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Notices

of the American Mathematical Society

May 2018

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AMS American Mathematical Society

About the Cover, page 514.

Call for Nominations

AMS MARY P. DOLCIANI PRIZE FOR EXCELLENCE IN RESEARCH

This prize is funded by a grant from the Mary P. Dolciani Halloran Foundation. Mary P. Dolciani Halloran (1923–1985) was a gifted mathematician, educator, and author. She devoted her life to developing excellence in mathematics education and was a leading author in the field of mathematical textbooks at the college and secondary school levels.

The AMS Mary P. Dolciani Prize for Excellence in Research recognizes a mathematician from a department that does not grant a PhD who has an active research program in mathematics and a distinguished record of scholarship. The primary criterion for the prize is an active research program as evidenced by a strong record of peer-reviewed publications.

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- Membership in the AMS at the time of nomination and receipt of the award is preferred but not required.

The prize amount is $5,000, awarded every other year for five award cycles. The first award will be made in 2019.

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

Nomination Period: March 1–June 30, 2018.

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Notices
of the American Mathematical Society

> **Nothing is exactly the way you dream it.**
>
> —Yves Meyer

May 2018

FEATURED

2017 Abel Laureate Yves Meyer tells his story in the *European Mathematical Society* interview. Günter M. Ziegler celebrates the fiftieth anniversary of Grünbaum's *Convex Polytopes* with illuminating examples. The Graduate Student Section includes a piece from the Graduate Student Blog on diverse mathematical communities and "WHAT IS...a Hyperbolic 3-Manifold?" Guest writers Elizabeth Platt Hamblin and Evelyn Lamb report on winners of the 2018 Exemplary Mathematics Program in a Mathematics Department and Programs That Make a Difference awards. In the northern climes and perhaps in the math world, spring is in full bloom and summer is just around the corner. —***Frank Morgan, Editor-in-Chief***

ALSO IN THIS ISSUE

FROM THE AMS SECRETARY

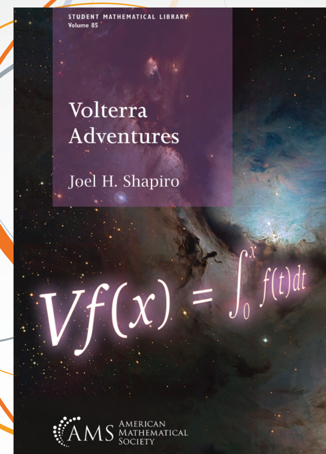
Notices
of the American Mathematical Society

FROM THE AMS SECRETARY, CONT'D.

IN EVERY ISSUE

CURRENT INVITATIONS FROM THE AMS

About the Cover: To go with the interview of Yves Meyer, 2017 Abel Laureate for his seminal work on wavelets, the cover pictures an artists's representation of a Meyer wavelet in white. The background is inspired by a detailed view of a typical heat map representation of the continuous wavelet transform of a time-dependent function; color represents the magnitude of the transform (from small cold values to large hot values) and the axes represent time and different scales.



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Volterra Adventures

Joel H. Shapiro, *Portland State University, OR*

This book introduces functional analysis to undergraduate mathematics students who possess a basic background in analysis and linear algebra. By studying how the Volterra operator acts on vector spaces of continuous functions, its readers will sharpen their skills, reinterpret what they already know, and learn fundamental Banach-space techniques—all in the pursuit of two celebrated results: the Titchmarsh Convolution Theorem and the Volterra Invariant Subspace Theorem.

Student Mathematical Library, Volume 85; 2018; 248 pages; Softcover; ISBN: 978-1-4704-4116-6; List US$52; All individuals US$41.60; Order code STML/85

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AMS AMERICAN MATHEMATICAL SOCIETY

IMPORTANT COMMUNITY UPDATE

The Combined Membership List (CML) will transition into a members-only AMS Member Directory on May 1, 2018.

The American Mathematical Society (AMS) gives precedence to safeguarding our members' information and privacy. In response to evolving privacy requirements and our desire to protect member information, the Combined Membership List (CML) will transition into the AMS Member Directory on May 1, 2018. The Directory will be accessible as an AMS member benefit on our password-protected membership platform. **Members will use their AMS login information to update their current contact information and locate their colleagues.**

The AMS and participating organizations in the CML* must comply with privacy requirements, such as the European Union's General Data Protection Regulation (GDPR). Due to these necessary changes, we will no longer have data about participating organizations' membership. AMS members who maintain a mailing address in the European Union (EU) must opt in to having their preferred contact information displayed in the Member Directory. **Members residing in the EU may update their information online by following this link: https://ebus.ams.org/ebus/MyAccount/Privacy.**

We are also taking this opportunity to plan for a new AMS Member Directory with a release date in 2019. We envision developing a valuable tool from which our members can connect with their professional community while we continue to protect their information and privacy. As we build a fresh concept for the future AMS Member Directory, we encourage members to log in and update their information on the current Directory. **Forgot your username or password? Retrieve it by visiting https://ebus.ams.org/SSO/Login.aspx.**

If you need assistance with logging in to the Directory, please contact **cust-serv@ams.org**.

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* The Combined Membership List (CML) included members of the American Mathematical Society (AMS), Society for Industrial and Applied Mathematics (SIAM), American Mathematical Association of Two-Year Colleges (AMATYC), the Association for Women in Mathematics (AWM), the Canadian Mathematical Society (CMS)—Société mathématique du Canada (SMC), and the Mathematical Optimization Society (MOS).

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For back issues see **www.ams.org/backvols.** Note: Single issues of the *Notices* are not available after one calendar year.

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LETTERS TO THE EDITOR

More on Mathematics and the Military

As a mathematician and a veteran, I read Thomas Gruber's letter to the editor (January 2018) decrying the influence of the military in mathematics with interest, and I thought it might be useful to add a different perspective to the conversation. My own decision to serve was based on a belief that the dictum *Si vis pacem, para bellum*[1] is correct and just as relevant now as when first penned. I served with men and women from all walks of life, of every race, religion, and background. Their motivation was almost always selfless: to protect the weak and free the oppressed; to stand watch in the night so that others could sleep without fear. I think that our increasingly polarized country could learn much from the military; I still remember my drill sergeant in basic training saying "The only color in the Army is green," and it was true.

Entering a PhD program after spending 4 years in the Army was tough, and brings me to my main point: military service makes returning to graduate school challenging. Many professors are unaware that veterans are the most underrepresented group in academia.

Before leaving University of Illinois last year, I worked with the veterans center to set up a mentoring program for student veterans. In the course of collecting data, I found that of 1900 tenure stream faculty, only 6 were veterans, and of the 800 faculty in STEM, I was the sole veteran. This is an underrepresentation in STEM faculty by a factor of over fifty times. So I'll close with a challenge for the AMS (and for all of us): How can we bring more of those who have served our country into the faculty ranks?

—Henry Schenck
Iowa State University
www.math.iastate.edu/hschenck

(Received January 8, 2018)

We invite readers to submit letters to the editor at notices-letters@ams.org.

1 (Schenck) *"If you want peace, prepare for war."*

Beurling Archive on the Web

Arne Beurling[1] (1905–1986) was one of the most influential mathematicians in the area of harmonic and complex analysis. During WWII Beurling cracked a German cryptomachine, the Siemens Geheimschreiber, which was a long kept secret.[2] In 1954 Beurling became Permanent Member and Professor at the Institute for Advanced Study.

Beurling was very selective in what he published and was known for keeping quite a few of his discoveries private. He always required that his work should have a final elegant form and left a considerable amount of unpublished notes and manuscripts. Some of them were included in his *Collected Works*, but some were not.

Several years ago, Beurling's grandchildren donated his Nachlass to Uppsala University Library. On the suggestion of Lennart Carleson, we selected portions to post at https://www.math.uu.se/collaboration/beurling. They include:

Beurling's handwritten notebooks;
Notes of Beurling's seminar talks in Uppsala (1938–1951);
Preparatory notes for courses;
Several unpublished manuscripts;
Short notes on various topics.

Apparently, this material includes results that were never published and might be new even now. We believe that it may be of interest for scholars and students of complex and harmonic analysis.

—Michael Benedicks
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—Mikhail Sodin
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(Received June 12, 2017)

1 (Benedicks and Sodin) *See the obituary by Ahlfors and Carleson,* Acta Math. *161 (1988) and the recollections by Ahlfors, Kjellberg, and Wermer in* Math. Intelligencer *15:3 (1993).*

2 (Benedicks and Sodin) *See Beckman's* Codebreakers: Arne Beurling and the Swedish Crypto Program During World War II, *Amer. Math. Soc., 2002.*

Notices Reprint Omits Important Mathematical Background of 2016 Nobel Prize in Physics

We are writing about an article on the 2016 Nobel Prize in Physics, which appeared in the *Notices of the American Mathematical Society*, **64**, Number 6, 557–567, (2017). The work for which this prize was awarded has an important mathematical component. We thus applaud the decision by the editors of the *Notices* to publish an article about it. However, we are dismayed by some aspects of the presentation.

The article reprinted in the *Notices* was compiled by the "Class for Physics of the Royal Swedish Academy of Sciences"; (names of authors are not listed). It describes the groundbreaking work of F. Duncan Haldane, J. Michael Kosterlitz, and David J. Thouless on a "topological phase transition," the so-called Kosterlitz-Thouless transition, and on "topological states of matter." It was excerpted from a longer article authored by the Academy. Unfortunately, the *Notices* chose to selectively include only *nine* of *fifty-five* references in the original article. We would like to know why the editors of the *Notices* chose to eliminate so many references to important work, and why they did not include any references to mathematical results that had already strangely been missing in the original article released by the Royal Swedish Academy.

We wonder whether the article published in the *Notices* was refereed. It appears that knowledgeable mathematicians were not contacted in this matter. Although the article may be well suited to a physics audience, it neglects to mention a significant body of mathematical research closely related to the work of Haldane, Kosterlitz, and Thouless, some of which we have been involved in. We believe that the editors of the *Notices* should have consulted the mathematical physics community before publication of this article. Addition of a mathematical perspective would have enriched the article and made it more relevant for the readership of the *Notices*. It might also have inspired further mathematical research. Below, we include references to some of the important mathematical work related to the 2016 Nobel Prize that we feel are useful to a mathematical readership,

I. Papers on Spin Chains:

1) E. H. Lieb, T. D. Schultz, and D. C. Mattis, Two Soluble Models of an Antiferromagnetic Chain, *Ann. Phys.* **16**, 407 (1961).

The authors prove that the spin-1/2 chain is gapless.

2) I. Affleck, T. Kennedy, E. H. Lieb, and H. Tasaki, Rigorous Results on Valence-Bond Ground States in Antiferromagnets, *Phys. Rev. Lett.* **59**, 799 (1987).

This work is mentioned in the *Notices*, but no reference is provided.

3) T. Kennedy and H. Tasaki. Hidden $Z_2 \times Z_2$ symmetry breaking in Haldane-gap antiferromagnets, *Phys. Rev. B*, **45**, 304 (1992).

This paper is cited in the original article of the Academy.

Also, A. Polyakov's fundamental prediction of the gap in the two-dimensional classical Heisenberg model should have been mentioned in connection with Haldane's work on spin chains: A. Polyakov, *Phys. Lett.* **59B**, 79 (1975).

The results in this paper are closely related to the gap in the integer spin chain. It is cited in the original article of the Academy.

II. Papers on Phase Transitions:

4) J. Fröhlich, B. Simon, and T. Spencer, Phase Transitions and Continuous Symmetry Breaking, *Phys. Rev. Lett.* **36**, 804 (1976). Details appear in: Infrared Bounds, Phase Transitions and Continuous Symmetry Breaking, *Commun. Math. Phys.* **50**, 79 (1976).

This work contains the first proof of "infrared bounds" and applies them to prove the existence of phase transitions accompanied by continuous symmetry breaking in classical spin systems.

5) F. J. Dyson, E. H. Lieb, and B. Simon, Phase transitions in quantum spin systems with isotropic and nonisotropic interactions, *J. Stat. Phys.* **18**, 335 (1978). See also: T. Kennedy, E. H. Lieb, B. Shastry, Existence of Néel Order in Some Spin-1/2 Heisenberg Antiferromagnets, *J. Stat. Phys.* **53**, 1019 (1988).

In these papers, symmetry breaking and Néel order are established for anti-ferromagnetic quantum magnets.

6) J. Fröhlich and T. Spencer, The Kosterlitz-Thouless Transition in the Two-Dimensional Plane Rotator and Coulomb Gas, *Phys. Rev. Lett.* **46**, 1006 (1981). Details appear in: The Kosterlitz-Thouless-Transition in Two-Dimensional Abelian Spin Systems and the Coulomb Gas, *Commun. Math. Phys.* **81**, 527 (1981).

This work contains the first rigorous proof of existence of the Kosterlitz-Thouless transition; (it actually settled a controversy on this question).

A more detailed analysis of this transition appears in: P. Falco, Kosterlitz-Thouless Transition Line for the Two-Dimensional Coulomb Gas, *Commun. Math Phys.* **312**, 559–609 (2012).

III. Papers on topological states of matter:

7) D. J. Thouless, Mahito Kohmoto, MP Nightingale, and M Den Nijs, Quantized Hall conductance in a two-dimensional periodic potential, *Phys. Rev. Lett.* **49**, 405 (1982).

The relation of this work to homotopy groups of certain natural vector bundles is pointed out in: J. E. Avron, R. Seiler, and B. Simon, Homotopy and quantization in condensed matter physics, *Phys. Rev. Lett.* 51, 51 (1983).

8) B. Simon, Holonomy, the Quantum Adiabatic Theorem, and Berry's Phase, *Phys. Rev. Lett.* **51**, 2167 (1983).

This article establishes a connection between Berry's work and that of Thouless et al. quoted above. This connection allows the author to use Berry's ideas to interpret the integers of Thouless et al. in terms of eigenvalue degeneracies.

9) Jean Bellissard, Noncommutative Geometry and Quantum Hall Effect, in: *Proc. of ICM'94*, S. D. Chatterji (ed.), Basel, Boston, Berlin, Birkhäuser Verlag 1995.

J. E. Avron, R. Seiler, B. Simon, Charge deficiency, charge transport and comparison of dimensions, *Commun. Math. Phys.* **159**, 399 (1994).

Berry's phase for fermions (which has a quarternionic structure) was studied in: J. Avron, L. Sadun, J. Segert, and B. Simon, Chern numbers and Berry's phases in Fermi systems, *Commun. Math. Phys.* **124**, 595 (1989).

10) J. Fröhlich and U.M. Studer, Gauge Invariance and Current Algebra in Non-Relativistic Many-Body Theory, *Rev. Mod. Phys.* 65, 733 (1993).

To our knowledge, the "spin Hall effect" in time-reversal invariant topological insulators with chiral edge spin currents has been described in this paper for the first time.

11) J. Fröhlich et al., The Fractional Quantum Hall Effect, Chern-Simons Theory, and Integral Lattices, in: *Proc. of ICM'94*, S.D. Chatterji (ed.), Basel, Boston, Berlin: Birkhäuser Verlag 1995. J. Fröhlich, U.M. Studer, and E. Thiran, Quantum Theory of Large Systems of Non-Relativistic Matter, in: *Proc. of Les Houches LXII, Fluctuating Geometries in Statistical Mechanics and Field Theory*, F. David, P. Ginsparg and J. Zinn-Justin (eds.), Amsterdam: Elsevier Science 1995.

In these papers (and refs. to original papers given therein), results on the Fractional Quantum Hall Effect and other phenomena related to topological states of matter are described. Topological Chern-Simons (field) theory and current algebra are applied to problems in condensed matter physics.

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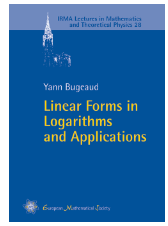
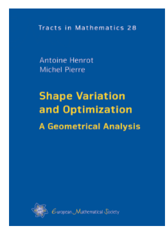


Linear Forms in Logarithms and Applications

Yann Bugeaud, *Université de Strasbourg, France*

The aim of this book is to serve as an introductory text to the theory of linear forms in the logarithms of algebraic numbers, with a special emphasis on a large variety of its applications.

IRMA Lectures in Mathematics and Theoretical Physics, Volume 28; 2018; 240 pages; Softcover; ISBN: 978-3-03719-183-5; List US$48; AMS members US$38.40; Order code EMSILMTP/28



Shape Variation and Optimization
A Geometrical Analysis

Antoine Henrot, *Université de Lorraine, Vandoeuvre-lès-Nancy, France,* and **Michel Pierre**, *ENS Cachan Bretagne, Bruz, France*

This book provides a self-contained introduction to modern mathematical approaches to shape optimization.

EMS Tracts in Mathematics, Volume 28; 2018; 379 pages; Hardcover; ISBN: 978-3-03719-178-1; List US$84; AMS members US$67.20; Order code EMSTM/28

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Interview with Abel Laureate Yves Meyer

Yves Meyer received the Abel Prize from King Harald of Norway.

Bjørn Ian Dundas and Christian Skau

Yves Meyer is the recipient of the 2017 Abel Prize of the Norwegian Academy of Science and Letters.[1] The following interview originally appeared in the September 2017 issue of the *Newsletter of the European Mathematical Society*[2] and is reprinted here with permission of the EMS.

Dundas and Skau: *Professor Yves Meyer, congratulations on being awarded the Abel Prize 2017 for your pivotal role in the development of the mathematical theory of wavelets. You will receive the Abel Prize from His Majesty the King of Norway in a ceremony tomorrow. The history of wavelets is fascinating and some aspects of it are old, but before we delve deeper into the mathematical side of things, perhaps you could share a bit of your personal journey.*

Becoming a Mathematician

Dundas and Skau: *You spent most of your childhood in Tunis. You attended the Lycée Carnot, which we understand was a very intellectually stimulating environment. But you were interested in many subjects. Why did you turn toward mathematics?*

Meyer: Yes, that was not an obvious choice because I was more interested in humanities. I was in love with Socrates and Plato, and I am still reading Plato right now, day after day, night after night. I am no longer reading Plato in Greek but I used to do that. I would say my main interest is literature. The point is that I am a bad writer. That is my bad side. So, I took mathematics because I was gifted – I was unusually gifted in mathematics. I cannot

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Christian Skau is professor of mathematics at the Norwegian University of Science and Technology, Trondheim, Norway. His email address is `csk@math.ntnu.no`.

[1] *See the June–July 2017* Notices `www.ams.org/publications/journals/notices/201706/rnoti-p592.pdf`

[2] `www.ems-ph.org/journals/newsletter/pdf/2017-09-105.pdf#page=16`, *pp.14–22*

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explain that. I understood mathematics from the inside in a very natural way. When I was in high school, I understood mathematics by myself and not by listening to my teachers.

Dundas and Skau: *So, you did not have any role models you found inspiring?*

Meyer: I had very good teachers and the teachers assessed me as being gifted in mathematics. The teachers were a stimulation but I had my own perception of mathematics. I had naive misconceptions. For example, I was thinking that all functions were continuous. And for me, you know, it was obvious and my mathematics was the mathematics of the time of Euler. So, not only were all functions continuous but they were all analytic.

Dundas and Skau: *Euler was also Abel's teacher! Abel learned mathematics from reading Euler.*

Meyer: That's beautiful – so we are back to Abel! It took me a while to understand that mathematics was not the toy I was playing with in my childhood. There were distinct subjects, so I had to mature to that fact when I was 19. That was rather difficult because, for me, mathematics was obvious. I always found a solution of a problem but with my own way of thinking, which was not canonical.

> "For me, mathematics was obvious."

Dundas and Skau: *So, in 1956, as a 17 year old, when you returned to France in order to prepare for the entering exam to the elite school l'École Normale Supérieure, you had mathematics as a career choice, would you say?*

Meyer: No, I was still hesitating. I took mathematics as a major because I was more gifted in mathematics than in humanities. Also, of course, I had to earn my living so I took mathematics for getting a job.

Dundas and Skau: *In 1957, after only one year of training at what in France is called "Classes de Préparation aux Grandes Écoles", you entered l'École Normale Supérieure in Paris, coming first in the entrance examination in mathematics. Could you give us a glimpse of your years there?*

Meyer: When I was at l'École Normale Supérieure, we were mixed with people in humanities. We were about 40 scientists—maths and physics—and 40 kids in humanities. And most of the time, I was discussing with my schoolmates in humanities, spending hours and hours. There was a Japanese student that was admitted as a foreign student, Abe Yoshio was his name – he is dead now. To my great surprise he wrote a memoir about the times at l'École Normale Supérieure. I read very recently the page of his memoir where I was described. According to Abe Yoshio, I am described as the only scientist to whom he could talk. So, for him, I was different, and I felt about myself that I was different. I was not obsessed by science. Now I have completely changed; now I am completely obsessed by science. But that took a part of my life to come around to. But in the beginning—because you always have a certain inertia in your life—since I had focused on humanities until my Baccalaureate (that is, the end of high school), the influence of humanities remained for about 10 years before I was convinced that mathematics was something absolutely marvelous. In the beginning, it was, in a sense, a little bit too easy for me to pass the exams, which was not doing mathematics at a research level. Then it could not be serious or such a big deal, I thought.

Dundas and Skau: *After three years as a teacher at Prytanée National Militaire (an experience we hope we can come back to when we talk about teaching in general), you moved to Strasbourg. Can you tell us something about those years and how you ended up doing your thesis in harmonic analysis?*

Meyer: The atmosphere at the Department of Mathematics at Strasbourg was absolutely marvelous. Because it was a very small department, there were 14 full professors. I was a teaching assistant and there were altogether 14 teaching assistants in the department. All the teaching assistants worked in just one office—a large office—and everyone was smoking. It was impossible to work, so we were just discussing. We were in complete freedom, so we could choose the subject of our PhD just by our own inclination, without a supervisor, so I decided upon my choice of thesis after reading the book by Antoni Zygmund: *Trigonometric Series*. I found the book fascinating and I asked myself what were the important problems in this subject? So I decided what were the important problems and I tried to solve the problems. I wrote 12 chapters of my thesis, my wife typed these 12 chapters and then I asked: "Who could be a supervisor of the thesis?" Pierre Cartier, who was a professor at the Université de Strasbourg, advised me to contact Jean-Pierre Kahane. So I took the train, brought to Jean-Pierre Kahane the 12 chapters and asked him to give me a PhD subject. And he said: "It is ridiculous – you have already written a PhD." And so I got a PhD that way. But if you do it that way it means that you are either stupid or arrogant. The penalty came immediately: at exactly the time I was submitting my thesis, Elias Stein proved a much better theorem. Elias Stein was still at the University of Chicago working with Alberto Calderón and they had made much more progress on the same problem I was doing.

Dundas and Skau: *Stein had much stronger tools, didn't he?*

Meyer: Yes, he had much stronger tools.

Number Theory and Quasicrystals

Dundas and Skau: *Is that why you decided to move to Diophantine approximations?*

Meyer: Yes. I was hired at the Université d'Orsay and then I was influenced by Jean-Pierre Kahane. He had a very good influence on me. The idea was that, in general, after you get a PhD, you should change subject because you should not remain under the influence of your supervisor. In my case, I had no supervisor but I decided to change subject anyway. At that time, the book by Jean-Pierre Kahane and Raphaël Salem, *Ensembles parfaits et séries trigonométriques*, appeared. I read the book and I fell in love with it. I decided to solve one of the main problems that Salem could not solve because he died prematurely. That took me about three or four years; it was a problem in number theory.

Dundas and Skau: *The keywords here are Pisot and Salem numbers. Actually, the concept of Pisot number was first introduced by the Norwegian mathematician Axel Thue, in connection with Diophantine approximations. A Pisot number is a real algebraic integer θ greater than 1 such that the conjugate numbers to θ have absolute values less than 1. A Salem number has the same definition except that the absolute values should be less than or equal to 1 with at least one having absolute value 1. There is a very fascinating story about these numbers. You won the Salem prize the third time it was awarded in 1970 and that was because you proved a theorem that Salem had posed, which you already alluded to. Could you describe it?*

> "I love this theorem!"

