, II*

1:00 pm– 5:50 pm *Dynamical Algebraic Combinatorics, II*

1:00 pm– 5:50 pm *Mathematics Research from the SMALL Undergraduate Research Program, II*

1:00 pm– 5:50 pm *Computational Combinatorics and Number Theory, I*

1:00 pm– 5:50 pm *Metric Geometry and Topology, II*

1:00 pm– 5:50 pm *Dynamical Systems with Applications to Mathematical Biology, I*

1:00 pm– 5:50 pm *Connections in Discrete Mathematics: Graphs, Hypergraphs, and Designs, I*

1:00 pm– 5:50 pm *Extremal Problems in Approximations and Geometric Function Theory, I*

1:00 pm– 5:50 pm *Geometric Analysis, II*

1:00 pm– 5:50 pm *Orthogonal Polynomials, Quantum Probability, and Stochastic Analysis, I*

1:00 pm–5:50 pm	**AMS CONTRIBUTED PAPER SESSIONS**
1:00 pm–5:50 pm	**ASL INVITED ADDRESSES**
	MAA INVITED PAPER SESSIONS
1:00 pm–4:50 pm	*Differential Equations and Their Applications to Neuroscience*
1:00 pm–3:00 pm	**MAA MINICOURSE #10: PART B** *Incorporating Mathematical and Statistical Forensics Activities into the Undergraduate Mathematics Classroom*
1:00 pm–3:00 pm	**MAA MINICOURSE #11: PART B** *Authoring Integrated Online Textbooks with MathBook XML*
1:00 pm–3:00 pm	**MAA MINICOURSE #9: PART B** *Teaching Undergraduate Mathematics via Primary Source Projects*
	MAA CONTRIBUTED PAPER SESSIONS
1:00 pm–5:30 pm	*Meaningful Modeling in the First Two Years of College*
1:00 pm–5:30 pm	*Scholarship on Teaching and Learning in Statistics Education*
1:00 pm–6:00 pm	**MAA GENERAL CONTRIBUTED PAPER SESSIONS**
1:00 pm–5:50 pm	**SIAM MINISYMPOSIUM ON PROBLEMS IN QUASILINEAR DESPERSIVE PDE**
1:00 pm–2:45 pm	**AMS SPECIAL PRESENTATION** *Who Wants to be a Mathematician—national contest.*
1:00 pm–2:20 pm	**MAA PANEL** *The Impact of Software on Learning in Upper Division Mathematics Courses*
3:00 pm–3:50 pm	**MAA-AMS-SIAM GERALD AND JUDITH PORTER PUBLIC LECTURE** *Political Geometry: Voting districts,"compactness," and ideas about fairness.* **Moon Duchin**
6:30 pm–7:30 pm	**AMS DINNER RECEPTION**
7:30 pm–10:30 pm	**AMS DINNER CELEBRATION**

The AMS Connects & Supports!

Attend the 2018

AMS DINNER

at the Joint Mathematics Meetings in San Diego, California!

Join your colleagues on this special occasion of celebration in the mathematical community. The AMS will recognize long-term members as well as honor the recipients of the Mathematics Programs that Make a Difference, Impact on the Teaching and Learning of Mathematics, and Exemplary Program or Achievement in a Mathematics Department awards. Enjoy delicious meals from gourmet food stations, take pictures at the photo booth, and enter to win fun prizes at the raffle table! Each guest will also receive a special gift from the AMS.

This evening of celebration will be held on **Saturday, January 13th** with a **reception at 6:30 pm** and doors opening at **7:30 pm**. Purchase your tickets when registering for the Joint Mathematics Meetings. *A limited number of tickets will be available at a special price for students.*

AMS
American Mathematical Society
www.ams.org

2018 Joint Mathematics Meetings Hotel Reservations – San Diego, CA

Please see the hotel information in the announcement or on the web for detailed information on each hotel. To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc. in the column on the left and by circling the requested bed confirguration. If your requested hotel and room type is no longer available, you will be assigned a room at the next available comparable rate. Please call the MMSB for details on suite configurations, sizes, availability, etc. All reservations, including suite reservations, must be made through the MMSB to receive the JMM rates. Reservations made directly with the hotels before **December 15, 2017** may be changed to a higher rate. All rates are subject to applicable local and state taxes in effect at the time of check-in; currently 10.5% state tax, the San Diego Tourism Marketing District assessment 2% tax, and the CA Tourism fee of US$0.77 per night. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee. Please note that reservations with check deposits must be received by the MMSB by December 5, 2017.** People interested in suites should contact the MMSB directly at mmsb@ams.org or by calling 800-321-4267, ext. 4137; (401-455-4137).

☐ **Deposit enclosed (see front of form**)
☐ **Hold with my credit card**. **For your security, we do not accept credit card numbers by email, postal mail or fax.** If the MMSB receives your registration form by any of these methods, it will contact you at the phone number provided on the reverse of this form.