Meyer: It's a fascinating story. I discovered quasicrystals by accident because they were a tool for solving this problem. The concept of quasicrystals did not exist at that time but it turned out they were exactly the correct tool for solving the problem raised by Salem. In solving this problem, I proved the following theorem, which is my favourite result. I can explain that almost with my bare hands. So, you have something that is now called a Meyer set. I called these sets "quasicrystals"—a precursor of this concept was my definition of a "model set" from as far back as 1972—but Robert Moody later called them "Meyer sets". So a Meyer set is a set of points in $\mathbb{R}^n$—so if n is 2 we are in the plane—that has two conflicting properties: the set is spread uniformly, which means that there is a radius R so large that each ball of radius R, whatever the location, contains at least one point, so the points are spread uniformly; but there are no concentrations, which means there is a small radius r such that each ball of radius r, whatever its location, contains at most one point.

Dundas and Skau: *This is what is called a Delone set, right?*

Meyer: Delone set, exactly! So, a Meyer set can be defined just by the following property—the definition is due to Jeffrey Lagarias, which improves a little bit on my definition—it is a Delone set Λ such that the set $\Lambda - \Lambda$ of all differences is still a Delone set. That is a Meyer set. So that is something I introduced with a seemingly more restrictive definition but Lagarias proved that my definition is identical to this one. And then you ask yourself, is it possible that a Meyer set Λ will be self-similar in the sense that for θ a real number, θ larger than 1, $\theta\Lambda$ would be contained in Λ? For instance, if Λ is an ordinary lattice and θ is a real number then $\theta\Lambda$ is contained in Λ if and only if θ is an integer. Amazingly, for a general Meyer set Λ, this is true if and only if θ is either a Pisot or a Salem number.

Dundas and Skau: *That is remarkable!*

Meyer: That is the most beautiful theorem I have proved. I love this theorem! It combines, you know, geometry and number theory. There is no analysis in this theorem, which is truly remarkable! And the converse is true: that is, if you are given a Pisot or a Salem number θ, there is always a Meyer set Λ such that $\theta\Lambda$ is contained in Λ.

Dundas and Skau: *What is the connection with quasicrystals, more specifically?*

Meyer: People discovered that in a very, I would say, accidental way. Once they understood the construction rule of a quasicrystal, which is the construction that I have given in my book *Algebraic Numbers and Harmonic Analysis* from 1972, they observed that there is what they call "inflation" of a quasicrystal, that a quasicrystal is self-similar. But they did not know that at the time because my book was pulped by the publisher Elsevier.

Dundas and Skau: *You mean it was not accessible or was out of print?*

Meyer: No, no, not out of print. It was destroyed! Elsevier wrote me a letter asking me for permission to destroy the copies that were left because there were too many copies and it was impossible to sell that garbage anymore, so they thought, I imagine. Of course I accepted because I was doing something else. I was no longer interested in what I had written; it was already remote past, you know.

Dundas and Skau: *What a fascinating story! Your book contains material that can aptly be described as a precursor—which went unnoticed for a long time—of quasicrystals. In fact, it essentially contains the abstract theory of the cut-and-project method, in the full generality of locally compact abelian groups. To cut a long story short, Roger Penrose subsequently introduced his tilings in 1974, and later came Dan Shechtman, in 1982, who discovered that you find quasiperiodic crystals in nature (for which he received the Nobel Prize for Chemistry in 2011). Who made the connection with what you had done?*

Meyer: I think Enrico Bombieri made the connection and then Robert Moody, who was an important person in this. Bombieri suspected that there was a connection and it was understood completely by Moody. Moody is a very fair person, a remarkably open-minded person. He read my book in full detail. And he observed that everything was predicted in some sense. Like Nostradamus in some obscure language! One more thing should be mentioned concerning Meyer sets and tilings. If Λ is a Meyer set in $\mathbb{R}^n$ and $V(\Lambda)$ is the associated Voronoi cells—these cells are simply connected polytopes—then $V(\Lambda)$ is a tiling of $\mathbb{R}^n$. What is remarkable is that there are only a finite number of Voronoi cells up to translation and so one gets a translation tiling of $\mathbb{R}^n$ by a finite number of prototiles.

Calderón's Conjecture

Dundas and Skau: *We move to the next big chapter in your mathematical discoveries and that is the solution of Alberto Calderón's conjecture. There is a long story behind that but the crowning achievement was the paper you wrote jointly with Ronald Coifman and Alan McIntosh that was published in 1982. Could you tell the story of this cooperation?*

Meyer: Oh yes, the story is so beautiful. It is, in many ways, an accidental story. It is a story I like very much because it relates to my younger years in Tunis. Arabic people have a tendency to be fatalists. They will say everything is written in the Book. You cannot avoid your fate, your destiny. It was a time when my colleagues in Orsay for some political reasons refused to give graduate courses. They were objecting to a decision by the Minister of Education or something. I hate to follow the crowd and so I decided to give a graduate course anyway, just to prove that I do not follow the crowd. So I gave the graduate course and there was a student following the course who was completely distinct from the other students and who seemed to be much older. So I spoke to this person. He was from Australia and his name was Alan McIntosh. I invited him to have lunch at the end of the course every week. After three weeks, he explained what he was trying to find – his programme. His programme was exactly what I was trying to do with Coifman, but he was a student of another mathematician Tosio Kato. Kato (he is dead now) was working in operator theory but from a very abstract viewpoint. Kato had a general conjecture from which Calderón's conjecture would follow as a simple corollary. Calderón did not know Kato and Kato did not know Calderón. When they were in the US, Calderón was at the University of Chicago and Kato was at Berkeley. McIntosh explained that the problem I was trying to solve could be rephrased in the terminology of Kato. As soon as I got this information, I discussed with Coifman the possibility of solving the problem through this new formulation. Coifman was excited and wrote a kind of draft version of the solution. Then I returned to France and I managed to find the missing points. So, without my discussion with McIntosh, who knows if the problem would have been solved by me? McIntosh did not play any further role but he knew that the problem had a double meaning, that it could be rephrased inside another completely distinct theory, and with this new perspective on the problem, the problem could be solved. So that is the reason why the paper is signed with the three names. Elias Stein was the Editor-in-Chief of the *Annals of Mathematics* at the time and he asked me to write the paper in French because it was clear to Stein that I had solved the problem and that just hints were given by McIntosh and Coifman. But I am very proud to have included McIntosh and Coifman as co-authors. Sadly, McIntosh died from cancer recently.

"I hate to follow the crowd."

***Dundas and Skau:** So this actually sprang out of a graduate course?*

Meyer: Yes, exactly, and just because I dislike following the crowd.

***Dundas and Skau:** This must be a prime example of solving a problem through rephrasing it in a new mathematical language?*

Meyer: Exactly, exactly. When this happens, it always gives me an intense feeling of happiness. This also shows that personality plays an important role in your mathematical life. The fact that I dislike following the crowd. Otherwise, I would never have met McIntosh. By the way, McIntosh worked with my students for about 30 years before he died, so it was a great collaboration with the group. I was then doing something else.

***Dundas and Skau:** Before we drop the Calderón programme and his conjectures, could you tell us briefly what it was all about?*

Meyer: In order to explain what Calderón's conjectures are, let me begin with the end of the story. The goal is the computation of the analytic capacity of a compact set $\mathbb{K}$ in the complex plane $\mathbb{C}$. The analytic capacity of $\mathbb{K}$ is 0 if and only if every function f on $\mathbb{C}\backslash\mathbb{K}$ that is holomorphic and bounded on $\mathbb{C}\backslash\mathbb{K}$ is constant. By Riemann's theorem, the analytic capacity of a single point is 0. The analytic capacity of an arc of a smooth curve is not 0. A problem raised by Painlevé is to find a geometric characterisation of compact sets with vanishing analytic capacity. This has been achieved by Xavier Tolsa and the best reference is the Proceedings of ICM 2006. Tolsa's work relies on what was achieved on Calderón's programme. Calderón asked the following. Let Γ be a closed rectifiable Jordan curve in the complex plane. Let $\mathbb{U}$ be the bounded domain limited by Γ and $\mathbb{V}$ be the exterior domain delimited by Γ. The Hardy space $\mathbb{H}^2(\mathbb{U})$ is the closure of the polynomials in $\mathbb{L}^2(\Gamma, ds)$, while the Hardy space $\mathbb{H}^2(\mathbb{V})$ is the closure in $\mathbb{L}^2(\Gamma, ds)$ of polynomials in the variable $1/z$ vanishing at infinity. Here, ds is the arc-length on Γ. Calderón wanted to know whether $\mathbb{L}^2(\Gamma, ds)$ is the direct sum of $\mathbb{H}^2(\mathbb{U})$ and $\mathbb{H}^2(\mathbb{V})$. I proved this fact when Γ is a Lipschitz curve. Then, Guy David proved it when Γ is a Lavrentiev curve. Finally, David solved the Painlevé problem in a joint effort with Tolsa (David did the first half and Tolsa the second half).

***Dundas and Skau:** We will now segue from Calderón to wavelet theory, the connecting thread being the so-called Calderón's reproducing identity, which you were intimately familiar with. But before we do that, tell us a little about your encounter with Calderón on a personal level.*

Meyer: I loved discussing with Calderón, also because we could speak in Spanish. I am fluent in Spanish and Calderón was from Argentina. After discussing mathematics, we talked about literature and other expressions of Spanish culture that we appreciated. I liked Calderón very much. He was like a spiritual father for me. He was joking about my political ideas because he was right-wing and I was left-wing, and we talked about Argentina and its political conflicts, which were serious. But even if we disagreed about politics, it was a delight to discuss with him. I have kept in contact with his second wife Alexandra Bellow and from time to time she says that Calderón viewed me as his spiritual son. Yes, I cherish Calderón in a very strong sense.

Wavelets

***Dundas and Skau:** We now come to a very exciting part of your research centred on wavelets—ondelettes in French. There is a very fascinating story of how you got into this and how your familiarity with some of Calderón's work turned out to be propitious. Could you tell us about this?*

Meyer: My discovery of wavelets is also completely accidental. It came about through the Head of the Department of Mathematical Physics at l'École Polytechnique, Jean Lascoux. I was teaching at l'École Polytechnique and I soon became a friend of Lascoux. Jean Lascoux was spending almost all his life at the photocopying machine. Mathematicians and mathematical physicists were sharing the same Xerox machine. He was making several copies of everything, absolutely everything, and distributing copies around. If you needed to make a copy, you had to wait until he had finished. Instead of being irritated, I liked discussing with Jean Lascoux and we soon became friends, and every time Jean had a mathematical problem, he was asking me for an idea or suggestion. And one day – this was in 1984—he said: "Yves, you should have a look at this paper. I am sure you will be interested." It was a preprint by Jean Morlet and Alex Grossmann about wavelets. What they proved in that paper was a simple version of a theorem by Calderón that I immediately recognised, namely Calderón's reproducing identity. They had the fantastic idea that this could be a revolution in signal processing. So that was a fantastic step. I was immediately excited by the paper and by the way it was written. They were working at the Centre de Physique Théorique in Marseille. So I took the first train to Marseille and I joined the group. I observed that they were using a very clumsy algorithm. They had a continuous version so they wanted a digital version and were just taking Riemann sums and so on and so forth. And then I began discussing with Ingrid Daubechies, who already belonged to the group. The three of them—Morlet, Grossmann and Daubechies—were in a sense ahead of me in their work on wavelets. So I was the "Quatrième Mousquetaire". They were Les Trois Mousquetaires—you know d'Artagnan was joining the group—so I was d'Artagnan. I discussed with Ingrid and then I had the idea to try to find an orthonormal basis of wavelets, which would make everything trivial on the algorithmic level. It took me three months of intense work but that is nothing compared to the seven years I spent proving Calderón's conjecture. In just three months, I found the basis.

Dundas and Skau: *The wavelet you found was in the space of rapidly decreasing functions, that is, it was in the Schwartz class, right?*

Meyer: That was in the Schwartz class. Then, a year later, I realised that Jan-Olov Strömberg had found another basis some years before. He was, at that time, working in Tromsø. Tromsø is a beautiful city in Norway north of the Polar Circle.

Dundas and Skau: *The wavelet Strömberg found was a spline function and so it was not in the Schwartz class.*

Meyer: No, it could not be in the Schwartz class. Neither Ingrid Daubechies nor Grossmann nor Morlet were aware of Strömberg's paper because it looked very technical.

Dundas and Skau: *We have to interrupt you right there because Strömberg gave a talk about these spline functions of his at a memorial for Zygmund. And you sat and listened to this.*

Meyer: Yes, exactly. I have to confess to that! That was in March 1981 and I was working madly on Calderón's conjecture. I was so obsessed with Calderón's conjecture, which I solved in May, that I could not even remember his talk. But it is true—I should be ashamed. My construction is completely distinct from Strömberg's and my solution paved the way for all the other solutions. The solution by Strömberg was more tricky. By the way, Strömberg also had the idea of multiresolution analysis. When I discovered Strömberg's paper, I sent a telegram to Tromsø—emails were hardly used at the time—telling Jan-Olov that he is the father and I am no longer the father of wavelets.

Dundas and Skau: *Let us stop for a moment and catch up on what we have been talking loosely about. Could you tell us briefly what is an analysing wavelet and what is a so-called mother wavelet, and how does Calderón enter the picture?*

Meyer: Roughly speaking, the wavelets mimic an orthonormal basis for $L^2(\mathbb{R}^n)$ and the reproducing identity is like an expansion of an arbitrary vector in this Hilbert space. In Calderón's formula, one begins with two functions $g(x)$ and $h(x)$ defined on $\mathbb{R}^n$ and satisfying the following identity

$$\int_0^\infty \hat{g}(tu)\,\hat{h}(tu)\frac{dt}{t}=1 \qquad (*)$$

for all u in $\mathbb{R}^n$ distinct from zero, where $\hat{g}$ and $\hat{h}$ are the Fourier transforms of g and h, respectively. One denotes by G_t and H_t the convolution operators associated to g_t and h_t, respectively, where $g_t(x)=t^{-n}g(t^{-1}x)$, and h_t is defined similarly. Finally, one obtains the identity

$$\int_0^\infty G_t H_t \frac{dt}{t}=1, \qquad (**)$$

which is Calderón's reproducing identity. In Morlet's approach, $h(x)=\overline{g(x)}$and (*) is precisely the compatibility condition he imposed on a wavelet. As in the one-dimensional case, the functions $t^{-n/2}g(t^{-1}(x-x_0))$ are called wavelets, the function g being the analysing wavelet. Let's for simplicity assume we are in the one-dimensional case. A mother wavelet is a function $\psi(x)$ such that its set of siblings $\{\psi_{k,j}\}$, where k and j are integers, and

$$\psi_{k,j}(x)=2^{j/2}\psi(2^j x-k)$$

is an orthonormal basis for $L^2(\mathbb{R})$. So the siblings are obtained from $\psi(x)$ by dilations and translations.

Dundas and Skau: *But then you took the story further to multiresolution analysis. Perhaps you could say something about that?*

Meyer: Yes. Multiresolution analysis is more natural than wavelets. It is my fault that I have always attributed the discovery of multiresolution analysis to my joint work with Stéphane Mallat, while it is due to my joint work with Coifman. So, multiresolution analysis is something completely trivial from the viewpoint of image processing: it is just to zoom in and zoom out—to see an image at distinct scales. Wavelets are the difference between two successive views of the image. So, once we have got multi-resolution analysis, all those other constructions were very natural. In analysing an image it is very natural to get another viewpoint, or a better perspective—you zoom in to see some details. It is like the difference between a sequence and a series: multiresolution analysis is a sequence of numbers or a sequence of views of an image; wavelets are the corresponding series, which corresponds to the difference between two terms of the sequence. So it is very natural.

Dundas and Skau: *Gauss gave four different proofs of the fundamental theorem of algebra that every polynomial over the complex numbers has a complex root. And he had more than six proofs of the quadratic reciprocity theorem. For the basic theorem within wavelet theory, there exist several proofs. Is it important to have different proofs?*

Meyer: Yes, it is very important because it gives distinct perspectives. It is also important from the viewpoint of the psychology of scientists. For example, there are some people who prefer wavelets visually, having the shape of an oscillating character and so on. Some other people prefer the viewpoint of multiresolution analysis. To the wavelet room, so to say, you can enter through distinct doors and it is good for the public. It was very good to have distinct approaches to wavelets.

> "Nothing is the way you dream about it."

Dundas and Skau: *Is it true that quadrature mirror filters are closer to applications?*

Meyer: Yes, and that is the great insight of Stéphane Mallat. Mallat wrote a PhD thesis in signal processing from the viewpoint of the electrical engineering community. So he belongs somehow to another community. He knew what quadrature mirror filters were. And he was 24 years old when he made this fundamental discovery that wavelets and quadrature mirror filters were telling the same story. That had a fantastic impact because all electrical engineering people were despising wavelets, saying that it is just a foolish theory by crazy mathematicians. Immediately, they changed their opinions, saying that we were all doing wavelets. But my student Albert Cohen discovered that there are some quadrature mirror filters that were used that cannot produce wavelets because when they are iterated you have some kind of instability. People could not explain that within the community of electrical engineering. When you iterated those filters, they did not converge to a wavelet. The good quadrature mirror filters were those that, once iterated, converged to a wavelet. So it illuminated the whole theory. So the discovery of Mallat played a fundamental role.

Dundas and Skau: *You have to tell us how wavelets were used for a really spectacular detection. We are thinking of gravitational waves that were discovered a couple of years ago.*

Meyer: Yes, that is also a funny story. It illustrates something I like about science: nothing is exactly the way you dream about it. So, the discovery of gravitational waves does not use my wavelets at all. They use another brand of wavelets that were dreamed about long before I worked on the subject. The first person who dreamed about such wavelets was Dennis Gabor. Dennis Gabor was a Hungarian physicist who won the Nobel Prize for Physics in 1971 for his invention of holography. He was an emigrant from Hungary to Great Britain because of Nazism and he wrote a fantastic paper in 1951 about digital speech processing. So this was in 1951, a few years after the transistor was invented. He was already anticipating the digital revolution and the idea that modern telecommunication would transform speech processing into a sequence of 0s and 1s. So, for that purpose, he guessed that there should be a basis in which each signal could be written as a series, a simple series, and it would suffice to transmit the coefficients of the series. That would be enough and that would be the fastest and the most efficient way to transmit speech and sound. But the basis he proposed was completely incorrect and another Nobel Prize winner Kenneth Wilson proposed a slightly different solution than the solution of Gabor. Wilson, incidentally, won the Nobel Prize for Physics in 1982 for his theory about renormalisation. Then, Ingrid Daubechies became aware of the paper by Kenneth Wilson. She was, at the time, working with two of my students, Stéphane Jaffard and Jean-Lin Journé, and they solved the problem. That means transforming the intuition of Kenneth Wilson into a mathematical theorem. So they proposed an algorithm and, by that, both Gabor and Wilson

From left to right: Yves Meyer, Christian Skau, and Bjørn Ian Dundas.

were justified in a sense. It is this algorithm that was used by Sergey Klimenko in his detection of gravitational waves. So, it is a parallel theory of wavelets but they are not the same wavelets as the ones I introduced. It is not zooming into finer and finer scales; it is a problem of catching the right frequency at the right time. It is like hearing a sonata and then writing the score, which is a completely distinct problem. They are both called wavelets but they are solving distinct physical problems.

Other Research Interests

Dundas and Skau: *You made certain forays into the Navier–Stokes equation. Could you tell us about this?*

Meyer: Oh, yes. That was also marvelous because it was a scientific disaster! Yes, but with a good ending. There was a paper written by Guy Battle and Paul Federbush claiming that using wavelets, time-scale wavelets, zooming into finer and finer scales, you could solve Navier–Stokes. Then, Jacques-Louis Lions, the father of Pierre-Louis Lions, asked me: "Yves, what do you think about this paper; you should read this paper and tell me the true story." So, with my Italian student Marco Cannone, we decided to accept this challenge and to read the paper. And, as usual, when a mathematician reads a paper he just forgets the paper he is reading and tries another tool for solving the problem. We first observed that using the Littlewood-Paley decomposition, which was known already in the 1930s, the proof of the paper could be much simplified. So wavelets did not have to play any role in the paper by Battle and Federbush. And then both of us became interested in Navier–Stokes regardless of wavelets; we just forgot about wavelets. We wanted to see what could be proved, what better theorem could be proved in the programme of Federbush. We obtained some interesting results and we were conjecturing that the best result should be so and so—it is technical. We were unable to prove the best result. The best result was proved by Herbert Koch and Daniel Tataru. So we gave up when we were reaching the final point. The good point is that I had three students working on Navier–Stokes (because as soon as I became interested I was able to convince other people to work in that direction). These three students are excellent (Fabrice Planchon, Lorenzo Brandolese and the already mentioned Marco Cannone) and after completing their PhDs they worked on some other aspects of non-linear PDEs. So, during my Navier–Stokes period, I did not prove anything really interesting. In June, we had a day at l'École Normale Superieure de Cachan for explaining my mathematics to the students. I refused to have someone explaining what I did on Navier–Stokes because I am slightly ashamed. But the beginning was good, you know: I wanted to answer the problem raised by Jacques-Louis Lions. And at the end, there were three excellent PhDs and the three people are now full professors, and that is fine.

Dundas and Skau: *Together with Coifman you did some important work related to pseudo-differential operators, which inspired J.-M. Bony's theory of so-called paradifferential operators and paraproducts. Could you tell us a little about this?*

Meyer: It is true that Bony's paraproducts are an example of the general theory developed by Coifman and I. Nevertheless, in Bony's hands, these operators yielded fantastic estimates on the regularity of solutions of non-linear PDEs (something Coifman and I never thought about).

An Intellectual Nomad

Dundas and Skau: *You have made contributions in several other fields of mathematics that we have not touched upon. This provokes a meta-question. You have been through various phases. You started in harmonic analysis, you went through number theory for a while and you worked on the Calderón problem and wavelets… Is there a common thread through what you are doing?*

Meyer: No, I have asked myself your question. Of course, the theorem I was describing on Pisot and Salem numbers and Meyer sets has absolutely nothing to do with Navier-Stokes. No, I like discovering another country. For example, this morning I woke up rather early and decided to explore Oslo by myself. That is just fantastic. I feel I am reborn when I explore a new city without a guide.

"One year at the Université Paris-Dauphine, I had 19 students simultaneously."

Dundas and Skau: *In mathematics, there is also this human aspect. You talk to people and you get input from them, and perhaps that changes your direction?*

Meyer: Yes, and most of the time my change is just accidental and under the influence of another person. But the idea to be born again, to start to learn… When I began working on Navier–Stokes, I felt like I was a child because I did all the mistakes you do in the beginning. That is something absolutely fantastic.

Dundas and Skau: *Even though you have switched fields several times, your main research thrust has been in what is broadly called harmonic analysis. You are the second one to win the Abel Prize in harmonic analysis; the first was Lennart Carleson.*

Meyer: Yes, of course I admire him very much. Lennart Carleson for me is like God, you know. I cannot be compared to Lennart Carleson; he is so much above.

Dundas and Skau: *We are not going to compare anybody. But you did use some results by Lennart Carleson at the time?*

Meyer: Yes, of course. I used what are called Carleson measures in a very deep way in the solution of Calderón's conjecture. I worked in a very intense way on his paper on the convergence of trigonometric series. I admire his style very much, not only the deepness of the results but also his style and irony. I am very different from Carleson but he is a model. I wouldn't say that I was close to Carleson the way I was close to Calderón. But it might be because with Calderón I was sharing the Spanish language and the Spanish culture and that helped a lot.

Dundas and Skau: *Carleson said in the interview we had with him that he was a problem solver. He was not interested in building theories. Do you count yourself as a problem solver or are you in-between?*

Meyer: I am in-between. For example, in the work on quasicrystals or on wavelets I was more building a theory. For quasicrystals, my book gave something very systematic and when it was rediscovered there were, I would say, hundreds of papers written on Meyer sets. I gave a basis of a theory but once I had done that I got immediately bored and changed subject. I leave it to students. Now, that explains why I have 50 PhD students. One year at the Université Paris-Dauphine, I had 19 students simultaneously.

Dundas and Skau: *How did you manage?*

Meyer: Some of them were finishing but I spent three hours every week discussing with the students, and at that time I lost five kilos! Yes, that was the worst. But I love transmitting the fire to the students and then doing something else. So, it is a way of cheating because it means that it will be their responsibility to make a building from my ideas, while I can escape. Like people who invite their friends and then disappear.

Teaching and Outreach

Dundas and Skau: *Actually, you have a very varied teaching experience, from the Prytanée National Militaire all the way to the Grandes Écoles. How has your philosophy about teaching evolved over time?*

Meyer: My teaching evolved very much; my teaching reflects my personality—I am eager to transmit my visions. When you write, you are very cautious. When you are teaching, you can make some slight exaggerations or, you might say, you can be less cautious. And that is very good because, being less cautious, you can take bets on the future of the subject.

Dundas and Skau: *You can give your own gut feelings?*

Meyer: Yes, and I think the oral aspect of teaching will disappear completely with the new way of courses prepared as electronic versions. It is too controlled.

Dundas and Skau: *So, you are sceptical of recording lectures?*

Meyer: Yes, exactly. I am sceptical because teaching is always an improvisation. It is like a performer: He never plays it exactly the same way twice. When teaching, you can convey the fact that making mistakes could be a benefit for the listener because mistakes can be creative in some way. But that is good for some students and bad for others. Everyone has a way of teaching that is beneficial to a part of the group and negative to the other part. My way of teaching is a way of trying to inspire. I like that people can react and be challenged. The idea is that the group should be challenged: begin to think either one or the other way, even if this is to criticise the view I am trying to convey to them. It is a kind of Socratic experience.

Dundas and Skau: *On a higher level, you have been quite clear on your views on the French model for higher education. In view of recent developments in France, do you have a new take on that?*

Meyer: Yes, this is a very important problem because there are several theories about how to improve the teaching of mathematics in France. I was very moved by the presentation of Hanan Mohamed Abdelrahman [the winner of the Holmboe Prize 2017] this morning. She made a very important point: give the same challenges to all students. In France, we have the tendency to say that we should not be as demanding with this group as with that group. But this is a way of underestimating the group to which you are less demanding. "This poor person coming from the North of Africa is so unhappy that we should not demand too much." But that is terrible for them!

Dundas and Skau: *Are you thinking of distinctions between the universities and the Grand Écoles?*

Meyer: That is another point, yes. I was speaking of high school level. It is a very difficult problem – it is a problem that cannot be solved in a theoretical way. For example, in the beginning, there existed an École Normale Supérieure de jeunes filles (for young girls) and an École Normale Supérieure de garçons (for boys). So, every year, in mathematics, there were 14 girls admitted to the exam for girls. And then a lot of very bright women in mathematics—faculty members—were women coming from l'École Normale Supérieure. They decided that this was unfair, that it underestimated women and that we should unify. Now it is unified and every year the total number is 44 in mathematics: there are 40 boys and 4 women (at most). And sometimes there are no women at all. It is a complete disaster!

It is difficult to find one solution for a big problem. The fact is that all the young students are distinct; they have distinct needs, they have distinct demands and they have distinct abilities. Should we say that their level is equal by definition and that we should impose the same burden on all or should we have an honours class? This is very difficult.

Dundas and Skau: *We wanted to talk about outreach. What do you think about the importance of popularising mathematics, like your own work? Is that futile?*

Meyer: On that I do not know. I can just give you an interesting example. In Tunis, cultural life was rather narrow because it was so far away from Paris at that time. Planes hardly existed and we took the boat to go to France. So, when a person was coming far away from France, it was a local attraction. As a high school student, I went to a talk given by Jean-Pierre Kahane. I remember the subject he was talking about was very interesting; it was a problem of trigonometric series he was trying to solve. He gave a talk—and he is a very good speaker—in such a way that I understood what he was talking about. I was a student in high school. I was truly fascinated. I was fascinated by his personality. Later, I went to Orsay and was there for about 15 years, and he had had a great influence on my work. What he did when he came to Tunis was a kind of popularisation of mathematics: going to Tunis, giving a talk for a general audience about his research.

"For every aspect of art, the difficulties are the same."

It was quite exceptional and I would like to say that this influenced my work. I cannot prove that it truly influenced my work. It might have been just something accidental but I love the story.

Dundas and Skau: *On the topic of popularising mathematics, Ludvig Sylow was a Norwegian mathematician and, in his eulogy at Sophus Lie's funeral, he said the following: "It is the mathematician's misfortune more than the other scientists, that his work cannot be presented or interpreted for the educated general public, in fact, hardly for a collection of scientists from other fields. One has to be a mathematician to appreciate the beauty of a proof of a major theorem or to admire the edifice erected by mathematicians over thousands of years." That was Sylow's attitude.*

Meyer: I slightly disagree. Because the point is that there is nothing special about mathematics. Take difficult literature or poetry, for example. I would say that I do not understand the living French poets. I try to read their poems and I do not understand them. The problem with mathematics is that people do not even understand the language. In the case of poetry, to be completely honest, I understand the words but I do not understand the language. It means that, for every aspect of art, the difficulties are the same. Like modern music – have you heard a work by Xenakis? Yes, I have. But you did not understand it! No… No, but people never say that, you know. They think they understand music but they do not understand music either! And nobody talks about that.

Private Passions

Dundas and Skau: *Perhaps concluding the interview, are there aspects that are not regularly touched upon? Some passions—private passions?*

Meyer: I have private passions. Yes, I have several passions. I am a passionate person.

People, I would say. I like people. I like discussing with people—meeting, admiring people. I would say the pleasure to do mathematics is related to the pleasure of joint work. Let me single out Raphy Coifman. I have been working with him for 40 years. He is like a brother and he is viewing me as a brother. I like his personality. I like his life.

I like people, and everything that is related to literature. My first addiction was literature—I took humanities as a child. I am still enjoying Plato with delight.

Dundas and Skau: *In Greek?*

Meyer: I am no longer reading Plato in Greek. I used to. And I was still doing that at l'École Normale Supérieure. In that way, I was admired by students in humanities and despised by scientists because a true scientist does not read Plato. I also love reading the Bible.

Dundas and Skau: *Both the Old and the New Testament?*

Meyer: Only the Old Testament. It is more spicy, you know: David and Bathsheba, and the relationship of David and Jonathan. It is completely fascinating because there is a smell of homosexuality. And the mourning of David when Jonathan dies—it is beautiful.

Dundas and Skau: *That is great poetry also.*

Meyer: Yes, it is completely marvelous that David said that their friendship was more important than the love of a woman. It is completely fascinating.

Dundas and Skau: *Also the story with Abraham sacrificing Isaac. You know that ...*

Meyer: Kierkegaard…

Dundas and Skau: *Kierkegaard, exactly! Søren Kierkegaard was extremely fascinated by the story about Abraham and Isaac. His book* Fear and Trembling *("*Frygt og Bæven*") is centred on this story.*

Meyer: Beyond mathematics, my very deep world is literature.

Dundas and Skau: *Also Russian literature, we understand?*

Meyer: Yes! Vasily Grossman, for example, and Aleksandr Solzhenitsyn and Anton Chekhov. I know by memory Tolstoy's *Anna Karenina*.

Dundas and Skau: *We heard the story that you even found wavelets in Russian literature.*

Meyer: Yes, in Solzhenitsyn's *The First Circle*. There you find not wavelets exactly but time frequency analysis. Solzhenitsyn was a physicist and then moved to literature—because of the war, because he was sent to a concentration camp. And he could not resist writing in *The First Circle* a chapter on time frequency analysis. I will not describe it—it is too long—but there is a page that I read each time I give a course on signal processing because it is so beautiful. He is describing exactly the problem that I will be describing on Wednesday: to catch something inside a signal, to catch a pattern. The problem in the detection of gravitational waves was to catch a specific pattern that would be the signature of the gravitational wave. The signal is completely noisy and the noise is a thousand times larger than the signal. So, we have to capture these very small, short-lived patterns. In *The First Circle*, it is an audio signal, a recording of the voice of someone, and the group has to detect the person through finding the characteristic patterns of the person, patterns that would be for the person the equivalent of fingerprints—the patterns of a voice. Solzhenitsyn calls that "voice-prints". He is describing the problem truly as a physicist, using the correct words and so on. It is completely fascinating. So, my interest in Russian and Soviet literature is related to my research work, as everything is… Of course, for students—but I am not teaching anymore—the problem when you speak about Solzhenitsyn today is that they don't know Solzhenitsyn, and the two of them who do know Solzhenitsyn have never read *The First Circle*. And then, when I am reading a page of *The First Circle*, they just fall asleep.

Dundas and Skau: *Do you have other interests beside mathematics and literature?*

Meyer: I like music—I am very fond of music. And I love painting.

Dundas and Skau: *Some special painters?*

Meyer: Oh, yes. But that changes from age to age. I would put at the very top two Spanish painters: Goya and Velázquez. I have special ties with Spain. But that is very personal. I wouldn't say that they are the greatest painters in the world but I love Goya.

Dundas and Skau: *On behalf of the Norwegian Mathematical Society and the European Mathematical Society, thank you very much for this interview. It has been most interesting.*

EDITOR'S NOTE. The Abel Prize website (`www.abelprize.no/nyheter/vis.html?tid=69766`) includes a three-minute video of Meyer, in which he says, "I loved attacking a problem with just bare hands…the true fight…and finding completely distinct ideas than the traditional ideas…." More on Meyer is planned for an upcoming issue.

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Christian Skau

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Deadline for nominations is September 15, 2018.

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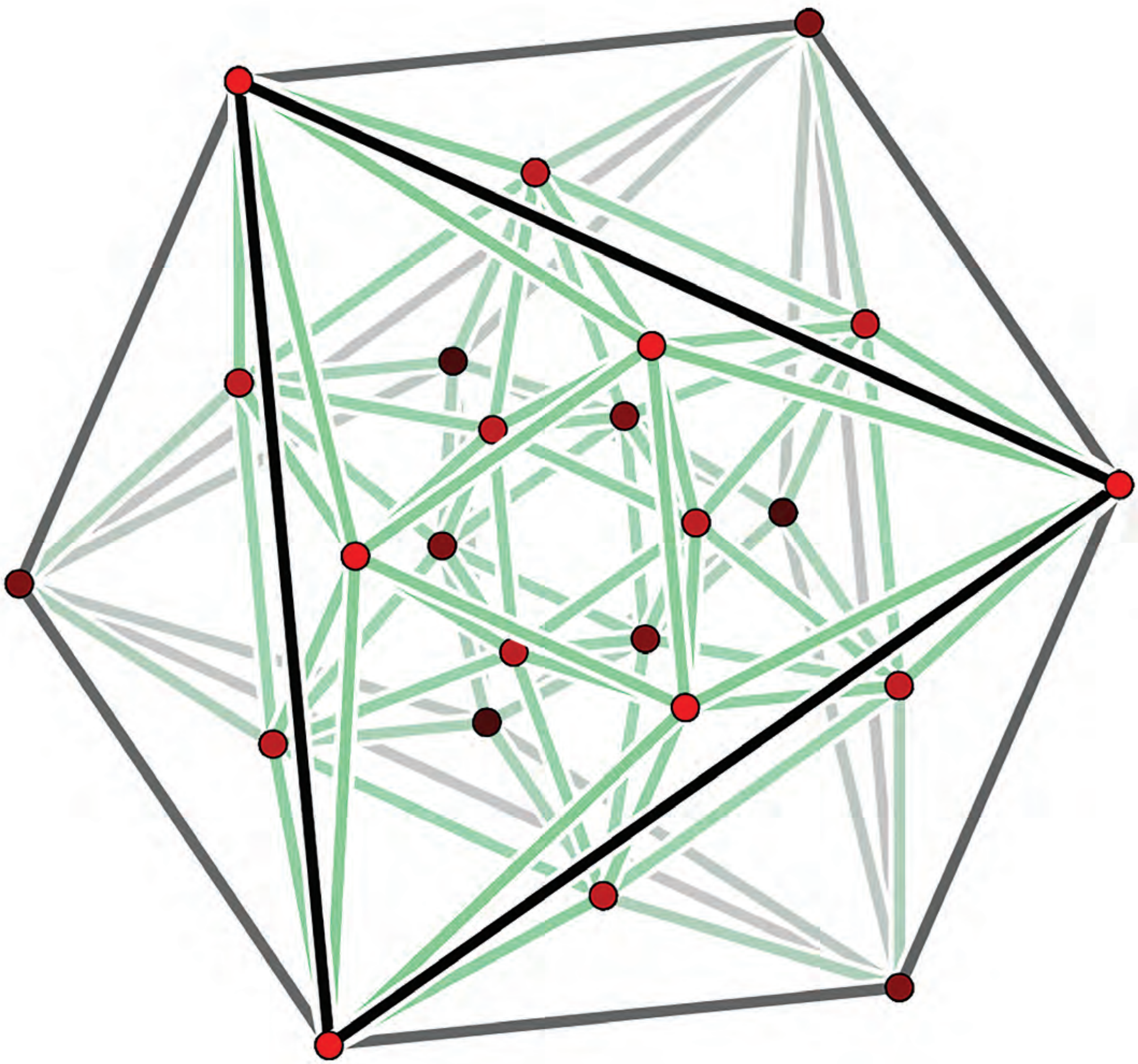
For Example: On Occasion of the Fiftieth Anniversary of Grünbaum's *Convex Polytopes*



Günter M. Ziegler

ABSTRACT. Let's take the fiftieth anniversary of the publication of Grünbaum's *Convex Polytopes* (1967) as an occasion for an excursion into polytope theory, FF looking for examples, images, and problems.

Are examples important? I think so! Just for illustration? Why do we need them if we understand the theory, you might ask. On the other hand, what's the worth of a theory for which there are no examples?

In his millennium survey on discrete geometry, Gil Kalai from Jerusalem put it this way:

> It is not unusual that a single example or a very few shape an entire mathematical discipline. Examples are the Petersen graph, cyclic polytopes, the Fano plane, the prisoner dilemma, the real n-dimensional projective space and the group of two by two nonsingular matrices. And it seems that overall, we are short of examples. The methods for coming up with useful examples in mathematics (or counterexamples for commonly believed conjectures) are even less clear than the methods for proving mathematical statements. [4, p. 769]

Discrete geometry, and the theory of convex polytopes in particular, thrives on a wealth of examples, which can be constructed, visualized, analyzed, classified, and admired.

The Icosahedron

Euclid's *Elements* ends with the construction and the classification of the five *Platonic solids*: the tetrahedron, the cube, the octahedron, the dodecahedron, and the icosahedron. What could be more classical than that? The British geometer Peter McMullen said that we should consider them as "wayside shrines at which one should worship on the way to higher things."

The most striking and enigmatic of the five platonic solids is arguably the icosahedron. The Mathematical Association of America (MAA) has it in its logo. However, the version of the MAA logo that was used from the early 1970s until 1984 got the geometry wrong, as Branko Grünbaum noticed in his highly entertaining paper "Geometry strikes again" [2]. Grünbaum also provided instructions for how to draw it correctly, and the MAA was quick to use this. The easiest and most striking way to get coordinates for the vertices of an icosahedron is to refer to the logo of the Berlin research center MATHEON, which recently celebrated its fifteenth anniversary: Write out coordinates $(\pm1,\pm t,0)$, $(0,\pm1,\pm t)$, and $(\pm t,0,\pm1)$ for the vertices of the three rectangles, and discover that they form the vertices of a regular icosahedron exactly if t is the golden ratio or its inverse, $\frac{1}{2}(\pm1+\sqrt{5})$. Moreover, the boundary curves of the rectangles topologically represent a Borromean link: They cannot be separated, although they are not linked pairwise! See Figure 1.

Figure 1. A regular icosahedron can be obtained from the corners of the three rectangles of the Matheon logo.

The Miller Solid

The next big step in polytope theory was a second class of examples, still classical: the *Archimedean solids*. They are polyhedra put together from regular polygons, which look the same at all the vertices. By tradition, the Platonic solids and the prisms and antiprisms are excluded. (Note that also the cube is a prism, and the octahedron is an antiprism.) There are only finitely many types. Who defined them first? Pappus of Alexandria credits Archimedes, but his writings are lost. Renaissance artists like Leonardo da Vinci and Albrecht Dürer searched for examples and produced amazing drawings (see Figure 2).

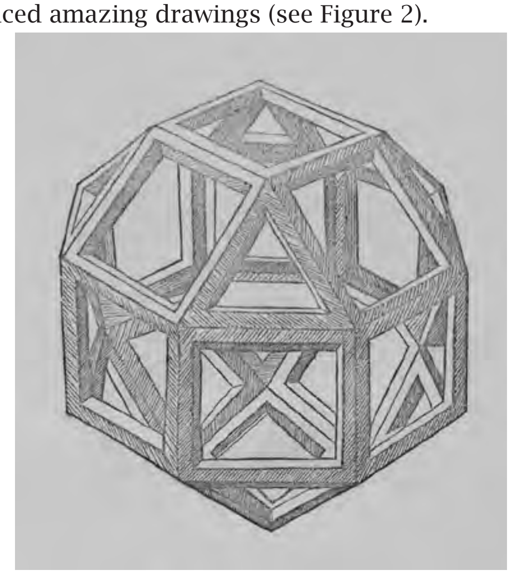


Figure 2. Leonardo da Vinci discovered and drew Archimedean solids, such as the pictured rhombicuboctahedron.

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Finally, the astronomer and mathematician Johannes Kepler gave a classification of the thirteen Archimedean solids in his 1619 book *Harmonices Mundi*.

Throughout history, there have been two conflicting definitions of an Archimedean polyhedron, a local one:

> a convex polyhedron whose faces are regular polygons, and which have the same cyclic arrangement at each vertex,

and a global one:

> a convex polyhedron whose faces are regular polygons, and whose symmetry group acts transitively on the vertices.

Grünbaum pointed out that the definitions are not equivalent: there is one single example that satisfies the first one but not the second. In a Kepler-style pseudo-Greek naming scheme this would be the "pseudorhombicuboctahedron." Coxeter and Grünbaum call this 14th polyhedron "Miller's Solid" after J. C. P. Miller (1906–1980), who worked with Coxeter, but it turns out that a planar diagram appears already in a paper from 1906 by Duncan M'Laren Young Sommerville. Of course this is my favorite Archimedean solid, even if it is only pseudo-Archimedean.

The 24-Cell

Our next example (and, in the author's opinion, the most beautiful one of all of them) is a 4-dimensional polytope. One shouldn't be scared of such objects, as we can describe them in coordinates, analyze them using linear algebra, and even study them in pictures known as *Schlegel diagrams*, (see Figure 3), after Victor Schlegel (1843–1905).

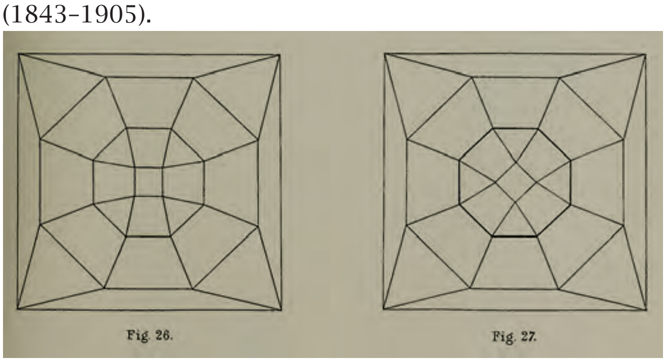

Figure 3. The Schlegel diagram of the rhombicuboctahedron and the pseudorhombicuboctahedron, which satisfies one definition of Archimedean solid but not another.

The Swiss geometer Ludwig Schläfli (1814–1895) classified, around 1850, the d-dimensional regular polytopes in all dimensions $d \geq 3$. It turns out that the most interesting case is in dimension $d = 4$, where there are six different types—even one more than in dimension 3! And the most interesting and exciting one of these six is the "24-cell": its vertices may be given by the centers of the 2-dimensional faces of a 4-dimensional cube. Thus, for example, one can take the 24 vectors in $\mathbb{R}^4$ that have two 0s and two ± 1s as coordinates; its faces then turn out to be 24 perfect regular octahedra. See Figure 4 for representations of a 24-cell.

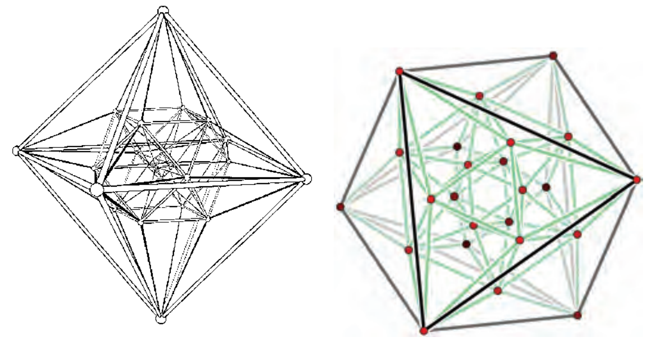

Figure 4. The regular 24**-cell in 4D.**

This turns out to be a polytope with remarkable properties. For example, it is the only centrally symmetric ($P = -P$) regular polytope that is isomorphic to its own dual! (The d-dimensional simplex is self-dual as well, but it is not centrally symmetric.)

The 24-cell has many more remarkable properties: for example, it is 2*-simplicial*, as all of its 2-faces are triangles, and it also has the dual property, being 2*-simple* (all edges lie in exactly three of the octahedron facets), as it is self-dual. Such 2-simplicial 2-simple 4-polytopes are rare. A few years ago, only eight examples of such *2s2s polytopes* were known: The simplex, the hypersimplex and its dual, a glued hypersimplex and its dual (constructed by Tom Braden), the 24-cell, and a 720-cell (derived from the 120-cell by Gábor Gévay) and its dual. Eppstein, Kuperberg, and Ziegler first managed to construct infinitely many examples. Now we know that a 2s2s 4-polytope with n vertices exists if and only if $n = 5$ or $n \geq 9$.

But still, the construction methods we have are not very flexible. We still cannot prove a conjecture by David Walkup that any 4-dimensional convex body can be approximated by 2s2s 4-polytopes.

Steinitz's Theorem and Grünbaum's Book

General polyhedra, in contrast to the regular (Platonic) or semiregular (Archimedean) ones, were studied only much later. What we now know as Euler's equation, $f_0 - f_1 + f_2 = 2$, was developed by Descartes and Euler, though Euler had to admit that he couldn't prove it. The combinatorial characterization of general polyhedra by 3-connected planar graphs was developed by Ernst Steinitz (1871–1928). However, the original version of Steinitz's theorem looked cumbersome and complicated. Only Grünbaum in his 1967 book *Convex Polytopes* presented Steinitz's theorem as we know it today:

Theorem 1 (Steinitz's theorem, Grünbaum's version [3, Sec. 13.1])**.** *A graph is realizable as a* 3*-dimensional polytope if and only if it is planar and* 3*-connected.*

Indeed, polytope theory as we know it today was largely shaped by Grünbaum's monumental monograph, which appeared fifty years ago: It is a treasure trove of results, methods, examples, and problems! In this paper we present examples of all four: results, methods, examples, and problems, all of them coming from Grünbaum's book.

Branko Grünbaum was born in 1929 in what was then Yugoslavia. In 1949 he emigrated to Jerusalem, where in 1957 he got his PhD with Aryeh Dvoretzky. After two years at the Institute in Princeton, Grünbaum returned to Jerusalem.

Figure 5. Polytope theory was largely shaped by Grünbaum's *Convex Polytopes*. Top: Grünbaum with his wife, Zdenka, and their son, Rami, about 1960. Bottom: Grünbaum in 1988.

In 1966, after a year at Michigan State, he finally settled at the University of Washington.