Date and Time of Arrival_____ **Date and Time of Departure** _____ **Number of adult guests in room**_____ **Number of children** _____

Name of Other Adult Room Occupant (s) _____ Arrival: _____ Departure: _____

Housing Requests:.(example: rollaway cot, crib, nonsmoking room, low floor) _____

☐ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are:_____

☐ I am a member of a hotel frequent-travel club and would like to receive appropriate credit. The hotel chain and card number are: _____

☐ I am not reserving a room. I am sharing with _____ , who is making the reservation.

Order of choice	Hotel	Single	Double 1 bed-2 people	Double 2 beds- 2 people	Triple 3 adults-2 beds	Quad 4 adults-2 beds	Rollaway/Cot Fee (add to special requests if reserving online)
	Marriott Marquis San Diego Marina (hdqrs)						Rollaways are available (at no charge) in king-bedded rooms only
	Bay View	US$ 222	US$ 222	US$ 222	US$ 242	UD$ 262	
	City View	US$ 207	US$ 207	US$ 207	US$ 227	UD$ 247	
	City View Student Rate	US$ 147	US$ 147	US$ 147	US$ 167	UD$ 187	
	Embassy Suites Hotel San Diego Bay	US$ 180	US$ 180	US$ 180	US$ 200	US$ 220	Rollaways are not available.
	Student Rate	US$ 160	US$ 160	US$ 160	US$ 180	US$ 200	
	Manchester Grand Hyatt San Diego	US$ 179	US$ 189	US$ 189	US$ 199	US$ 209	Rollaways are available (at no charge) in king-bedded rooms only.
	Student Rate	US$ 147	US$ 147	US$ 147	US$ 157	US$ 167	
	Omni Hotel San Diego	US$ 179	US$ 189	US$ 189	US$ 199	US$ 209	Rollaways are available (at no charge) in king-bedded rooms only
	Student Rate	US$ 147	US$ 147	US$ 147	US$ 157	US$ 167	
	Hilton Gaslamp San Diego	US$ 176	US$ 176	US$ 176	US$ 176	US$ 176	Maximum 4 people per room. Rollaways are available for US$ 20 per day in king-bedded rooms only.
	Student Rate	US$ 158	US$ 158	US$ 158	US$ 158	US$ 158	
	Hard Rock Hotel San Diego	US$ 170	US$ 170	US$ 170	US$ 190	US$ 210	Rollaways are available for US$ 30 per day in king-bedded rooms only.
	Student Rate	US$ 159	US$ 159	US$ 159	US$ 179	US$ 199	
	Best Western Plus Bayside Inn	US$ 165	US$ 165	US$ 165	US$ 175	US$ 175	Rollaways are available on request for US$ 10 per day.
	Student Rate	US$ 155	US$ 155	US$ 155	US$ 165	US$ 165	
	Solamar Hotel San Diego	US$ 165	US$ 165	US$ 165	US$ 185	US$ 205	Rollaways are available for US$ 40 per day in king-bedded rooms only.
	Student Rate	US$ 149	US$ 149	US$ 149	US$ 169	US$ 189	
	Palomar Hotel San Diego	US$ 160	US$ 160	US$ 160	US$ 185	US$ 210	Rollaways are not available.
	Student Rate	US$ 149	US$ 149	US$ 149	US$ 174	US$ 199	
	Horton Grand Hotel	US$ 159	US$ 159	US$ 159	US$ 179	US$ 199	Rollaways are not available.
	Student Rate	US$ 139	US$ 139	US$ 139	US$ 159	US$ 179	
	Porto Vista Hotel	US$ 125	US$ 125	US$ 125	US$ 145	US$ 165	Rollaways are not available.

2018 Joint Mathematics Meetings Advance Registration/Housing Form

JOINT MATHEMATICS MEETINGS
SAN DIEGO • JAN 10–13, 2018
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

Name _____
(please print your name as you would like it to appear on your badge)

Mailing Address _____

_____

Telephone _____ Fax: _____

In case you have an emergency at the meeting: Day #: _____ Evening #: _____

Email Address _____ Additional email address for receipt _____

Acknowledgment of this registration and any hotel reservations will be sent to the email address(es) given here. **Check this box to receive a copy in U.S. Mail:** ☐

Affiliation for badge _____ Nonmathematician guest badge name: _____
(company/university) (Note fee of US$21)

In an effort to make the JMM more environmentally friendly as well as save on printing expenses to the meeting, the JMM program books will now only be distributed to participants who ask for them. More up-to-date program and meeting information will be available on the JMM website and mobile app.
Do you want to receive a copy of the program book? Yes ☐ No ☐

☐ I DO NOT want my badge and program (if printed program is requested) to be mailed to me on 12/8/17. Materials will be mailed to the address listed above unless you check this box. Materials will not be mailed for registrations completed after November 22, or to individual commercial or artist exhibitors. Exhibiting companies may opt to have booth staff badges mailed to a company contact.