How did the book come about? Grünbaum writes:

> In Summer of 1963 I spent three months in Seattle, as guest of Vic Klee, …This was a serendipitous time for what became "Convex Polytopes". Vic Klee was finishing his path-breaking papers on the Dehn–Sommerville equations and the Upper Bound Conjecture. I was working through the Steinitz-Rademacher book, translating Steinitz's complicated process of establishing the "Fundamentalsatz der konvexen Typen" into the easy-to-follow proof of the graph-theoretical formulation. On returning to Jerusalem I organized a seminar to study convex polyhedra and polytopes. The first topic I assigned dealt with Klee's recent results on f-vectors, based on preprints of his papers. The students came back to say they are not able to understand Klee's papers. Since I had to concede that the papers are hard to follow, I reformulated them in a much more understandable form—that worked for the students. My proof of Steinitz's theorem was easy to follow, and was presented to the seminar. During the following academic year (1964/65) I gave a course on combinatorics of convex polytopes, for which I prepared lecture notes.

These lecture notes, in particular, contained Grünbaum's version of Steinitz's theorem. This theorem is deep: By now we have three different types of proofs: the Steinitz-type proofs by local modifications [3, Sect. 13.1], the Tutte rubber band proofs, and the Koebe–Andreev–Thurston circle packing proofs. Each of these is different, each of them provides extra information and consequences the others don't, all of them are nontrivial. But mystery remains: For example, can any type of polyhedron be realized with small integer coordinates, say with vertices in $\{0, 1, \dots, n^2\}^3$, if it has n vertices? We don't know!

Grünbaum's lecture notes with Steinitz's theorem in them quickly grew into a full-fledged monograph.

The Cyclic Polytopes

The cyclic polytopes appeared already in the opening Kalai quote. Their construction is deceptively simple: You take the convex hull of n points on the curve $\gamma(t) := (t, t^2, \dots, t^d)$ in d-dimensional space and call the result a *cyclic polytope* $C_d(n)$.

For $d = 2$ these are n points on the standard parabola, so their convex hull is a convex n-gon. For $d = 3$ we get the *twisted cubic*. But for $d \geq 4$ things become interesting, as the resulting polytope turns out to be *neighborly*; that is, any two vertices are connected by an edge (and indeed more: any $\lfloor d/2 \rfloor$ of the points form the vertices of a face). Moreover, it turns out that the combinatorics of the polytope does not depend at all on which points you take on the moment curve: this is known as "Gale's evenness criterion" [3, p. 62], named after David Gale.

Apparently it was Constantin Carathéodory who discovered the cyclic polytopes in 1907 and found them to be neighborly. Theodore Motzkin studied them and computed their number of facets. However, in his 1956 abstract Motzkin also claimed that the cyclic polytopes are the only neighborly ones. We now know that this is dramatically wrong: there are *huge* numbers of neighborly d-dimensional polytopes on n vertices if d and n are large.

On a different aspect, Motzkin was right, however: He claimed that the cyclic polytope $C_d(n)$ has the maximal number of k-dimensional faces among all convex d-dimensional polytopes with n vertices. This became known as the "Upper Bound Conjecture," until Peter McMullen finally proved it in 1970.

Perles's Irrational Polytope

Grünbaum's book, on the way to the publisher, was delayed once more:

> When it seemed that the book is finally ready, I started getting long letters from Micha A. Perles.…Written in Hebrew, Perles was systematically developing the material on Gale transforms and diagrams, as well as improvements on many other results.

What Perles designed (and called "Gale diagrams," though they really should be called "Perles diagrams") was a magnificent linear algebra technique by which low-dimensional point configurations (say configurations of points in the plane) can be used to represent polytopes of low codimension (in the sense that their number of vertices is only little more than the dimension). This allowed him to classify and count d-dimensional polytopes with at most $d+3$ vertices. The most striking instance was Perles's irrational polytope: A configuration of twelve points in the plane that occupy nine different locations determined by a regular pentagon by Perles's technique represented an 8-dimensional polytope with twelve vertices, and the fact that the planar configuration cannot be drawn without using the golden ratio $\frac{1}{2}(-1+\sqrt{5})$ as a cross-ratio translated into the fact that the 8-dimensional polytope cannot be realized with rational vertex coordinates; see [5]. What a discovery!

With this final gem added, Grünbaum's book was eventually published by Wiley-Interscience in 1967, labeled "with the cooperation of Victor Klee, M. A. Perles, and G. C. Shephard." It was very well received, but it also went out of print quickly, and Wiley didn't want to reprint it, and later Grünbaum didn't want it reprinted without updates. After one or two failed attempts, a second edition with short notes on each chapter was eventually published in 2003. It received the AMS Steele Prize for Mathematical Exposition in 2005; the citation said that the book "has served both as a standard reference and as an inspiration for three and a half decades of research in the theory of polytopes" and its second edition "will extend the book's influence to future generations of mathematicians."

Are Examples Important?

Fields Medalist Gerd Faltings once said in a TV interview, "Whenever in my career I tried to work out an example, it has led me astray." Indeed, there are the theory guys in mathematics, who may do amazing things without looking at a single example—these are the "birds" in Freeman Dyson's categories of "birds and frogs" [1]—and there are the mathematicians whose work starts with interesting examples. I guess I am a frog.

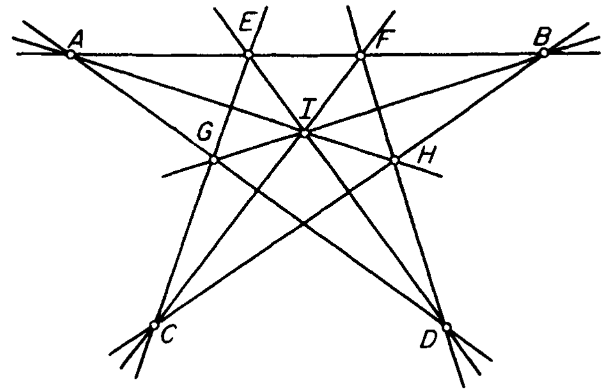

Figure 5.5.1

Figure 6. Gale represented interesting examples of polytopes by planar configurations. The Gale diagram for Perles's polytope without a rational realization [3, p. 93].

ACKNOWLEDGMENTS. Thanks to Branko Grünbaum for decades of inspiration by his books and for his emails about the genesis of *Convex Polytopes*, to Isabella Novik for support, and to MSRI Berkeley and Lufthansa Business Class for wonderful writing environments.

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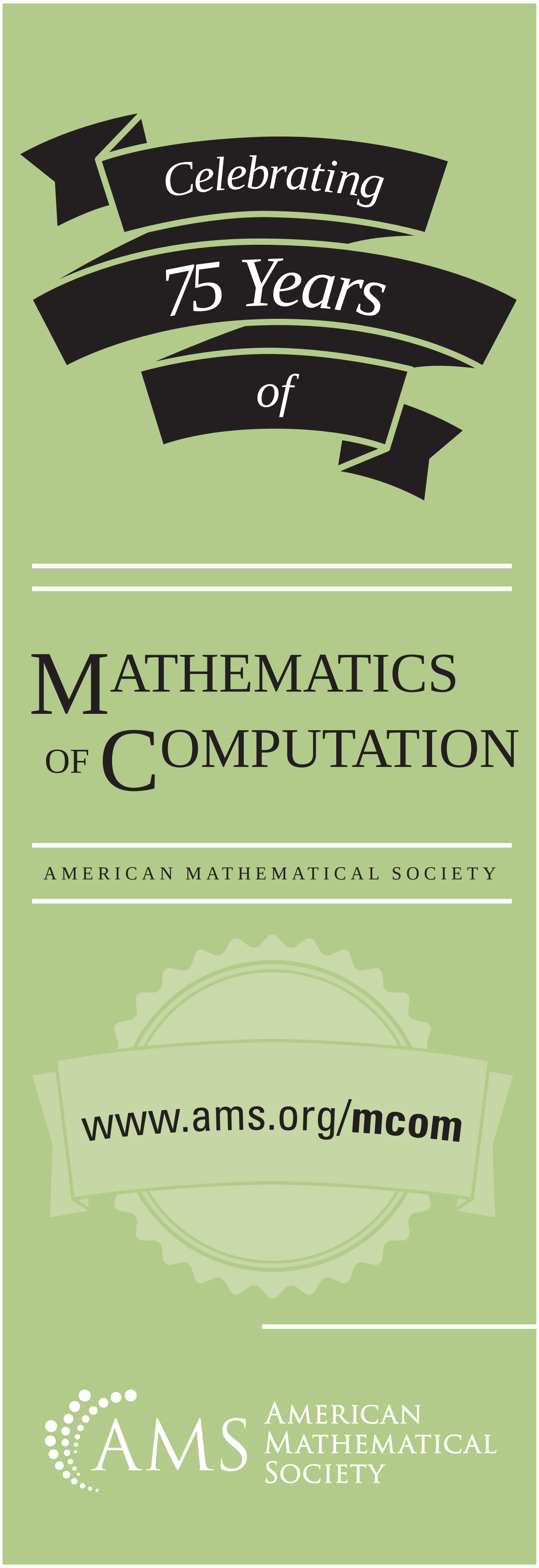
Figure 2 Da Vinci's regular rhombicubotahedron, with twenty-six open faces (*Vigintisex basium planum vacuum*) courtesy of the S.C. Williams Library, Archives and Special Collections; S.C. Williams Library, Stevens Institute of Technology, Hoboken, NJ.

Figure 3 Figures from Sommerville, D. (1906). XXIX. Semi-regular Networks of the Plane in Absolute Geometry. *Transactions of the Royal Society of Edinburgh*, **41**(3), 725–747 © Royal Society of Edinburgh 1906, published by Cambridge



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Günter M. Ziegler

ABOUT THE AUTHOR

Günter M. Ziegler's work on convex polytopes has produced various intriguing classes of examples, among them "neighborly cubical polytopes," "projected deformed products of polygons," and "simple 4-polytopes without small separators." His *Lectures on Polytopes* appeared in 1994. In 2003 he co-edited the second edition of Grünbaum's *Convex Polytopes*.

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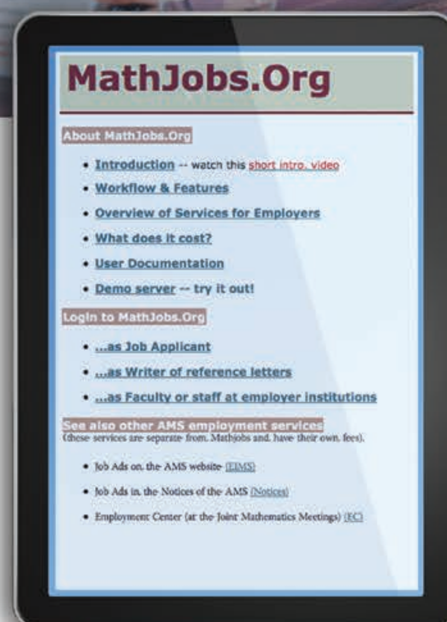

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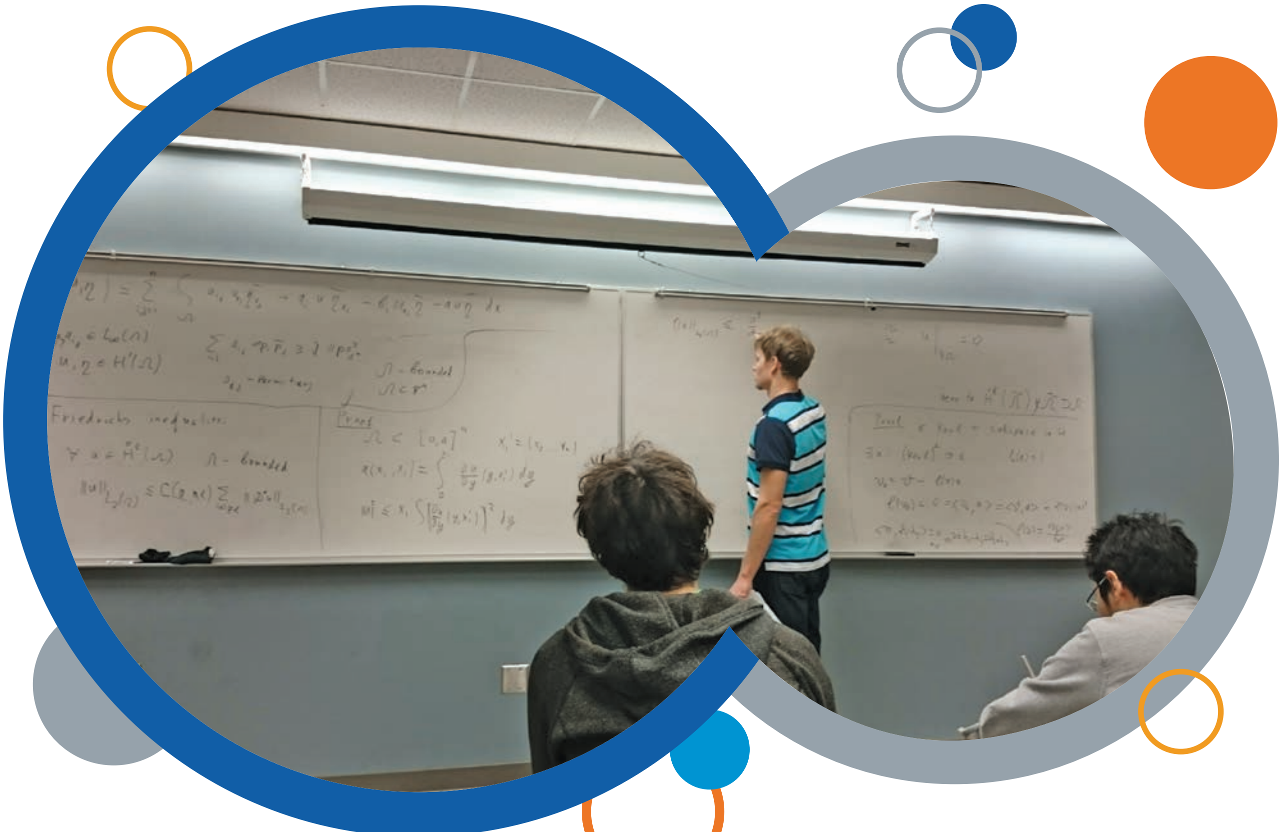
AMS GRADUATE STUDENT CHAPTER



MISSION

1 To organize activities which effectively help graduate students to broaden/deepen their mathematical knowledge. The activities that are designed to fulfill the above purpose include: (a) Faculty research talks (b) Grad-student research talks (c) Various mini-courses offered by advanced PhD students and postdoctoral students.

2 To organize instructive activities which help the students in a more general way. The only activity that is planned to fulfill the above purpose is an HTML workshop. We are also thinking about organizing a Matlab/Maple/Mathematica/Latex workshop.

More details about our activities can be found in our webpage: sites.google.com/view/ams-iupui

CAN YOU SHARE A SUCCESS STORY OR A TIME WHERE THINGS DIDN'T GO ACCORDING TO PLAN?

We believe that organizing every single event is by itself a success story, but undoubtedly the main success story is to really see that we have indeed successfully organized almost every event that we planned for in the beginning of the academic year; getting things done as planned is the true success for all officers of the chapter. Also getting positive feedback from the participants always motivates us even further to fulfill our promise to the best of our abilities.

WHAT DO MEMBERS ENJOY MOST ABOUT THIS AMS STUDENT CHAPTER?

We think that they mainly enjoy the knowledge that they gain during the events; they particularly enjoy the fact that the content of the talks/mini-courses are properly chosen for the audience. They also visibly enjoy the socialization in the background of the activities and of course the refreshments that we provide!

AMS American Mathematical Society

INDIANA UNIVERSITY – PURDUE UNIVERSITY INDIANAPOLIS (IUPUI)

HOW DID YOU BECOME INTERESTED IN MATHEMATICS?

When I was a mechanical engineering student at Shiraz University, Iran, I became very interested in the mathematics underlying the engineering and physics courses in our syllabus. After getting more familiar with the local professor M. Mahzoon and attending a few math courses that he taught for MSc and PhD students, I then became strongly determined to pursue mathematics more seriously in my future studies.

WHERE DO YOU SEE YOURSELF IN TEN YEARS?

Hopefully a professor of mathematics at a research university.

HOW HAS BEING THE STUDENT CHAPTER PRESIDENT ASSISTED YOU WITH LEADERSHIP TRAINING FOR YOUR FUTURE?

Organizing various events and preparing all the requirements in advance, collaborating with chapter officers, sharing the responsibilities, and attending "brainstorm sessions" along with the other officers, all helped me to a great extent to become more disciplined; to get used to collaborative work; and to get a deeper insight regarding the numerous details of organizational/leadership duty.

WHERE ARE YOUR INTERESTS?

In Mathematics: Applications of Riemann-Hilbert approach to various branches of mathematics specifically to asymptotic problems in random matrix theory and statistical physics. Theory of modern integrable systems.

I am also very interested in Mysticism, Eastern/Islamic philosophy, Illuminationism, and Persian literature.

I also used to be a professional chess player (I have an FIDE international rating) but have dismissed it recently.

WHAT IS YOUR STRONGEST QUALITY?

Maybe my strongest quality is that I (at least) try to live a multidimensional life, but the main challenge is always how well I can make a balance between the various dimensions of my life.

WHO OR WHAT MOTIVATES YOU TO BE A BETTER PERSON?

Thinking that I have to live my best in every single moment and trying to think of it more as a duty rather than a choice!

WHAT IS THE BEST ADVICE YOU CAN GIVE TO SOMEONE PURSUING A DEGREE IN MATHEMATICS?

I believe that as people are different in almost every aspect of their lives, they are also different in how they learn a subject, in particular mathematics. So my first advice would be: Know yourself! And study mathematics accordingly. Respect yourself! Try to eliminate your weaknesses gradually by more and more practice and hard work.

FOR WHAT DO YOU WANT TO BE REMEMBERED?

I would like to be remembered for being a good mathematician and more importantly a decent human being.

Roozbah Gharakhloo, from Iran, Chapter President 2015–2017.

AMERICAN MATHEMATICAL SOCIETY

William Stein Interview

Conducted by Alexander Diaz-Lopez

William Stein is professor of mathematics at University of Washington and founder/CEO of SageMath, Inc. In addition to his research and books related to modular forms and number theory, he created the open source computer software Sage. William is an avid vert skateboarder and co-owner of Seattle Vert Ramp. His email address is wstein@gmail.com.

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DOI: http://dx.doi.org/10.1090/noti1673

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

Stein: I'm not really sure what "a mathematician" is, and I don't necessarily label myself as such. I first got a taste of math research when I was a 12 year old in rural Texas, and I figured out how to quickly sum the first n integers, since I heard that Gauss had done that. I also really liked computing things using calculators, slides rules, and abacuses. I didn't know there was such a thing as a "mathematician" until college.

I was first exposed to the idea of research mathematics when I was a junior in college (at age 19) in Flagstaff, Arizona. I was browsing the computer programming book section at a used bookstore called Bookmans, when I hit a misfiled book called *An Introduction to Modern Algebra* by Burton Jones. I looked in it, and was amazed with what was there—groups, rings, fields, and all these beautiful ideas that I had never seen before!

I signed up for a summer course on how to write proofs and work with algebraic structures, and did every single problem in the textbook *Foundations of Higher Mathematics* by Fletcher and Patty, and was hooked. I changed my major from computer science to math, and pursued mathematics research starting then.

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

Stein: At Northern Arizona University (NAU), two math professors—Peter Horn and Adrian Riskin—most encouraged me. They noticed and strongly supported my interest in mathematics, and encouraged me to go to graduate school at NAU for a year, and then go to Berkeley when I got admitted. (In contrast, another professor at NAU told me *not* to go to Berkeley, which had a notorious reputation in the 1990s for failing out many of their grad students.)

At Berkeley, I met Hendrik Lenstra, who became my thesis advisor and spent an enormous amount of time just doing mathematics with me, mostly involving group cohomology. I also talked frequently with the prolific author and instigator Serge Lang, who spent his summers at Berkeley; he gave me dozens of books on math, politics, and much more, and really got me into arithmetic geometry. Hartshorne's courses on algebraic geometry and Ken Ribet's on modular forms were also extremely inspiring.

Then Kevin Buzzard showed up and breathed incredible new energy into the department. I also worked with Robert Coleman and with Barry Mazur when he came to visit for a month. Then I graduated and became Barry's postdoc at Harvard, where he, Dick Gross, and Noam Elkies really inspired me.

For writing software, in grad school Joe Wetherell first got me interested in computing modular forms. After taking a few years off from programming, I started writing a LOT of code again, and David Kohel encouraged me to make my code open source and expand the value of what I was doing by reimplementing my code in Magma, so it could be combined with other number theory code. I visited the Magma group in Sydney, Australia three times, and while there I was deeply inspired by Allan Steele's passion for first rate mathematical software and John Cannon's deep long term strategic approach to building large software systems.

I also worked a lot on computational number theory research with undergraduate students such as Jennifer Balakrishnan and Corina Tarnita (pictured below) when I was an assistant professor at Harvard University.

Corina Tarnita, a former student and collaborator at Harvard University.

Though many people have encouraged and inspired me, some others have instead discouraged me. For example, Richard Fateman, a computer science emeritus professor at Berkeley, has frequently and steadily publicly questioned and discouraged the Sage math software project ever since I started it.[1]

Diaz-Lopez: *How would you describe your research to a graduate student?*

Stein: I have created tools for computing with mathematical objects, mostly in number theory and linear algebra. I started SageMath, which is open source free software for computational mathematics research and teaching. I also published three books; they are on modular forms, undergrad number theory, and the Riemann Hypothesis (with Barry Mazur).

I've developed some new techniques for explicitly computing with objects connected to modular forms, motivated by the problem of computing all quantities appearing in generalizations of the Birch and Swinnerton-Dyer Conjecture.

I also created CoCalc, which is a web application that makes it easy to collaboratively use open source mathematical software in research and teaching.

Diaz-Lopez: *What theorem are you most proud of and what was the most important idea that led to this breakthrough?*

Stein: My biggest contribution to making the world of mathematics more accessible was starting Sage. The most important idea behind Sage is to build the car, instead of reinventing the wheel... then work really, really hard and ignore the "fact" that what I'm doing feels completely impossible. Many other people joined the project, and together we made Sage really useful.

The goal was always to create a practical and useful tool.

My perspective with Sage has always been to try to make a tool that people could use to compute mathematical objects more easily, with minimal friction. They should not have to pay a lot of money, they should have full access to readable source code, and have many good code examples that definitely work. With Sage, instead of worrying about getting a grant, or future grants, I focused completely on writing software to make computation in mathematics more accessible and opened. The goal was always to create a practical and useful tool, rather than do something new and impressive, then get a grant.

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

Stein: If you like programming at all, then learn to program well while you're still in math graduate school, since it significantly expands your job prospects. You might think you most want a career as a professor or academic researcher, but by putting a reasonable amount of effort into learning programming, you'll have more options later. In addition to taking a course in programming, do something deeper like getting involved with and contributing to open source projects like Sage!

Unfortunately, some of the mathematical community genuinely considers the creation of mathematical software as not being "real mathematics." If you most love improving mathematical software, you will probably end up having to leave academia (pure math, at least). For example, all of my PhD students now work at Google, Facebook, Microsoft, etc. If you're a student in a "pure math" department, be sure to look outside to other departments for courses on software.

[1] *See* `mathforum.org/kb/message.jspa?messageID=4132045`

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

Stein: I am discouraged right now, and have been for a while.

In 2012, after about eight years of putting a huge amount of effort into Sage, I became discouraged first because I stopped getting grants. I got even more discouraged when Jim Simons and David Eisenbud told me that their plan to "fund open source math software" was to pay to make Magma freely available (but still closed source) to everybody in North America.[2]

I have received substantial grant support over the years, but the grants were mostly for traditional research mathematics in number theory. I naively thought applying for what I passionately really wanted to do, what I thought mathematics really needs, would work. It didn't. I don't know why. Maybe I was just unlucky regarding trendiness? Maybe I just wasn't politically savvy or connected enough? Maybe I got discouraged too quickly? Or maybe it's exactly what Fateman said in his quote:

> By avoiding applications (say, to engineering design, finance, education, scientific visualization, etc etc) the activity is essentially doomed. Why? Government funding for people or projects will be a small percentage of the funding for pure mathematics. That's not much. And the future is pretty grim…

As a result, I started a company, SageMath, Inc., whose main product right now is CoCalc. I work full time on this company now, rather than in academia. Eventually, I hope the company will be successful and will be able to fund what I've always really wanted to do. After much hard work, this dream is now on the horizon.

If my goals and ambition for what Sage can become weren't so big, then maybe I wouldn't feel so discouraged. It's especially hard for me because I see how amazing Sage could be, what it could offer the mathematical community, and how we could get it there, but I can't make my vision a reality because of a woeful lack of resources.

Diaz-Lopez: *Now that you have created your own company, what is the current status of SageMath, and the recently-created CoCalc?*

Stein: Though I'm the founder of SageMath, I currently have little money or resources (time, students) to put towards Sage development, so I do far less compared to what I did 2004–2012. I wish this lack of resources would change, but there is currently no end in sight. Fortunately, many other people contribute to Sage.

Sage itself is extremely powerful for work in combinatorics, linear algebra, manifolds, and number theory. Also, the programming language I chose for Sage is Python™, which has turned out to be a fortunate choice, because Python is incredibly popular in data science and many other related areas, which has led to Sage being part of a fantastic ecosystem.

Sage development proceeds at a steady pace, with many Sage Days workshops in both the US and Europe; for example IMA in Minnesota is sponsoring many workshops this year and OpenDreamKit in Europe too! Most work on Sage is motivated by the needs of research mathematicians for their own work. Releases keep happening, and around 100 people contribute to each release.[3]

CoCalc is a web application that makes it easy to collaboratively use LaTeX, R, and Sage.

CoCalc is a web application that I started writing in 2013, which makes it easy to collaboratively use LaTeX, R, and Sage for teaching and research. The collaborative aspects of CoCalc are also extremely useful for undergrad REUs, e.g., Edray Goins uses CoCalc extensively in an REU, so the students have easy collaborative access to both Sage and LaTeX.

It has about 20K weekly active users and the software stack is fairly mature at this point, after years of users battle testing it. Four people work fulltime on CoCalc.

Diaz-Lopez: *Looking into the future, what are your expectations and goals for both SageMath and CoCalc?*

Stein: The goal of the Sage project is to create a viable open source alternative to Magma, Maple™, Mathematica, and MATLAB, which are all closed source. This means that people have choice—they at least have the option to use open source software for their math research and teaching in all the academic areas represented by those software. Providing such a choice entails both implementing all relevant algorithms in Sage (with competitive efficiency and correctness), and creating corresponding textbooks and documentation.

William Stein together with Edray Goins, a frequent user of CoCalc in REU programs.

[2] *See* `sagemath.blogspot.com/2015/09/the-simons-foundation-and-open-source.html` *for more details.*

[3] *See* `https://wiki.sagemath.org/Workshops`.

Overall, Sage has so far failed at this goal, though it has succeeded in certain specific areas, such as algebraic combinatorics. There are probably less than 100K monthly active users of Sage, but the other commercial software have far more users, based on web traffic and combined annual revenue of likely over 100 million. There are over 4000 people working full time on the commercial math software competitors, whereas the Sage project has far less full-time equivalent contributors.

CoCalc makes it really easy to collaboratively use open source mathematics software.

CoCalc makes it really easy (especially for beginners!) to collaboratively use open source mathematics software in their web browser. It works well now, and my goal is to greatly increase the number of people using it.

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

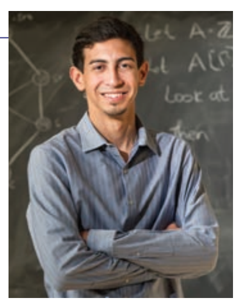
Stein: Rigorous proof greatly improved mathematics research in the 20th century, and open source software may play a similar role in the 21st.

Image Credits

CoCalc banner by Harald Schilly.
All other images courtesy of William Stein.

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

AMS on Social Networks

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.

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WHAT IS...

a Hyperbolic 3-Manifold?

Colin Adams

Communicated by Cesar E. Silva

The simplest example of a hyperbolic manifold is hyperbolic geometry itself, which we describe using the Poincaré disk model. In Figure 1 we see the 2-dimensional version $\mathbb{H}^2$ and the 3-dimensional version $\mathbb{H}^3$, each the interior of a unit 2-disk or 3-disk. In both cases, geodesics are diameters or segments of circles perpendicular to the missing boundary. Notice that for any triangle with geodesic edges, the sum of the angles adds up to less than 180 degrees. This choice of geodesics can be used to determine a corresponding metric, which turns out to have constant sectional curvature -1, justifying the statement that hyperbolic space is negatively curved.

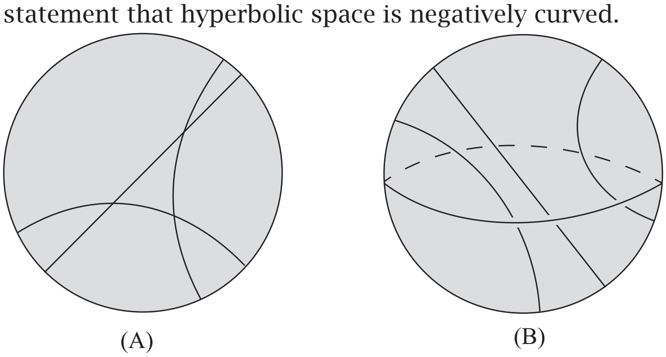

Figure 1. The Poincaré disk models of hyperbolic 2-space $\mathbb{H}^2$ and hyperbolic 3-space $\mathbb{H}^3$ with geodesics that are diameters and segments of circles perpendicular to the missing boundary.

We say that a surface (a 2-manifold) is hyperbolic if it also has a metric of constant sectional curvature -1. We can use this as a definition of a hyperbolic surface, but there are two other helpful ways to think about a hyperbolic surface.

When a surface S has such a metric, we can show that the universal cover of the surface is $\mathbb{H}^2$ and there is a discrete group of fixed-point free isometries Γ of $\mathbb{H}^2$ that act as the covering transformations such that the quotient of $\mathbb{H}^2$ by the action of Γ is the surface.

By choosing a fundamental domain for the group of isometries Γ, we can also think of S as being obtained from a polygon in $\mathbb{H}^2$ with its edges appropriately glued together in pairs by isometries as in Figure 2. In particular, at each point in S, there is a neighborhood isometric to a neighborhood in $\mathbb{H}^2$. So locally, our surface appears the same as $\mathbb{H}^2$.

Among all topological surfaces, how prevalent are the hyperbolic surfaces? Considering compact orientable surfaces without boundary, only the sphere and the torus are not hyperbolic. All other orientable surfaces are hyperbolic as in Figure 3. If we throw in nonorientable surfaces, only the projective plane and the Klein bottle are not hyperbolic. And if we allow punctures, the only additional surfaces that are not hyperbolic are the once-

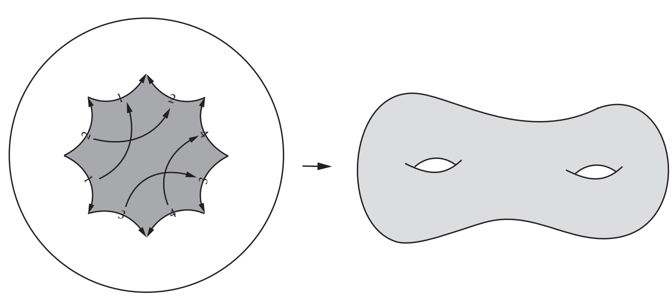

Figure 2. Gluing together pairs of edges of a hyperbolic fundamental domain yields the genus two surface.

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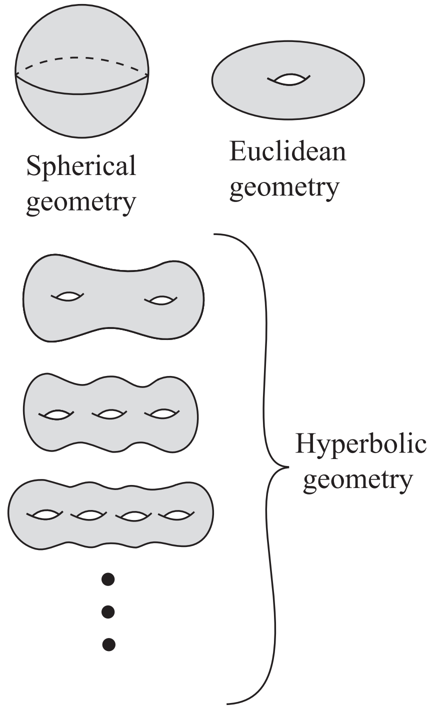


Figure 3. A list of closed orientable surfaces and their respective geometries.

and twice-punctured sphere and the once-punctured projective plane. So among the infinitude of closed surfaces and closed surfaces with arbitrarily many punctures, all but seven are hyperbolic. So if we want to understand the geometries of surfaces, it's all about the hyperbolic case.

A 3-manifold is a topological space M that is locally 3-dimensional. That is to say, every point has a neighborhood in the space that is homeomorphic to a 3-dimensional ball. For instance, the 3-dimensional spatial universe in which we all live is such a 3-manifold. Another example would be to take 3-space (or the 3-dimensional sphere if we want to begin with a compact space) and remove a knot. Then it is still true that this is a 3-manifold, as every point still has a ball about it that is 3-dimensional. We just have to pick the ball small enough to avoid the missing knot.

In the 1970s and 1980s, work of William Thurston (1946–2012) and others led to the realization that many 3-manifolds are hyperbolic. Here again, to be hyperbolic just means that there is a metric of constant sectional curvature -1 or, equivalently, that there is a discrete group of fixed-point free isometries Γ acting on $\mathbb{H}^3$ such that the quotient of the action is M.

A famous example is the figure-eight knot complement. Here, the fundamental domain for the action of the discrete group of isometries is a pair of ideal regular hyperbolic tetrahedra (all angles between faces are $\pi/3$), as in Figure 4.

An ideal hyperbolic tetrahedron is one with geodesic edges and faces such that it is missing its vertices as they sit on the missing boundary of $\mathbb{H}^3$. The sum of the volumes of this pair of ideal regular tetrahedra is 2.0298 … , a number of interest to number theorists as well as topologists, since it is also related to the value of the Dedekind zeta function at 2. (See for instance Zagier's *Inventiones* article from 1986.) This volume was proved to be the smallest hyperbolic volume of any knot by Cao and Meyerhoff in an *Inventiones* article from 2001.

Why is it useful for a 3-manifold to be hyperbolic? One extraordinary advantage is the Mostow–Prasad Rigidty Theorem, which says that if you have a finite volume hyperbolic 3-manifold, its hyperbolic structure is completely rigid. All such structures on a given 3-manifold are isometric. In particular, every such 3-manifold has a unique volume associated with it. We have turned floppy topology into rigid geometry.

Compare that to the Euclidean case. We could take a cube and glue opposite faces straight across. This yields the 3-dimensional torus. But we can make it out of a small cube or a big cube, so there is no unique volume associated to it. We could even trade in the cube for a parallelepiped, and we would still have a valid Euclidean structure on the 3-torus.

On the other hand, the figure-eight knot has a hyperbolic complement with volume 2.0298 … . So we now have an incredibly effective invariant for distinguishing between 3-manifolds. This was an essential tool used in the classification of the 1,701,936 prime knots through 16 crossings by Hoste, Thistlethwaite, and Weeks in 1998.

In the case of knots, volume is not enough to completely distinguish them for two reasons. First, there are nonhyperbolic knots. Thurston showed that knots fall into three categories: they can be torus knots, satellite knots, or hyperbolic knots. A torus knot is a knot that

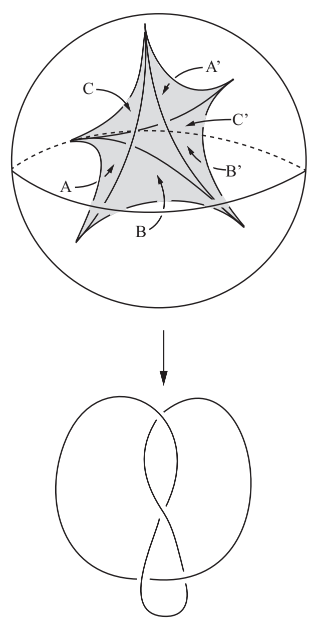


Figure 4. A fundamental domain for the figure-eight knot complement constructed from two ideal regular tetrahedra in $\mathbb{H}^3$.

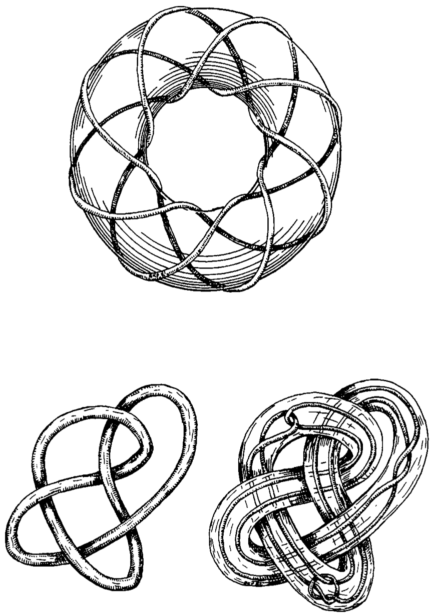


Figure 5. A torus knot at top and a satellite knot, bottom right. Every other knot must be hyperbolic.

lives on the surface of an unknotted torus, as in Figure 5, and is determined by how many times it wraps the long and short way around the torus.

A satellite knot is what you might guess, a knot K that orbits another knot K' in the sense that it exists in a neighborhood of K', which is to say a solid torus with K' as core curve. It is a truly marvelous fact that after excluding just these two categories of knots, all other knots are hyperbolic.

Second, although rare for low crossing number, there can be two different knots with the same volume. For instance, the second hyperbolic knot 5_2 has the same volume as the 12-crossing $(-2, 3, 7)$-pretzel knot as in Figure 6.

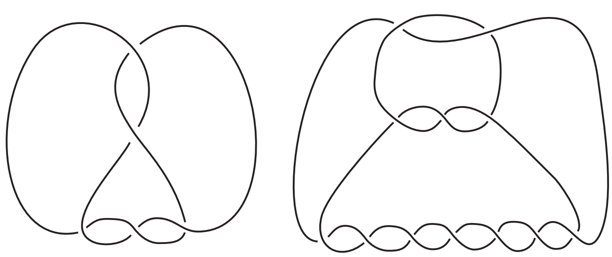


Figure 6. There do exist examples of hyperbolic knots with the same volume, such as the pair pictured here.

What we would like is a complete classification of all closed 3-manifolds. This means we would like a way to "list" them all and to decide, given any two, whether or not they are homeomorphic.

In 1982 William Thurston proposed the Geometrization Conjecture. It says that every closed 3-manifold can be cut open along an essential set of tori and spheres into pieces, and after capping off the spheres with balls, each of the components would be 3-manifolds with one of eight specified geometries, one of which is $\mathbb{H}^3$. In 2003 Grigory Perelman revolutionized low-dimensional topology by proving the Geometrization Conjecture. (He also proved the Poincaré Conjecture in the process, which was a necessary piece in the proof of the larger Geometrization Conjecture.)

So we would like to determine the manifolds with each of the eight geometries. In fact, the manifolds associated to the seven other geometries have been classified and are well understood. There only remains the manifolds that are hyperbolic. Why have we not succeeded in classifying those? The situation is analogous to what happened with surfaces. This is the richest of the geometries, with the preponderance of the manifolds. It is the mother lode.

Thurston also proposed the Virtual Haken Conjecture, implicit in the work of Waldhausen, that every closed 3-manifold satisfying mild conditions (having infinite fundamental group and no essential spheres) either contains an embedded essential surface or possesses a finite cover that does so, thereby allowing the decomposition along the surface into simpler pieces. The proof of the Geometrization Conjecture allowed for a proof of the Virtual Haken Conjecture for all 3-manifolds except hyperbolic 3-manifolds, which is not such a surprise, since again, this is where the action is. It was this case that Ian Agol completed in 2012, thereby settling this fundamental conjecture. Agol received the three million dollar Breakout Prize in mathematics for this and related work.

Research continues forward as we attempt to understand hyperbolic 3-manifolds, their volumes, and other related invariants. This geometric approach to low-dimensional topology has become fundamental to our understanding of 3-manifolds and will continue to play a critical role for years to come.

Additional Reading

Volumes of Hyperbolic Link Complements, Ian Agol, https://www.ias.edu/ideas/2016/agol-hyperbolic-link-complements.

Image Credits

Figures 1–4 and Figure 6 courtesy of Colin Adams.
Figure 5 from *A Topological Picturebook*, courtesy of George Francis.
Photo of Colin Adams courtesy of Alexa Adams.

Colin Adams

ABOUT THE AUTHOR

Colin Adams researches knots, hyperbolic 3-manifolds, and the connections between the two. When not doing math, he likes to write about math, including his comic book, *Why Knot?*, and his novel, *Zombies & Calculus*.

AMS Blogs
AMERICAN MATHEMATICAL SOCIETY

Graduate Student Blog
by and for math graduate students

The AMS Graduate Student Blog, by and for math graduate students, includes puzzles and a variety of interesting columns, such as this one from January 2018. `blogs.ams.org/mathgradblog`.

Towards Embracing Diverse Mathematical Communities

by Vanessa Rivera-Quinones

As graduate students, we interact with a wide variety of people: local communities, students, peers, and professors. Within these interactions, there is great diversity: different backgrounds, experiences, and cultures. I believe this is something that makes our mathematical community vibrant if we choose to embrace it.

However, through our training as mathematicians, are we asking ourselves: How are we contributing to this diversity? How do we create environments that embrace the identities of those who "do" mathematics? Are we making mathematics accessible and inclusive? These are questions that I ask myself, but would be interested in making them part of a larger narrative.

When I started thinking about these topics I found myself overwhelmed with the knowledge that this affects the lives of many on a daily basis. This is part of their personal story and in many ways an unavoidable part of their journey to become mathematicians. It affects my students who look into who does mathematics and may not see someone who they can relate to. It affects my peers and professors who may be the first "blank" or the only or the few "blank" in their classrooms, at a conference, or departments.

Then the question became, what do I do? I searched high and low for a magical answer and found that…it's complicated. But, I think there are certainly small things we can do to open up the conversation as individuals and as a community. Here are a few things I've found useful, and I hope that this list helps others who wish to start discussing some of these questions:

1. Create spaces for conversation.

A. It may look like small coffee chats with peers, one or two conversations with faculty, or participating in conferences that facilitate these conversations. For example, the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) is a great one! Others that come to mind are Latinxs in the Mathematical Sciences, Field of Dreams Conference, and Blackwell-Tapia Conference.

B. As part of our AWM student chapter, we have created a Teaching and Diversity Seminar where we bring speakers to tackle some of these questions. We look in neighboring departments and we look for passionate individuals within our fields. One of our speakers this semester, Dr. Rochelle Gutierrez, has a piece on this blog I encourage you to read. Other great speakers we've engaged with as part of our TA (teaching assistant) training include Aditya Adiredja and Esther Enright.

2. Learn, keep learning, and challenge your assumptions.

Join a reading group, attend talks about these topics, or follow blogs by diverse mathematicians. Some of my favorites are Francis Su's article, "Mathematics for Human Flourishing" and Piper Harron's blog, The Liberated Mathematician. We may never have all the answers but we can become more aware that our roles as mathematicians extend beyond our discipline. Sometimes this looks like being mindful of our biases or empathizing with the experiences that are not similar to our own. It could mean being a voice and it could mean passing the [mic] to let other voices be heard.

3. Be honest, listen, and take care.

Embrace and share your stories as part of what makes you a mathematician. The challenges and triumphs. This is difficult if you find yourself in an environment that doesn't embrace the identities you bring to your mathematics. Having open and honest conversations require listening to others with no judgment and accepting that their experiences have a place in our community. Some will be uplifting and others not so much. But it is important to create a space to share both. These conversations may be challenging so always seek to take care of yourself as well.

Mathematics is a beautiful field that blossoms with our own unique perspectives and experiences. Let's work towards opening those conversations, let's challenge our assumptions and foster the growth of a more diverse mathematical community…together.

Photo Credit

Photo of Vanessa Rivera-Quinones courtesy of Department of Mathematics, University of Illinois at Urbana–Champaign.

ABOUT THE AUTHOR

Vanessa Rivera-Quinones is a fifth-year PhD student in mathematics who enjoys teaching, learning applications of math in different disciplines, and making math accessible to everyone. Her research interests involve using mathematical models to understand how interactions among hosts, parasites, and the environment shape the spread of disease. A graduate of the University of Puerto Rico at Río Piedras, she also enjoys taking pictures, painting, and bowling. Her email address is riveraq2@illinois.edu.

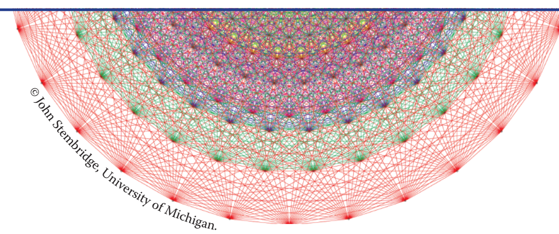
Vanessa Rivera-Quinones

Faces of Women in Mathematics

Women mathematicians from around the world give their names and say "I am a mathematician" in 14-minute film prepared by Eugenie Hunsicker, chair of the London Mathematical Society's Women in Mathematics Committee, and her sister Irina Linke, a cinematographer. A request for selfie film clips yielded 146 clips of 243 women mathematicians from 36 countries. Hunsicker said, "I want that the next time people hear about Nigeria, Nepal, or the Philippines, they think, `Oh, yeah, that is the place with all of those fantastic women mathematicians!'"

Check out the 2-minute trailer at: **https://vimeo.com/260633621**.

—From Hunsicker and Linke's press release "*Faces of Women in Mathematics* film released for International Women's Day"



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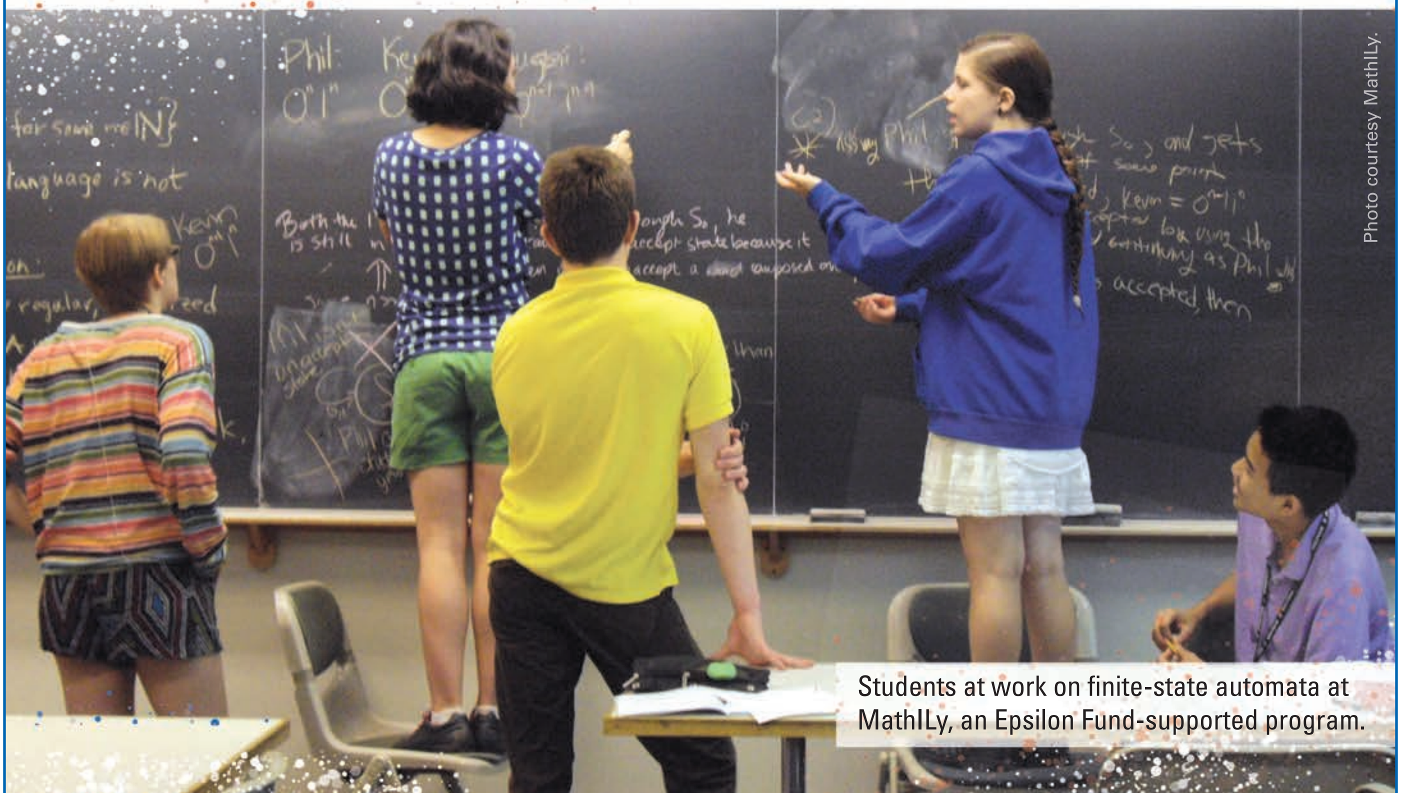

Students at work on finite-state automata at MathILy, an Epsilon Fund-supported program.