Registration Fees

Membership please ✓ all that apply. First row is eligible to register as a member.
For undergraduate students, membership in PME and KME also applies.
☐ AMS & MAA ☐ AMS but not MAA ☐ MAA but not AMS ☐ ASL ☐ CMS ☐ SIAM
Undergraduate Students Only: ☐ PME ☐ KME
Other Societies: ☐ AWM ☐ NAM ☐ YMN ☐ AMATYC

Joint Meetings	by Dec 20	at mtg	Subtotal
☐ Member AMS, MAA, ASL, CMS, or SIAM	US$ 329	US$ 433	
☐ Nonmember	US$ 522	US$ 666	
☐ Graduate Student Member (AMS, MAA ASL, CMS, or SIAM)	US$ 74	US$ 86	
☐ Graduate Student (Nonmember)	US$118	US$ 130	
☐ Undergraduate Student (Member AMS, ASL, CMS, MAA, PME, KME, or SIAM)	US$ 74	US$ 86	
☐ Undergraduate Student (Nonmember)	US$118	US$ 130	
☐ High School Student	US$ 7	US$ 14	
☐ Unemployed	US$ 74	US$ 86	
☐ Temporarily Employed	US$ 268	US$ 307	
☐ Developing Countries Special Rate	US$ 74	US$ 86	
☐ Emeritus Member of AMS or MAA	US$ 74	US$ 86	
☐ High School Teacher	US$ 74	US$ 86	
☐ Librarian	US$ 74	US$ 86	
☐ Press	US$ 0	US$ 0	
☐ Exhibitor (Commercial)	US$ 0	US$ 0	
☐ Artist Exhibitor (work in JMM Art Exhibit)	US$ 0	US$ 0	
☐ Nonmathematician Guest of registered mathematician	US$ 21	US$ 21	

$_____

AMS Short Course: *Discrete Differential Geometry (1/8-1/9)*

☐ Member of AMS	US$ 114	US$148	
☐ Nonmember	US$ 175	US$205	
☐ Student, Unemployed, Emeritus	US$ 62	US$ 83	

$_____

MAA Minicourses (see listing in text)
I would like to attend: ☐ One Minicourse ☐ Two Minicourses
Please enroll me in MAA Minicourse(s) #_____ and #_____
Price: US$ 100 for each minicourse.
(For more than 2 minicourses, call or email the MMSB.) $_____

Graduate School Fair Table
☐ Graduate Program Table US$125 US$125
(includes table, posterboard & electricity)
Dept. or Program to be represented (write below or email)
_____ $_____

Receptions & Banquets
☐ Graduate Student/First-Time Attendee Reception (1/10) (no charge)
☐ NAM Banquet (1/12)
#____Chicken #____Fish #____Vegan US$ 75
#____Kosher (*Additional fees apply for Kosher Meals.*) US$ 125
Total for NAM Banquet $_____
☐ AMS Dinner (1/13) Regular Price #____US$ 75
Student Price #____US$ 30
(*For special dietary requests, please email mmsb@ams.org)*
Total for AMS Dinner $_____

Total for Registrations and Events $_____

Payment

Registration & Event Total (total from column on left) $ _____

Hotel Deposit (only if paying by check) $ _____
If you send a hotel deposit check, the deadline for this form is December 5.

Total Amount To Be Paid $ _____

Method of Payment
☐ Check. Make checks payable to the AMS. For all check payments, please keep a copy of this form for your records.
☐ Credit Card. All major credit cards accepted. For your security, we do not accept credit card numbers by email, fax, or postal mail. If the MMSB receives your registration form by any of these methods, it will contact you at the phone number provided on this form.

Signature: _____

☐ Purchase Order # _____ (please enclose copy)

Other Information

Mathematical Reviews field of interest # _____

☐ I am willing to serve as a judge for the MAA Undergraduate Student Poster Session
☐ For planning purposes for the MAA Two-year College Reception, please check if you are a faculty member at a two-year college.
☐ I am a mathematics department chair.
☐ Please do not include my name and postal address on any promotional mailing lists. (The JMM does not share email addresses.)
☐ Please do not include my name on any list of JMM participants other than the scientific program if I am, in fact, making a presentation that is part of the meeting.
☐ Please ✓ this box if you have a disability requiring special services.

Registration for the Joint Meetings is not required for the short course but it is required for the minicourses and the Employment Center. To register for the Employment Center, go to http://www.ams.org/profession/employment-services/employment-center. For questions, email: emp-info@ams.org.

Registration Deadlines

To be eligible for the complimentary hotel room lottery:	Oct. 31, 2017
In time to receive badges/programs in the mail:	Nov. 22, 2017
Hotel reservations with check deposit:	Dec. 5, 2017
Hotel reservations, changes/cancellations through the JMM website:	Dec. 6, 2017
Advance registration for the Joint Meetings, short course, minicourses, and dinner tickets:	Dec. 20, 2017
Cancel in time to receive 50% refund on advance registration, banquets, minicourses, and short course	Jan. 4, 2018*

*no refunds issued after this date.

Mailing Address/Contact:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887 Fax: 401-455-4004; Email: mmsb@ams.org
Telephone: 401-455-4144 or 1-800-321-4267 x4144 or x4137

IN THE NEXT ISSUE OF NOTICES

NOVEMBER 2017...

AMS Fall Western Sectional Sampler

Paul Balmer, *Pavel Etingof*, and *Monica Vazirani* kindly provide introductions to their Invited Addresses on tensor-triangular geometry; double affine Hecke algebras and their applications; and combinatorics, categorification, and crystals.