Photo courtesy MathILy.

Your generous gifts help hundreds of mathematically talented youths receive immersive mathematics education each summer. Thank you for your donations!

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For questions or more information, contact the AMS Development office at 401.455.4111 or development@ams.org

2018 Award for an Exemplary Program or Achievement in a Mathematics Department

The Math Center for Educational Programs (MathCEP) at the University of Minnesota is the recipient of the 2018 Award for an Exemplary Program or Achievement in a Mathematics Department. See a profile of this program and a conversation with its current director on page 580.

Citation

The American Mathematical Society is pleased to announce that the 2018 Award for an Exemplary Program or Achievement in a Mathematics Department goes to the Math Center for Educational Programs (MathCEP) at the University of Minnesota for its outreach programs aimed at children K–12, teachers, graduate students, and postdocs.

MathCep and UMTYMP director Jonathan Rogness.

The flagship program of MathCEP is the University of Minnesota Talented Youth Mathematics Program (UMTYMP), an accelerated five-year program of courses and mentoring for middle school and high school students. The first two years of UMTYMP cover the high school mathematics curriculum from algebra through precalculus; then in the next three years, students take honors courses on calculus, set theory, logic and methods of proof, linear algebra, and vector calculus. If students complete all of these courses before graduating from high school, they can take advanced topics courses offered by UMTYMP as well as upper level math classes of their choice at the university. Such students also have the opportunity to be involved in research projects and to participate in real world modeling. All of the courses offered by UMTYMP not only aim to teach students the material, but also how to write mathematics. In addition, faculty work with students in the program to develop independence, motivation, good work habits, and problem-solving skills.

MathCep and UMTYMP founder and former director Harvey Keynes.

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DOI: http://dx.doi.org/10.1090/noti1683

Girls Excel in Math students play with tessellations.

UMTYMP has existed for forty years and has served more than 6,000 students, with over 500 participants at any given time. Each year UMTYMP admits 140–150 new middle school students, and despite the intensity and time commitment involved, the program has an 85 percent retention rate from one year to the next. While UMTYMP started at the University of Minnesota campus in Minneapolis, it now also runs classes on other college and university campuses throughout Minnesota, including Duluth, Rochester, Moorhead, and St. Cloud. Almost all UMTYMP alumni go into STEM fields with an average of 18.17 percent going into mathematics. The goal of the program is not only to create future mathematicians; rather it is to give participants a deep understanding and appreciation of mathematics which they will carry with them into whatever fields of study they choose.

MathCEP offers multiple other programs in addition to UMTYMP. This includes Saturday morning enrichment programs for children, summer camps, professional development for teachers, a master's degree in mathematics with an emphasis on math education, and post-doc positions targeted at new PhDs who are interested in careers at teaching oriented institutions. Of particular note is the MathCEP outreach program Girls Excel in Math which is an enrichment program serving more than 250 girls in grades 4–6. The goals of this program are to excite girls about math, create a sense of community, build confidence, and reinforce the feeling that they belong and can excel in mathematics. In addition, this program is designed to motivate its participants to apply to UMTYMP in 5th or 6th grade, thereby increasing the number of female participants in UMTYMP.

Altogether, MathCEP is unique in the number of outreach programs it offers, the number of people its programs serve, the success of alumni from UMTYMP in STEM fields including mathematics, and the longevity of the flagship program UMTYMP. Not only is MathCEP a truly exemplary program, but its directors are happy to advise other colleges and universities who might be interested in trying to implement similar programs at their institutions.

For all of these reasons, we are delighted to present the AMS Award for Exemplary Program or Achievement in a Mathematics Department to the Math Center for Educational Programs at the University of Minnesota.

About the Award

The Award for an Exemplary Program or Achievement in a Mathematics Department was established by the AMS Council in 2004 and was given for the first time in 2006.

The purpose is to recognize a department that has distinguished itself by undertaking an unusual or particularly effective program of value to the mathematics community, internally or in relation to the rest of society. Departments of mathematical sciences in North America that offer at least a bachelor's degree in mathematical sciences are eligible. Through the generous support of an anonymous donor, the award carries a cash prize of US$5,000. The award is presented by the AMS Council acting on the recommendation of a selection committee. The members of the 2018 selection Committee are Craig Evans, Erica Flapan (Chair), Rhonda Hughes, Cristoph Thiele, and Sylvia Wiegand.

The 2018 Award for an Exemplary Program or Achievement in a Mathematics Department is the thirteenth bestowed by the American Mathematical Society. Previous recipients of the award are Harvey Mudd College (2006); University of California, Los Angeles (2007); University of Iowa (2008); University of Nebraska, Lincoln (2009); North Carolina State University (2010); University of Arizona (2011); Bryn Mawr College (2012); University of Texas at Arlington (2013); Williams College (2014); Iowa State University (2015); California State University at Northridge (2016); and The Department of Mathematics at the University of Illinois—Champaign (2017).

For more information, see: www.ams.org/department-award.

Photo Credits

All photos courtesy of University of Minnesota.

The 2018 Mathematics Programs That Make a Difference Award

The COUGARS AND HOUSTON AREA MATH PROGRAM (CHAMP) is the recipient of the 2018 Mathematics Programs That Make a Difference Award. See a profile of the Program, its challenges and successes on page 572.

Citation

The American Mathematical Society is pleased to announce that the 2018 Mathematics Programs That Make a Difference Award goes to The Cougars and Houston Area Math Program (CHAMP).

CHAMP is a Mathematics and STEM outreach program for high school and middle school students from underserved communities surrounding the University of Houston (UH), directed by Dr. Mark Tomforde. Started in Fall 2013, CHAMP runs throughout the academic year and has three main goals: encouraging participating high school students to graduate from high school, attend college, and consider majoring in a STEM field.

Volunteer UH tutors, who include a mix of UH Math majors and prospective high school teachers in training, run these tutorial sessions. In addition, UH admission officers meet with CHAMP participants to encourage them to go to college, preferably in a STEM field.

The demographics of CHAMP participants in its first four semesters are impressive: 89 total, of whom 81 are African American and 8 are Hispanic; 58 are female.

Most of the early CHAMP participants are from Hope Academy, which was a high school in Houston's Third Ward district and had a student body that was 95% African-American. In the past two years, CHAMP has expanded to serve KIPP Sunnyside High School, KIPP Liberation Middle School, and Ryan Middle School in the Houston Independent School District. In addition to weekly tutoring for high school and middle school students, each semester CHAMP runs a Middle School Math Day that brings middle school students to the University of Houston campus for a Saturday of math activities combined with opportunities to learn about college.

The CHAMP program has also made an impact on the professional plans for its tutors, nearly half of whom are from under-represented groups. Former tutor Zachary Garvey (now a graduate student at Dartmouth) writes, "My participation in CHAMP greatly helped me to cultivate a passion for education and outreach (and even mathematics) that had previously been only cursory. This has also naturally contributed to my decision to attend graduate school for mathematics."

Mark Tomforde, director and founder of the CHAMP Program.

About the Program

The program's director and founder, Dr. Mark Tomforde of the University of Houston's Department of Mathematics, made a counterintuitive choice when establishing CHAMP in 2013. Rather than seeking out significant grant or nonprofit support—with all the time-consuming administrative requirements and record keeping that entails—he elected to develop his program on a shoestring budget, relying on personal donations and unpaid volunteers at first and adding inputs from small grant programs as CHAMP expanded. This decision allowed CHAMP greater

A CHAMP volunteer working with a student at an in-school CHAMP meeting.

flexibility in determining activities and approaches. It also gave Tomforde the ability to focus his time and energy on identifying enthusiastic volunteer instructors and tutors to work one-on-one with the small groups of students from local schools.

This choice has an important short-term payoff: the volunteers themselves gain valuable experience and encouragement to develop their own path in mathematics and STEM by virtue of their contribution—and some make an immediate impact on the diversity of STEM fields. Of the 40 volunteers participating in CHAMP since 2013, 15 (9 men, 6 women) enrolled in graduate programs in mathematics, and 9 more (8 women, 1 man) became math teachers. Moreover, 6 of the volunteers who went on to become math teachers were ethnic minorities, enabling them to be role models to their minority students.

As it expands, CHAMP faces expenses related to supplies and transportation and will need additional exposure and financial support to continue its services. The American Mathematical Society is delighted to be able to provide both via this award, in recognition of the program's efforts in guiding Houston-area students toward further education and careers in mathematics.

About the Prize

The Mathematics Programs That Make a Difference Award is awarded by the AMS Committee on the Profession.

This Award for Mathematics Programs that Make a Difference was established in 2005 by the AMS's Committee on the Profession to compile and publish a series of profiles of programs that:

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

2) have achieved documentable success in doing so; and

3) are replicable models.

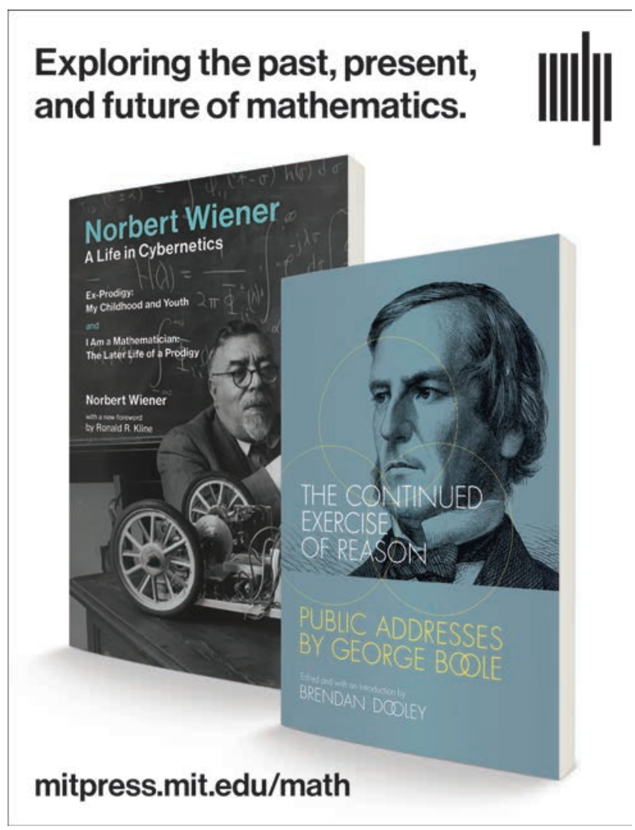
Preference is given to programs with significant participation by underrepresented minorities.

Beginning in 2018, this recognition includes an award of $1,000.00 provided by the Mark Green and Kathryn Kert Green Fund for Inclusion and Diversity.

Photo Credits

All article photos courtesy of Mark Tomforde.

The 2018 Mathematics Programs That Make a Difference Award is the thirteenth bestowed by the American Mathematical Society. Previous recipients include the National Alliance for Doctoral Studies in the Mathematical Sciences (2017), The Mathematics Department at Morehouse College (2016), and the Center for Undergraduate Research in Mathematics (CURM) at Brigham Young University / Pacific Coast Undergraduate Mathematics Conference (PCUMC) (2015).
For more information, see:
`www.ams.org/make-a-diff-award`.



Call for Nominations

AMS AWARD FOR MATHEMATICS PROGRAMS THAT MAKE A DIFFERENCE

Nominate a mathematics program that aims to bring more persons from underrepresented groups into some portion of the mathematics pipeline starting at the undergraduate level, or retains them once in the pipeline.

The AMS Committee on the Profession will select one award recipient for 2019, who will receive **$1,000** provided by the Mark Green and Kathryn Kert Green Fund for Inclusion and Diversity.

Photo courtesy of Donald R. Cole.

Photo courtesy of Debra Klimes.

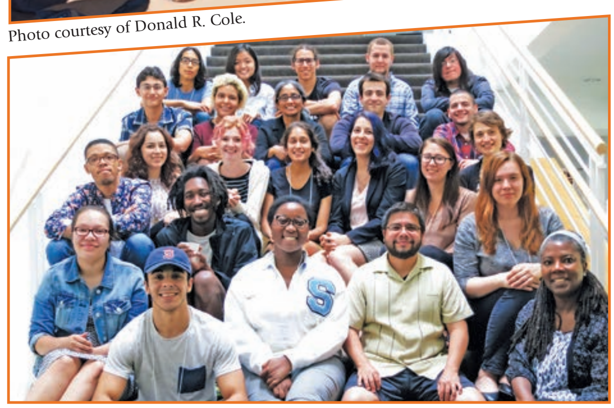


Photo courtesy of Jennifer Murawski.

For details on the award criteria and the nomination process, and to learn about past winners of the award, see **www.ams.org/make-a-diff-award**.

Email questions to dir-edd@ams.org.

Deadline: September 15, 2018

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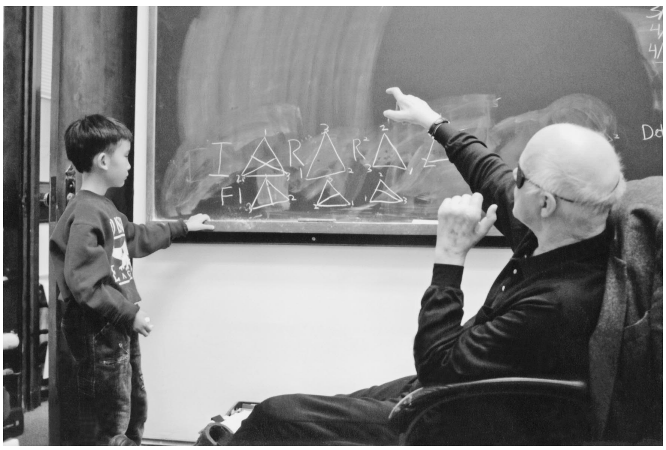
Paul J. Sally Jr. (1933–2013)

Jeffrey Adler, John Boller, Stephen DeBacker, and Loren Spice



Discussing symmetry in Sally's office.

Paul Sally, legendary leader and agitator on behalf of both mathematics and mathematics education, passed away on December 30, 2013. Paul was a one-of-a-kind character: boisterous yet humble, gruff yet charming, sophisticated yet coarse. Tough as nails and blessed with boundless energy, a phenomenal memory, and a heart of gold, Paul was relentless in the pursuit of his three great passions: mathematics, teaching, and basketball. Through a series of personal reminiscences and an afterword, we provide a glimpse of a remarkable man and his achievements.[1] We have ordered these reminiscences in an attempt roughly to parallel the course of his life, from beginning graduate student to the "powerhouse 'pirate'" [1] who was such an iconic part of the University of Chicago mathematics department.

Jeffrey Adler is professor of mathematics at American University. His email address is jadler@american.edu.

John Boller is senior lecturer in mathematics at the University of Chicago. His email address is boller@math.uchicago.edu.

Stephen DeBacker is Arthur F. Thurnau Professor of Mathematics at the University of Michigan. His email address is smdbackr@umich.edu.

Loren Spice is associate professor of mathematics at Texas Christian University. His email address is l.spice@tcu.edu.

[1] *We encourage you to view the excellent 2010 interview* [4] *of Paul by Diane Herrmann and Hugo Rossi that is part of the Simons Foundation's Science Lives series. Additional biographical information may be found in the announcement of the 2014 AMS Award for Impact on the Teaching and Learning of Mathematics* [3].

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One of Paul's great delights was the surprise of finding a problem unexpectedly easy or hard (or even unsolvable), and he insisted that *real* math problems do not come carefully posed to single out a unique answer (or even a unique interpretation). For him, figuring out a correct formal version of an informal problem was part of the fun, and he believed that the best problems lead to further problems rather than wrapping up a story. Throughout this article, we list Paul's favorite ten problems. Some hints and answers are included at the end of the article.

Kenneth I. Gross

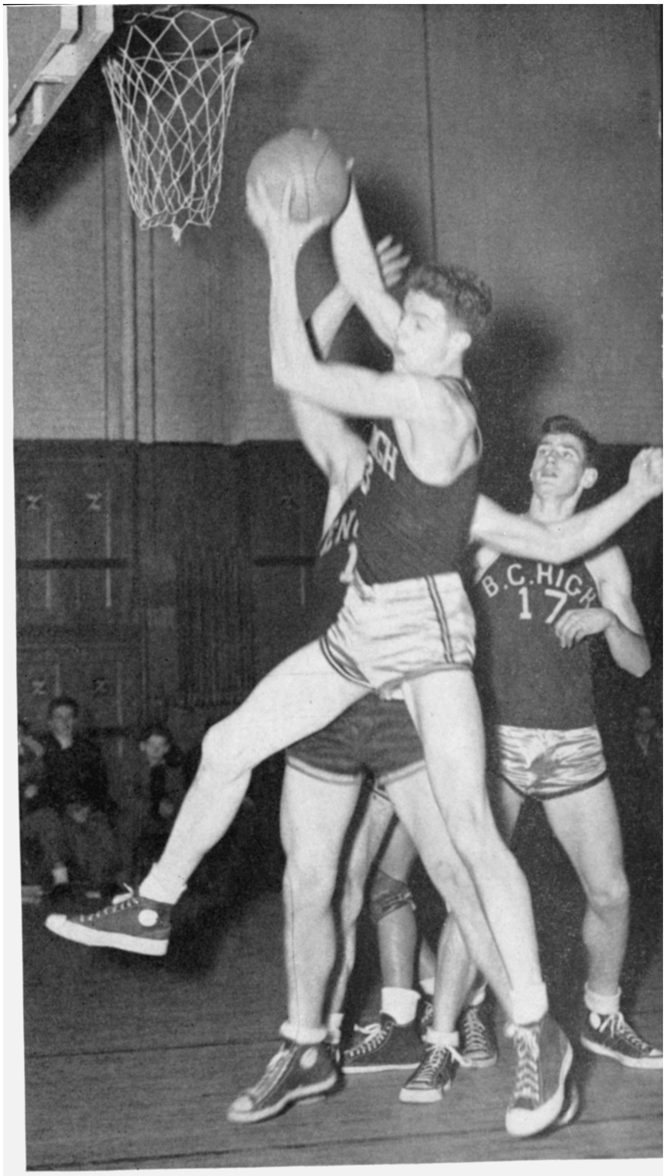
Nowadays, the words "unique," "awesome," "legendary," and "larger than life" are thrown about casually, overused, and abused. However, when I write that these are the words that first come to mind when I think of Paul, I am using them in the strictest possible interpretation.

How does one write about a legend? I could focus on Paul's extensive research accomplishments; his extraordinary achievements as an educator; his commanding presence which characterized everything he did and separated him from mere mortals; or the immense courage he exhibited in the face of type I diabetes; which eventually robbed him of his vision and legs, but did not diminish his upbeat disposition or the passion with which he pursued his twin loves of mathematics and teaching. However, I am going to focus this encomium on another great passion of Paul's: basketball.

Paul and I first met at Brandeis University when I was an undergraduate and he was a graduate student there. Paul was in the inaugural graduate class, his wonderful wife, Judy, was in the second, and I was in the third.

The program was at a high level of rigor and abstraction, and it took Paul and me a while to find our stride. Fortunately, Ray Kunze [2] was on the faculty. "Find

Kenneth I. Gross (1938–2017) was the Azarias Williams Professor of Mathematics emeritus at the University of Vermont, and director emeritus of the Vermont Mathematics Initiative.



Sally grabs a rebound.

Judy and Paul Sally.

Sally leading his sons.

our stride" meant finding Ray, who was the ideal thesis advisor. Both of us owe our academic careers to Ray.

Ray left Brandeis in 1962 for Washington University in St. Louis, and Paul and I went with him. It was there that our life long friendship blossomed. Paul and Judy had three young children—David, Steven, and Paul III—for whom I served as baby sitter of last resort. Paul and I interacted mathematically on a regular basis, informally and in Ray's seminar, and we played basketball nearly every day.

Paul had been an All-Scholastic basketball player at Boston College High School and was on the Boston College team as an undergraduate. He was left-handed and had two signature shots: a hook shot that positioned his right elbow at precisely the level of one's jaw and a one-hand outside shot for which his left knee came up at the precise height to necessitate protecting one's most vulnerable organs. Like many competitive players, Paul had only one entry in his basketball rule book: do whatever you can get away with. One of many memorable vignettes will serve as an illustration.

As a backdrop, I will say something about Paul's career-long affinity for the representation theory of p-adic groups, which had its origin in Ray's seminar. The topic Ray chose was Gelfand and Graev's landmark paper on representations of SL(2) over a locally compact field. The seminar spawned a collaboration with Mitch Taibleson, and their joint paper launched Paul's p-adic career. Almost overnight, representation theory over p-adic fields was a thriving enterprise in which Paul was

River Problem. There are two boats docked on opposite sides of a river. The sides of the river are parallel and the current is negligible. The two boats set out at the same time to cross the river, and each maintains a constant speed. They first meet at a distance D_1 from side 1, then proceed to the opposite side and turn around. Next, they meet at a distance D_2 from side 2. How wide is the river? Does your answer make sense?

a pioneer. Paul proved the uniform boundedness of the analytic continuation of the principal series for SL(2) over local fields, and he and Joe Shalika proved the Plancherel formula for SL(2) over local fields.

Charles Gulizia, a doctoral student of mine at Dartmouth College, built on those papers to prove the Kunze–Stein L^p convolution theorem over a local field, and I invited Paul to be a member of the PhD examining committee. Paul made his acceptance contingent on my arranging a two-on-two basketball game. One of my undergraduate advisees joined us. He had been an all-state high school basketball player, was the Ivy League high-hurdles champion, and was Paul's height, but Paul manhandled him right from the start. Finally, having had enough of Paul's contemptible tactics, he overcame his reluctance to play physically with a distinguished professor from the University of Chicago who was twice his age, and he leveled Paul. Looking up from the floor, Paul said, "Hey, kid, where the H__ you been for the past ten minutes?"

That was the final time Paul and I played. Soon after, the ravages of diabetes started to set in, but you would never have known that from talking with him. He was always "great," and life was always "beautiful."

The last time I saw Paul, four months before his death, we were in the living room of his apartment, and he was unusually expansive about his life. We discussed mathematics and the book he and I were writing, and I told him I admired the way he could "see" the intricate details of mathematics though nearly blind. He replied that he had prepared for blindness for many years by doing mathematics without pencil and paper and with his eyes closed. We also talked about his education programs, and he revealed which of them he held most dear. If money ever got tight, he said he could reluctantly give up SESAME[2] and say that it had had a fantastic decades-long run. "But my Young Scholars Program, that's a different matter."

Now it is up to the ages to take care of Paul. If good deeds and a life well lived are the entrance requirements, then Paul is in a hallowed place. I hope for your sake, Paul, that the refs in heaven don't call a tight game.

[2]*Reflecting his enjoyment of word play, Paul was more attached to the name SESAME than to any particular interpretation of the acronym. He eventually settled on "Seminars for Endorsement of Science and Mathematics Educators."*

Three-Gap Problem. Let N be a positive integer, θ an angle in $(0, 2\pi)$, and S^1 the unit circle. Consider the map $f\colon \{0, 1, 2, \ldots, N-1, N\} \to S^1$, defined by $f(k) = k\theta \mod 2\pi$. Show that the image of f divides S^1 into arcs of exactly 1, 2, or 3 different lengths.

Norman Winarsky

I met Paul when I came to the College of the University of Chicago in 1966. I came as an eighteen-year-old boy, somewhat intimidated, alone, and concerned for my future.

I was remarkably fortunate to take classes from Paul and so to learn mathematics, from foundations to advanced analysis, from one of the best teachers in the world. The classes were small, perhaps fifteen people, and they were always exciting, challenging, and inspiring. He was the one who taught me how to think, from developing ideas from first principles, to proving theorems, to creating theories. Most of all, he taught me the beauty of mathematics.

I graduated in 1969. Paul advised me to go elsewhere for graduate school to have a broader mathematical and social experience. I was accepted at Princeton and decided to pursue my PhD in mathematics there.

The Vietnam War and the draft changed my plans. All graduate student deferments were discontinued, and the lottery determined who would be drafted. My number was low and I became 1A, which effectively guaranteed that I would go to Vietnam. Paul and Izaak Wirszup came up with a plan for which I am forever grateful. They worked to make me an instructor at Chicago, and so I petitioned my draft board for a deferment, not as a grad student, but as a teacher. The draft board agreed, and I received the deferment. That was great problem solving!

In graduate school Paul became my thesis advisor. Once again, he had a dramatic impact on my life. He decided to spend the 1971–72 academic year at the Institute for Advanced Study (IAS) at Princeton, where there was a seminar series on p-adic groups being led by Harish-Chandra. Paul arranged for me to be invited to join him as an IAS visitor. It was a remarkable time, learning from the greats in this field and developing my thesis topic on representations of semisimple p-adic groups.

After getting my PhD, I taught at the State University at Albany, SUNY, for two years, and then felt a deep need to do mathematics in the real world of industry. I think Paul was disappointed that I didn't continue in academia, but he never showed it. I joined RCA Labs' David Sarnoff Research Center and, over the next decades, led my division in helping to develop new technologies such as electron-beam systems, human vision analysis, HDTV, Siri, and more.

Norman Winarsky is former president of SRI Ventures and was a co-founder of Siri (later acquired by Apple). He is a lecturer at Stanford Graduate School of Business and co-author with Henry Kressel of If You Really Want to Change the World: A Guide to Creating, Building, and Sustaining Breakthrough Ventures.

The most important lesson I learned from Paul is not about mathematics, but about life in the face of what might seem to be overwhelming adversity. Paul lost two legs and one eye to diabetes, and he was nearly blind in the other eye. I never once heard him complain or even seem depressed. Every time I visited him, I heard the warm and friendly "Yo, Norman!" and then we caught up together like old times. His chalkboard was still full of mathematics, and his enthusiasm, energy, and happiness were infectious. He continued to do his research and had many plans for future books and papers. Whenever I visited, numerous visitors would be waiting in line, yet he always wanted to hear more about what I was doing.

Each of us is fortunate in our lives if we find a teacher who is interested in us, who gives us guidance and support, and who has passion for our chosen field. Paul was even more than that: he was a friend to me and a model for my life and for the lives of countless students and friends. His encouragement, values, enthusiasm, and love for mathematics were gifts that will go on forever.

David Vogan

I met Paul Sally sometime in the fall of 1972, when he returned to the University of Chicago after spending a year at the Institute for Advanced Study. I was an undergraduate, attached to math but with no idea what kind was most interesting. Fortunately, *Paul* knew very well what kind of math was interesting: harmonic analysis. His vita described his specialty as "harmonic analysis on semisimple groups."[3] None of this "representation theory" stuff: The goal was to understand spaces of functions with group actions. Representations were a tool for doing harmonic analysis.

I started taking courses from Paul, trying to understand a few of the seminar speakers he invited, and reading papers that he gave me. What I learned was that this mathematics was hard, but that Paul could always make it clearer and easier, or at least convince me that it was worth the effort to figure out.

I left Chicago in 1974, sent with Paul's guidance to the best place for studying group representations: MIT. From then on, I could absorb his wisdom (and his deflation of anything pretended) only in occasional short meetings, which still had long-term effects. I visited him in his fourth-floor office in Eckhart Hall about 1976, very anxious to tell him about all the great algebraic stuff I now knew about representations. He listened and asked, "So what's that tell you about *unitary* representations?" (In other words, how did all this algebra advance harmonic analysis?) The answer was that it didn't immediately tell you very much. That question—and all of his teaching before—had a serious effect on my work. Algebra is still almost all that I do, but at every opportunity it's algebra aimed at harmonic analysis.

Like many mathematicians, Paul understood well the enormous number of levels at which mathematics can be played. He sometimes compared it to basketball. Everyone understands the great difference between the kids on the school playground, high school teams, college teams, and the pros, and the further differences within each of those levels. (When Paul was playing basketball at Boston College, he sometimes practiced on the same court with the Boston Celtics. He said that sometimes, for a little while, he could feel that he was playing at their level. But then one of them would make a move, and he was just left in the dust.)

What made Paul unique was how deeply he cared about the people doing mathematics at all those levels, about Harish-Chandra, and about elementary school teachers. They were all doing math, and he wanted all of them to give it everything they had. As he did.

David Vogan and Sally discussing harmonic analysis.

House Problem. Suppose your street has houses on only one side and the houses are numbered consecutively, from south to north, starting with 1 and ending with some number m. Suppose you live at a house where the sum of the numbers to the south of your house is equal to the sum of the numbers to the north of your house. What is the number of your house? What happens if the street has odd and even numbers on opposite sides?

Rebecca Herb

I first got to know Paul and his work in the early 1970s while I was a graduate student at the University of Washington working with Garth Warner. Garth suggested that I look at his paper with Paul and attempt to generalize it to real rank two. It was slow work at the beginning but became easier for me after the Williamstown conference

David Vogan, Norbert Wiener Professor of Mathematics at the Massachusetts Institute of Technology, is a former president of the American Mathematical Society. His email address is dav@math.mit.edu.

[3] *His business card described it slightly differently: "Representing Groups in All Fields." He enjoyed seeing how people interpreted this description.*

Rebecca Herb is professor of mathematics emerita at the University of Maryland. Her email address is rah@math.umd.edu.

in the summer of 1972. I met Paul there, and his interest was instrumental in boosting my determination to write a thesis.

Motivated by efforts to generalize my thesis work to arbitrary real rank, Paul and I wrote a joint paper. We started working on it when I was a Dickson Instructor at the University of Chicago. Being there and working with Paul at the beginning of my research career was a wonderful opportunity because of his encouragement, enthusiasm, and knowledge of current work in the field. But it also had its frustrating side. On many occasions, I waited in the hall outside Paul's office while he listened patiently to an undergraduate talking about personal problems.

Over the years I kept coming back to the problem of the Fourier transform of orbital integrals and the Plancherel formula on semisimple Lie groups. Whenever I learned more about discrete series characters, I was able to refine the Fourier inversion formula. While I was working primarily on real Lie groups, Paul concentrated on p-adic groups, and he never gave up on his dream of gaining a good enough understanding of discrete series characters in the p-adic case to carry out the derivation of the Plancherel formula using the Fourier transform method.

As Paul's mobility and vision declined, he became even more focused on mathematics. As he remarked to David Goldberg, "After 80, you can really get things done." The title of an expository talk he gave a few years ago was "The Plancherel Theorem Done Right: Characters Tell All." For the Zuckerman conference in 2009, he planned an expository paper summarizing the real case and the program, goals, and current progress in the p-adic case. Paul asked me to join him in writing up the resulting paper summarizing my results in the real case. The paper emphasizes Paul's philosophy of representation theory as an extension of classical harmonic analysis and gives a brief history of this approach to the Plancherel formula, starting with the classical Plancherel theorem of 1910. Paul ends the paper with, "We expect to return to this subject in the near future."

Although he remained active as a research mathematician, Paul's biggest impact during the time that I knew him was on the research of others. I think that my experiences with him were typical. When I attended my first Joint Meetings as a graduate student, Paul was one of only two senior mathematicians who took the time to talk with me. Whenever we met, Paul asked what I was working on and reassured me that it was interesting and important. One afternoon at tea in Fuld Hall at IAS, when he was chatting with Harish-Chandra, Paul spotted me and called me over, saying, "So, what are you working on these days?" Of course, we had already had that conversation, but Paul wanted to give me the chance to tell Harish-Chandra about it and knew that I was too timid to approach him on my own. Paul also served as a clearinghouse for information about who was working on what in the days before email and online posting of preprints. Finally, he did his best to make sure that the work of junior mathematicians was appreciated, serving as a cheerleader for them at a time when others were less generous.

> **Harmonic Sum Problem.** Let n be a positive integer. Define $S_n = 1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \cdots + \frac{1}{n}$. Show that for $n \geq 2$ the sum S_n is never an integer.

Paul was also a booster of the city of Chicago. When I was an instructor at Chicago in the mid-1970s, Paul had already initiated the Midwest Representation Theory Conferences[4] by inviting a few colleagues to Chicago during spring breaks. Besides talking math, we also sampled the attractions of Hyde Park and greater Chicago: beer and arm wrestling at Jimmy's; blood soup at an eastern European restaurant on the West Side; and driving tours of the Loop, including Lower Wacker Drive, a subterranean street used by delivery trucks and Paul. On my more recent visits to Chicago, Paul was proud to show off his Hyde Park penthouse apartment. The elevator only went as high as the floor below his apartment, and I was pretty nervous walking behind Paul as he wobbled up the flight and a half of stairs on his two prosthetic legs.[5] But, for Paul, it was worth the effort, since the apartment had a large roof terrace overlooking the city.

The past forty years wouldn't have been nearly as much fun without him.

Allen Moy

I became Paul Sally's student in the summer of 1979. At the time, I did not have a strong research direction, but I had learned some class-field theory and become acquainted with the Langlands conjectures. The fact that Paul was in representation theory, along with the general understanding among graduate students that Paul did not have any personality peculiarities, played important roles in my choice.

In the film *Kramer vs. Kramer*, Dustin Hoffman's character delivers truths about parenting that I have always felt applied to the way Paul mentored his students: "It has to do with constancy, it has to do with patience, it has to do with listening, it has to do with pretending to listen when you cannot listen anymore." The qualities of constancy, patience, and listening were, in my mind, Paul's best attributes as an advisor.

In spring 1982 I finished at Chicago and then went to Yale as a Gibbs instructor. At Yale I became acquainted with Paul's younger sons, who were undergraduates there. In May 1984 the family came to Yale for Steven's graduation, and they took me up on an offer to use my

[4] *Now named "The Paul J. Sally Jr. Midwest Representation Theory Conference."*

[5] *Later, Paul found it easier simply to remove his legs and scooch up backwards, lifting himself one by one up each of the tens of stairs between him and his penthouse—a move he called the "Sally-scooch." He never once considered moving.*

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The *n*-gon Problem. Let P_n be a regular n-gon. Place dots at the n vertices and the midpoints of the n edges. Can one place the integers from 1 to $2n$ in a one-to-one fashion at each of the dots in such a way that the sum of the three integers on any edge is the same?

apartment. I still vividly remember the Sally family walking down York Street, Judy beaming with happiness while arm-in-arm with her sons Steven and Paul.

My position at Michigan during 1990–2001 allowed me frequent contact with Paul. I spent May 1991 as Paul's academic visitor. One day, towards the end of my stay, I told Paul: "Look, I have $400. Let's go scalp two tickets to see the NBA playoff game between Michael Jordan's Chicago Bulls and the Detroit Pistons Bad Boys." We did. Our seats were in the rafters, but we had a joyous time.

In January 2000 my father passed away in my hometown of Chicago. We held the wake in Chicago's Chinatown. My mother and I were quite touched that Paul, by then assisted by a student helper because of his first leg amputation, came to my father's wake.

Roger Howe

Not many mathematicians evoke the phrase "larger than life," but it fits well with Paul Sally. For one thing, he *was* big—6 feet, 3 inches to the end of his days, even though his doctors recommended that after losing his lower legs to diabetes-related infections, he should use shorter prostheses. He refused, saying that 6 foot 3 is the perfect height from which to view the world.[6] He used the prostheses for more than walking. When he attended meetings, he sometimes rolled up in his wheelchair, took off his legs, and put them on the table in front of him, so that they functioned as a sort of nameplate.

Paul loved mathematics, he loved people, and he loved life. In my memory, the adjective he used the most was "beautiful." He loved telling stories about himself or friends. However, he was not reverent about mathematics. He was more likely to be reverent about people. His feelings about Harish-Chandra in particular showed tendencies toward awe. Paul's main area of research interest was the representation theory of p-adic groups, and he entered the field just as Harish was putting the finishing touches on his Plancherel theorem for real reductive groups and shifting his attention to the p-adic theory. Harish's theory was always Paul's model for describing p-adic representation theory.

I was about to start my first job when we met at a NATO Summer School in Namur, Belgium, in early September, 1969. Paul liked beer and at that time indulged freely, so being in Belgium was close to being in heaven. He and the conference organizer closed the bars every night. The organizer looked droopier with each succeeding day, but Paul continued to look fresh.

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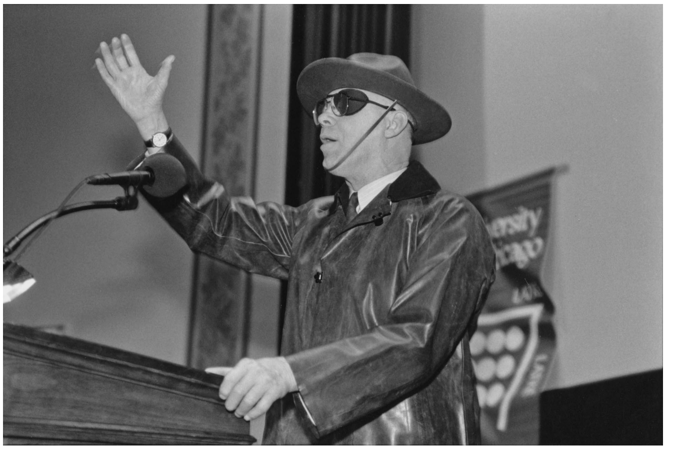
[6] *Paul was also known to say, "Now that I have two prosthetic legs, I could be 7 feet tall if I wanted to be."*



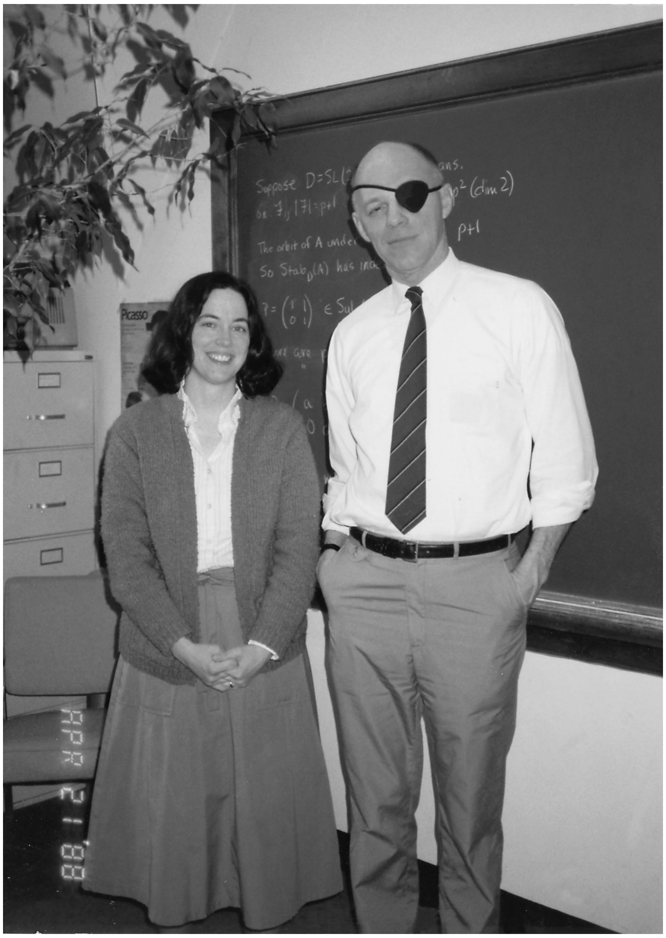
Sally at the annual Latke–Hamantash Debate.

Paul was generous with time and attention as well as with money to many people. My student Ju-Lee Kim was at the University of Illinois at Chicago from 2002 to 2007. During that time, she proved a major result about representations of p-adic groups. After complications from his diabetes necessitated a second leg amputation, Ju-Lee called him in the hospital to wish him a good recovery. The first thing he said was, "I heard the proof is right!"

Diane Herrmann

For more than thirty years I worked closely with Paul Sally. Maintaining respect for each other as colleagues and continuing to enjoy each other as friends was a remarkable gift. We worked together to sustain and improve the undergraduate program at Chicago, bringing it to a place where mathematics is the fourth most popular major on campus while upholding challenging and rigorous standards. For Paul, teaching at any level was a great joy. Whether his audience was the "pyrotechnically endowed" problem solvers in our Honors Analysis course (which he unashamedly called "Kick-Ass Mathematics"), hopeful but often mathematically less experienced middle-grade teachers, or our undergraduates, teaching mathematics was his passion. He often got sidetracked in class, going off on tangents that intrigued him, but he always pursued them with enthusiasm. I also watched and learned from him outside the classroom, as he used his knowledge of human nature to extract students' admissions of cheating (he seemed to have learned his fair share of techniques during his Jesuit high school years), to coax better spoken English out of an international graduate student trying to become a better teacher, or to say "no" to a student request, and mean it, and then have the student thank him on the way out of the office.

Diane Herrmann was associate director of undergraduate studies in mathematics at the University of Chicago from 1983 until her retirement in 2015.



Diane Herrmann and Sally

Packing Tetrahedra Problem. How many congruent regular tetrahedra, with edge length 1, can be packed inside a sphere of radius 1 if each tetrahedron has a vertex at the center of the sphere?

Despite the fact that Paul and I had different styles, we shared things that mattered to both of us. He made the department, and my job, more human. He supported me as I balanced work and home life. He came from humble origins and respected my path as a first-generation college attendee from a small liberal arts college to a place like the University of Chicago. During some of our first conversations, he was almost as interested in my backstroke times as in my mathematics background. He let me know that life outside mathematics mattered and was important. I still try to follow his advice about professional meetings: take a day and see the place you're visiting. On a particularly icy evening during an AMS meeting in the 1980s, I enjoyed an Atlanta Hawks basketball game with Paul and his thesis advisor, Ray Kunze, where Paul sang along to the Bruce Springsteen tunes played at the breaks in the game. He loved music, and it was a particular joy to have him come to concerts I sang in, whether it was the Brahms Requiem in Rockefeller Chapel or the close harmony of my barbershop quartet. When I became more interested in art, especially mathematics and needlework, he was mystified and yet supportive at once. I'm not sure he understood how I could turn away from academic mathematics, but he encouraged my new direction. As long as you were working at something you were passionate about, that's what mattered to Paul.

Paul had a strong sense of fair play and often used his position and his knowledge to benefit those who did not have the advantages that come with privilege. He knew the effectiveness of Arnold Ross's summer program for high school students and wanted to offer that same kind of deep mathematical experience to Chicago youth. He and I founded the University of Chicago Young Scholars Program (YSP) in 1988 in the hope that by starting with the best young students from Chicago public school classrooms, we could "grow our own" mathematicians. Of the hundreds of YSP students over the years, there are many mathematical success stories, including those who have earned PhDs in mathematics and those who have become lead teachers in their own Chicago public school classrooms. Paul looked forward to each eager new crop of YSP students in July, and he enjoyed their enthusiasm and antics almost as much as he delighted in their mathematical discoveries.

We often talked about our students, our teaching, our successes, and our failures. No one else I have ever known had the capacity to inspire fear and admiration, disagreement and respect all at once. His passion for mathematics and his presence in the classroom have influenced countless mathematicians, as well as lawyers, teachers, and even basketball players. In the last few weeks of his life, as we were talking about our teaching, I read him a poem that he'd first shared with me. The first stanza of Billy Collins's "Schoolsville" reads:

> Glancing over my shoulder at the past,
> I realize the number of students I have
> taught
> is enough to populate a small town.

The students of Paul's who populate his small town are lucky to have been a part of his legacy.

Raja Malyala

My first encounter with Professor Sally was during summer 1982 at a lecture for high school students enrolled in an eight-week residential summer mathematics program. He had a tall, imposing frame and a pirate-like appearance, which made him at first appear somewhat less like a mathematician than a performer on a stage. However, as I had opportunity to observe on many occasions, Professor Sally was only a performer on the surface. As you stayed with him, you realized that there was great depth to this character.

Two years later, as a senior in high school, a classmate from the summer program and I were privileged to meet

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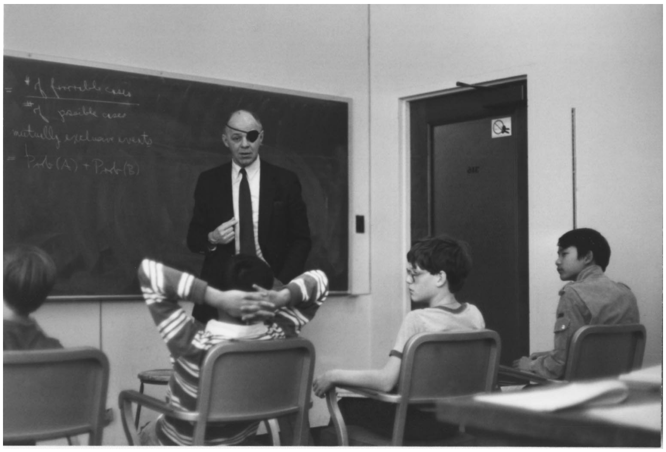

Sally instructing high school students.

> **Jim and John Problem.** John is 32. He is twice as old as Jim was when John was as old as Jim is now. How old is Jim?

for monthly two-hour problem-solving sessions at his home. Together we would solve problems from Herstein's *Topics in Algebra*, often spending an hour or more on one of the more difficult ones. He had a childlike curiosity; we would be scribbling something on paper, and he would be writing on the chalkboard, puffing his cigar and concentrating. There was absolutely no theater at all. This was the real Professor Sally, with deep curiosity and concentration. He was an extremely generous man, who tutored us for about a year without asking for any compensation, simply to attract young talent to mathematics. Professor Sally was a truly humble man who had no pretentiousness about him, and the theatrics were simply a way he was able to communicate with a wide variety of audiences, including high school students.

During my college years I did not have occasion to attend his courses, but I sat in on many of his lectures. He would start with the simplest concepts and, with a few pauses where he took some puffs from his famous pipe, would escalate slowly, leading to major theorems and explaining important concepts by unfolding them step by step, along the way challenging even the best students in the class. At the same time, he would laugh and make light of everything, which was not at all common among the faculty teaching the higher-level courses.

He was always a picture of strength and good humor and had the enthusiasm to struggle with the most difficult concepts through even the most difficult times. He realized that it is a gift not only to create great mathematics but even just to be able to understand and comprehend what the greatest mathematicians have left behind for us. His perspective undoubtedly also made him able to go on, despite his numerous health problems, as he could still find a way to feel positive. I am privileged to have known him.

Matthew Leingang

I entered the University of Chicago with the strong desire to become a mathematician but without much preparation beyond high school calculus and recreational reading. I placed into the most challenging calculus stream, Math 160s, which was the perfect course for me at the time. As director of undergraduate studies, Paul was adamant that each of the streams be serious. "We teach ε and δ in the 130s," he boasted, and to those who claimed the students in that sequence couldn't understand it he replied, "That's because you don't *expect* them to." Paul also declared that no calculus course at Chicago would use a textbook that did not prove the Mean Value Theorem. To him, the Mean Value Theorem was the most important theorem in calculus. I impart this very same wisdom to hundreds of my own students each year.

In my second year of college I took the Math 207–208–209 Honors Analysis sequence. This was my first experience with Paul in the classroom. Paul was the driving force behind 207–208–209 for decades, before and after I took it. He said that the true name of the course was "Kick-Ass Mathematics" but that the university would not let him put that in the catalog. Paul eventually wrote a textbook for the course, and the publisher likewise rejected this title, suggesting *Fundamentals of Mathematical Analysis* instead. At the beginning, it was not entirely clear whose posterior was to be kicked, ours or the mathematics'. I think he meant it both ways: in the beginning, ours were getting kicked, but, by the end, we were doing the kicking ourselves. On the first day of class, he gave the rules:

- Rule 1: Erase the boards before class begins and put them in the proper order.
- Rule 2: Minimum 25 hours per week of studying.
- Rule 3: Form study groups.
- Rule 4: Speak up in class. This is a participatory dictatorship.

He then gave us a 48-hour take-home diagnostic exam consisting of about half a dozen open-ended questions, many of which he and his wife, Judy, whom he described as "my first-class collaborator," later wrote about in one of their books.

Just as he expected the 130s students to handle εs and δs, Paul expected more from me than any other teacher ever has. He assigned homework on the fly during lecture by placing stars by various statements. In my notes, I dutifully transcribed his legend:

- One star: do it, don't turn it in.
- Two stars: do it, turn it in.
- Three stars: PhD thesis.

But he also loved us as no one else did. As most who spent any time with him soon discovered, his gruff mannerisms were an act and failed to hide his broad, warm smile. At one point in 207 I answered a question in a way he

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"Kick-Ass Mathematics" in Eckhart 206.

thought insightful. He invited me not to shake his hand nor to high-five, but just to touch his fingers.

In the spring of 1993 his diabetes claimed one of his legs, and during his recovery from the resulting surgery, class was moved temporarily to the hospital's lecture hall. (I doubt cancellation was ever considered.) The following summer I was working as a counselor in YSP when my grandfather died. My mother called the math department, and it fell upon Paul to break this news to me. I even recall seeking his advice about a relationship I was pursuing. He gave a much more colorful version of the adage that there are plenty of fish in the sea.

I was lucky enough to see Paul once or twice a year at conferences, and several years ago we were giving reports in the same session. Paul spoke after me and remarked, "By the way, Matt Leingang was my student at the University of Chicago. I taught him everything he knows." I felt he was telling me publicly, but without embarrassing me, that he was proud of me. It's a compliment that I will always remember.

Phil Kutzko

I know, I know. I am the guy who hit all the bars with him, who stayed up all night with him, telling jokes, swapping stories, smoking cigars. I am the guy who held the other foot.[7] But that is not who Paul Sally was to me. I could tell you stories, and they might make you laugh, but they would shed no light on the meaning of Paul's all-too-brief time with us. In fact, as he did for so very many other people, Paul changed the course of my life for the better, not once but many times.

I remember hearing my phone ring as I neared my office one day in my first semester at Iowa. I almost didn't get to the phone in time. I heard Paul's voice, its Boston cadence not so different from the voices I grew up with in New York, and thought, "Maybe there is a place for me in this profession." He had no obligation to reach out to me, but he did, and almost immediately he set out—as we would say today—to mentor me. I was not an easy person to mentor. I had what is called these days an "attitude." Paul's approach to this was simple. When I would express angry sentiments, he would get quiet. When my expressions of these sentiments would get louder, he would get more quiet. No one had ever treated me that way before. Then, after thinking for some time, he would break his silence to tell me that he had found my opinions "very interesting." That was it; that was all he would say. It took me a while, but eventually I came to understand that Paul could see no point in these sorts of negative utterances, that he viewed them as a luxury that people from our background could not afford. He told me once that I didn't know what it meant to have power. It was a sentiment similar to those expressed by my minority colleagues, and I didn't understand. But then, one day, Paul came out to Iowa to give a math talk, and in the room were four African-American graduate students from other fields who, it turned out, were alumni of YSP. These students had come to thank Paul for changing their lives, and I began to understand what he had been trying to tell me.

Paul Sally was a giant among men—he towered over all of us. The programs that he started have touched tens of thousands of students, many from minority backgrounds, and provided them with a path to success. His programs for K–12 teachers indirectly affect the lives of even more students.

I visited Paul in the fall of 2013, and he asked me to tell him about the work I was doing in minority graduate education. I knew better than to try to tell him how much he had affected the course of my life, how much I was in his debt, but I could see that he knew. Instead, we talked about our families and our grandkids, and he told me about his plans for the years to come, full, as always, of enthusiasm and hope. And then we told a couple of jokes and made some amusing remarks about people we knew. Just like the old days. And that was the last time I saw him.

It is hard to think that we will never see you again, Paul, but if ever a person did what he was sent here to do, it was you.

Parallelepiped Problem. Find the volume of a parallelepiped in $\mathbf{R}^n$ by dissection.

Afterword

Nothing pleased Paul more than hammering away at a good math problem. If he could engage other people in the hammering, all the better. His enthusiasm attracted a wide spectrum of students, and he taught them all—from elementary school students, to graduate students, to teachers. Moreover, Paul would teach anywhere that

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[7] *Contrary to the prize announcement* [3], *Paul's colleague was suspended, not from a hotel balcony, but near the railing, so the story that Paul told to the* Boston Globe [1] *is not completely apocryphal.*

A Modest Differentiation Problem. Let f_α denote the function that takes the value $q^{-\alpha}$ at p/q in lowest terms and is zero otherwise. Show that when $\alpha > 1$ the function f_α is discontinuous at each rational and continuous at each irrational. Moreover, for $\alpha > 2$ it is both differentiable off a set of measure zero and differentiable at each irrational algebraic number.

Sally leading a discussion around 1960.

would have him—from Dedham Junior High School, to Chicago's Juvenile Detention Center, to the University of Chicago.

When he ran out of places to teach, he created his own teaching opportunities. During the 1970s more than a thousand Chicago public high school students per year participated in his annual math competitions, and many went on to attend his subsequent enrichment classes. In the mid-1970s Arnold Ross brought his Summer Science Training Program in mathematics to Chicago and operated it for several years. Paul eventually embraced the program, taught in it most years, and, following Ross's departure, sustained it through 1982. It was a precursor to YSP, which has operated from 1988 until the present. Reflecting his lifelong love of Paris, he created a study-abroad program for faculty and upper-level students at the University of Chicago's Center in Paris; while he fully intended to teach there, he never did.

Consistent with his adage that "to teach real mathematics, you had best know some," he worked with thousands of K–12 teachers throughout his career. From 1972 to 1982 he taught pedagogy courses for Chicago high school mathematics teachers, and in 1992 he founded SESAME, a staff development program for in-service teachers from the Chicago public schools which is still flourishing and was extended to the Boston area in the early 2000s. In addition, he helped to develop the Chicago-wide Algebra Initiative, and worked extensively with the Chicago Urban Teacher Education Program.

Isometries of ℓ^p space. Show that, if $p \neq 2$, then a linear isometry of $\mathbf{R}^n$ with the ℓ^p norm must be a generalized permutation matrix.

Nineteen graduate students completed doctorates under Paul's supervision:

Ernest Thieleker, 1968
Stephen Franklin, 1971
Norman Winarsky, 1974
Charles Asmuth, 1976
Wen-Min Chao, 1977
Charles David Keys, 1979
Courtney Moen, 1979
Walter Tuvell Jr., 1981
Allen Moy, 1982
Ronald Scott, 1984
Fiona Murnaghan, 1987
David Jabon, 1989
Daniel Goldstein, 1990
Chris Jantzen, 1990
Jeffrey Adler, 1996
Stephen DeBacker, 1997
Reid Huntsinger, 1997
John Boller, 1999
Loren Spice, 2004

Indeed, a significant number of the researchers studying the (complex) representation theory of reductive p-adic groups are Paul's students. It was not uncommon for his graduate students to show up for an appointment only to find it pushed back ("come back in half an hour") so that Paul could continue working with an undergraduate visitor or anyone else who needed his help. Occasionally, "in half an hour" would become the next day, or the next week. The meeting itself might be brief and punctuated by phone calls and knocks on the office door. In spite of this, Paul was always his students' best cheerleader. He was a perceptive and empathetic listener, attentive and genuinely interested in what they had to report, especially about mathematics they had learned or their progress on research projects, and he was remarkably effective at providing the kind of encouragement that inspired students to believe in themselves and to thrive and succeed.

Following the death of Joseph Shalika, Paul wrote a description of the work that led to their seminal papers. Nothing we write can convey Paul's love of mathematics better than his own words, so we close with them.

"I was at the Institute in Autumn 1967, lecturing on p-adic SL(2), following the works of Bruhat, Gelfand–Graev, and a few others, including Shalika. Joe was at Princeton. We finally got together in early 1968 and started working. It was an incredibly exciting adventure for two non-tenured, rambunctious rookies. We soon discovered the road map for our project (Harish-Chandra, *Plancherel formula for the* 2×2 *real unimodular group*). We thought we could do it all: Characters, Plancherel Theorem, and the Fourier Transform of Elliptic Orbital Integrals. We also had the Big Guy down the hall, for regular advice and direction.

"We worked mainly in the Seminar Room in Building C, computing, shouting, and wrangling for eight to ten hours at a time. It was spring, and the days were getting longer. So after we finished work, we would walk across the golf course to Andy's Bar on Alexander Street. There, we would drink four or five beers, eat two or three cheeseburgers, revel in the day's successes, and look forward to the same effort the next day. For those who have been in the chase, there is no need to talk further about the exhilaration that accompanies this."

Zappa-dappa.

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[S9] P. J. Sally Jr. and M. H. Taibleson. (1966). Special functions on locally compact fields, *Acta Math.* **116**, 279–309. MR0206349

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As promised, we provide some hints and answers to Paul's ten favorite problems. They are listed in no particular order.

- 24.
- Bertrand's postulate isn't necessary, but the Thue–Siegel–Roth theorem is.
- At least one problem remains unsolved at the time of writing.
- At least 20.

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Call for Nominations

AWARD FOR IMPACT ON THE TEACHING AND LEARNING OF MATHEMATICS

The Award for Impact on the Teaching and Learning of Mathematics is given annually to a mathematician or group of mathematicians who have made significant contributions of lasting value to mathematics education. Priorities of the award include recognition of (a) accomplished mathematicians who have worked directly with precollege teachers to enhance teacher impact on mathematics achievement for all students or (b) sustainable and replicable contributions by mathematicians to improving the mathematics education of students in the first two years of college.

The **$1,000** award is provided through an endowment fund established by a contribution from Kenneth I. and Mary Lou Gross in honor of their daughters Laura and Karen. The AMS Committee on Education selects the recipient.

Nominations with supporting information should be submitted online to **www.ams.org/impact**.

Letters of nomination may be submitted by one or more individuals. The letter of nomination should describe the significant contributions made by the nominee(s) and provide evidence of the impact these contributions have made on the teaching and learning of mathematics. The letter of nomination should not exceed two pages and may include supporting documentation not to exceed three additional pages. A brief curriculum vitae for each nominee should also be included.

Deadline for nominations is September 15, 2018.

AMS American Mathematical Society

2018 AMS Award for Impact on the Teaching and Learning of Mathematics

Eric Stade of the University of Colorado has been named the recipient of the 2018 AMS Award for Impact on the Teaching and Learning of Mathematics.

Eric Stade

Citation

Eric Stade, professor of mathematics at the University of Colorado, is an accomplished mathematician who has not only made sustainable and replicable contributions to mathematics education for students in the first two years of college but has also worked directly with precollege teachers to enhance their impact on mathematics achievement. His outstanding contributions exemplify perfectly the priorities of the award.

Dr. Stade has published consistently over his career in top journals and has authored a textbook on Fourier analysis. Moreover, he is an outstanding teacher who has received every teaching award that his home institution offers. Most recently, he won a University of Colorado Boulder Best Should Teach Gold Award (2015), an ASSETT Award of Excellence for Technology in Teaching (2013), and the Mathematical Association of America Rocky Mountain Section's Burton W. Jones Award for Distinguished College or University Teaching of Mathematics (2006). Moreover, in 2010 he received the University of Colorado's highest teaching honor, a Lifetime designation as President's Teaching Scholar, and in 2013 he was appointed a Fellow of the International Society for Design and Development in Education (ISDDE).

However, to earn the Impact Award, an individual's impact on teaching and learning must go beyond his or her own classroom to impact his colleagues or community. Within his department, Dr. Stade worked with colleagues to transform, first, the precalculus and calculus pathways and, later, more than five courses in the undergraduate mathematics curriculum. One of these courses is described as "a lively background in calculus for non-math majors," which was developed in conjunction with colleagues from the School of Education and the biology department. A signature feature of Dr. Stade's course redesign was the addition of learning assistants, or LAs, to the course structure. LAs are talented undergraduates who interact with graduate teaching assistants in recitations to help students make the leap from passive to active learning. Dr. Stade has been recognized for his work not only in awards but also in grants totaling over US$220,000 and in invited speaker engagements nationally (e.g., MSRI) and internationally (Fukui National Institute of Technology, Japan).

To see that his work is sustainable and replicable, one need only observe that his collaborative redesign projects are not only department-wide and interdisciplinary but are also institutionalized. In fact, Dr. Stade has taken the time to found organizations on campus such as the Colorado University Boulder Center for STEM Learning. The mission of this center is to improve science, technology, engineering, and mathematics (STEM) education at the University of Colorado Boulder and to serve as a state, national, and international resource for such efforts.

Dr. Stade is also a founding member of the Mathematics Teacher Education Partnership (MTEP), an initiative of the Association of Public and Land-Grant Universities (APLU), created to coordinate research, development, and implementation efforts for secondary mathematics teacher preparation programs and to promote research and best practices in the field. This organization is at the national level, and it focuses on bringing to scale best practices in training precollege teachers.

Dr. Stade's involvement in MTEP is no surprise, as he has been active in working with precollege teachers and students. He is currently involved in a ten-year ongoing outreach project, "CMTL: A Community of Math Teachers and Learners," funded by grants from the University of Colorado Outreach Committee. With this funding, "he has

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arranged to send over a hundred University of Colorado students, most of them prospective teachers, into Boulder Valley School District classrooms." The students help with homework clubs, math clubs, math nights, tutoring, and designing active learning math lessons.

For his many sustainable and replicable contributions to mathematics and mathematics education at both the precollege and college levels, the AMS Committee on Education is delighted to award Dr. Eric Stade the AMS Award for Impact on Teaching and Learning Mathematics.

Biographical Sketch

Eric Stade received his PhD from Columbia University in 1988. From 1988 to 1990 he was John Wesley Young Research Instructor of Mathematics at Dartmouth College. In 1990 he joined the University of Colorado Boulder as assistant professor, becoming associate professor in 1996 and full professor in 2002. In 1996 he served as consulting mathematician to O.R. Technology of Boulder, providing the mathematical modeling behind their design for a high-capacity computer disk drive. From 2012 to 2016 he was consulting mathematician to the Math Learning Center in Portland, Oregon, where he helped create Common Core-ready K–5 mathematics curricular materials that emphasize conception and visual approaches. Since 2015 he has been consulting mathematician to the Nueva School in Hillsborough/San Mateo, California. He was director of the Libby Arts Residential Academic Program, leading the redesign of the curriculum, broadening the focus on visual and performing arts to a more general emphasis on creativity across academic disciplines. He is presently director of the Sewall Residential Academic Program, leading the introduction of a focus on education and on the teaching professions into the curriculum. Stade tells the *Notices*: "Many of my students call me 'Dr. Slam.' It's a nickname I got when I played drums on a Math Department rock band, and it stuck." He also owns more than one hundred pairs of sneakers.

Response

Thank you for this tremendous honor. And thanks to the COE and the AMS for supporting undergraduate education—particularly work with preservice teachers and lower-division offerings. These are the most inspiring and rewarding parts of my job, and the AMS sends a powerful message by valuing and promoting these things. Thank you again. I am humbled and deeply appreciative.

About the Award

The Award for Impact on the Teaching and Learning of Mathematics was established by the AMS Committee on Education (COE) in 2013. The US$1,000 award is given annually to a mathematician (or group of mathematicians) who has made significant contributions of lasting value to mathematics education. Priorities of the award include recognition of (a) accomplished mathematicians who have worked directly with precollege teachers to enhance teachers' impact on mathematics achievement for all students, or (b) sustainable and replicable contributions by mathematicians to improve the mathematics education of students in the first two years of college. The endowment fund that supports the award was established in 2012 by a contribution from Kenneth I. and Mary Lou Gross in honor of their daughters Laura and Karen. The award is presented by the AMS COE acting on the recommendation of a selection subcommittee. For the 2018 award, the members of the subcommittee were:

- Katherine Stevenson (chair)
- Joseph Silverman
- Ravi Vakil

Previous recipients of the Impact Award are:

2014 Paul J. Sally, Jr.
2015 W. James Lewis
2016 Michael Gage and Arnold Pizer
2017 Kristin L. Umland

—AMS Committee on Education

香港中文大學
The Chinese University of Hong Kong

Applications are invited for:-

Department of Mathematics
Research Assistant Professors
(Ref. 170002LV) (Closing date: June 30, 2018)

Founded in 1963, The Chinese University of Hong Kong (CUHK) is a forward-looking comprehensive research university with a global vision and a mission to combine tradition with modernity, and to bring together China and the West.

The Department of Mathematics in CUHK has developed a strong reputation in teaching and research. Many faculty members are internationally renowned and are recipients of prestigious awards and honours. The graduates are successful in both academia and industry. The Department is highly ranked internationally. According to the latest rankings, the Department is 51st-75th in the Academic Ranking of World Universities, 36th in the QS World University Rankings and 34th in the US News Rankings.

The Department is now inviting applications for the position of Research Assistant Professor in all areas of mathematics. Applicants should have a relevant PhD degree and good potential for research and teaching.

Appointments will initially be made on contract basis for up to three years commencing August 2018, renewable subject to mutual agreement.

Applications will be considered on a continuing basis but candidates are encouraged to apply by March 31, 2018.

Application Procedure
The University only accepts and considers applications submitted online for the posts above. For more information and to apply online, please visit http://career.cuhk.edu.hk.

Hacon and McKernan Awarded 2018 Breakthrough Prize

Christopher Hacon of the University of Utah and James McKernan of the University of California San Diego have been awarded the 2018 Breakthrough Prize "for transformational contributions to birational algebraic geometry, especially to the minimal model program in all dimensions."

Christopher Hacon

James McKernan

The prize committee summarizes their work: "'Projective spaces' are a field of algebraic geometry. They are related to the concept of perspective in art: perspective is a way of 'projecting' a 3-dimensional scene onto a 2-dimensional canvas. There are certain rules for doing this: for example, parallel lines on a 2D surface never meet; but to show the parallel lines of our 3D world—such as train tracks—on a 2D canvas, they should appear to converge on a 'vanishing point' in the distance. The human mind can only visualize 3 dimensions. But mathematicians can use algebra to explore far higher dimensions—in fact, indefinitely high. Through their collaboration, Hacon and McKernan worked out the 'rules' for projecting objects in multi-dimensional spaces onto lower-dimensional spaces."

The *Notices* thanks Antonella Grassi of the University of Pennsylvania for providing the following short description of their work: "In 2006 Hacon and McKernan, in collaboration with C. Birkar and P. Cascini, proved the finite generation of the canonical ring for a smooth variety of general type of any dimension. (A variety of general type is the higher dimensional analogue of a Riemann surface of genus $g \geq 2$.) The result is a crucial ingredient in the classification of algebraic varieties.

"In the case of curves, there is a unique smooth projective curve in each birational equivalence class, and the canonical ring is finitely generated. For surfaces, the Castelnuovo-Enriques-Kodaira classification gives minimal models; the finite generation of the canonical ring was proved by Mumford in the second half of the last century. It is in higher dimension that minimal models, canonical models, and finite generation get intertwined. The case of threefolds was solved in the 1980s, and it relies on the explicit classification of the possible singularities involved. Already in dimension four such a classification becomes highly complex.

"Hacon and McKernan's proof is a wonderful roundabout induction on the dimension of the variety, using their proof of existence of minimal models for varieties of general type.

"Since the 2006 results, many other important advances have been made, some by Hacon and McKernan, with many applications."

Biographical Sketch: Christopher Hacon

Christopher Hacon was born in Manchester, United Kingdom, and grew up in Italy. He received his PhD from the University of California Los Angeles in 1998 under the direction of Robert Lazarsfeld. He was a Wylie Assistant Professor at the University of Utah in 1998 and assistant professor at the University of California Riverside from 2000 to 2002. He joined the faculty at Utah in 2002. He says, "Salt Lake City is a mecca for math, after famed mathematician and avid mountaineer János Kollár moved there to do research." Hacon's father was a mathematician, and his first math memory dates to age eight, when he meticulously counted all the books in the house. He believes that most mathematicians are about 100 years ahead of their time because many of the proofs that they unravel are only much later usable in advancing technologies such as cryptography, computer graphics, GPS, MRIs, and others. He speculates that his and McKernan's work may someday be used in advancing string theory.

Hacon received a Clay Research Award in 2007 and has been awarded the Frank Nelson Cole Prize in Algebra (with James McKernan) in 2009, the Antonio Feltrinelli Prize in Mathematics, Mechanics, and Applications (2011), and the E. H. Moore Research Article Prize of the AMS (with James McKernan, 2016). He was an AMS Centennial Fellow in 2006–2007 and a Simons Foundation Investigator in 2012. He was an invited speaker at the International Congress of Mathematicians in 2010, was elected a Fellow of the AMS in 2012, and was elected to the American Academy of Arts and Sciences in 2017. He and his wife, Aleksandra Jovanovic-Hacon, have six children between six and eighteen years old. The family enjoys spending time together outdoors, hiking, skiing, and rock climbing.

Biographical Sketch: James McKernan

James McKernan was born in London and received his PhD in 1991 from Harvard University. He taught at the University of California Santa Barbara from 1995 to 2007 and at the Massachuetts Institute of Technology from 2007 to 2013 before joining the University of California San Diego. His father was an electrical engineer who taught calculus in the evenings at a school for working adults. He says his father encouraged him—he was quite slow but stubborn and had what they now call "grit." Of his work, McKernan says, "What I studied goes all the way back to the Greeks—who first analyzed sections of cones—and now, 2000 years later, a version of the conic sections turns up in string theory!"

McKernan has been the recipient of a Clay Research Award (2007) and the 2009 Cole Prize in Algebra (with Christopher Hacon). He was named a Simons Foundation Investigator in 2016. With Christopher Hacon, he was awarded the 2016 E. H. Moore Research Article Prize. He gave an invited lecture at the ICM in 2010. He was elected to the Royal Society of London in 2011.

About the Award

The Breakthrough Prize in Mathematics was created by Mark Zuckerberg and Yuri Milner in 2013. It recognizes major advances in the field, honors the world's best mathematicians and supports their future endeavors, and aims to communicate the excitement of mathematics to the general public. The prize is accompanied by a cash award of US$3 million. Previous winners of the Breakthrough Prizes are:

2015 Simon Donaldson, Maxim Kontsevich, Jacob Lurie, Terence Tao, and Richard Taylor
2016 Ian Agol
2017 Jean Bourgain

Naber, Viazovska, and Zhang Awarded New Horizons in Mathematics Prizes

The New Horizons in Mathematics Prizes are awarded to promising early-career researchers who have already produced important work in mathematics. The recipients this year are:

Aaron Naber of Northwestern University "for work in geometric analysis and Riemannian geometry, introducing powerful new techniques to solve outstanding problems, particularly for manifolds with Ricci curvature bounds."

Maryna Viazovska of Ecole Polytechnique Fédérale de Lausanne "for remarkable application of the theory of modular forms to the sphere packing problem in special dimensions."

Wei Zhang of the Massachusetts Institute of Technology and Columbia University and Zhiwei Yun of Yale University "for deep work on the global Gan-Gross-Prasad conjecture and their discovery of geometric interpretations for the higher derivatives of *L*-functions in the function field case."

Naber and Viazovska will receive a cash award of US$100,000 each; Yun and Zhang will share a cash award of US$100,000.

—Elaine Kehoe, from Breakthrough Prize Committee and University of Utah announcements

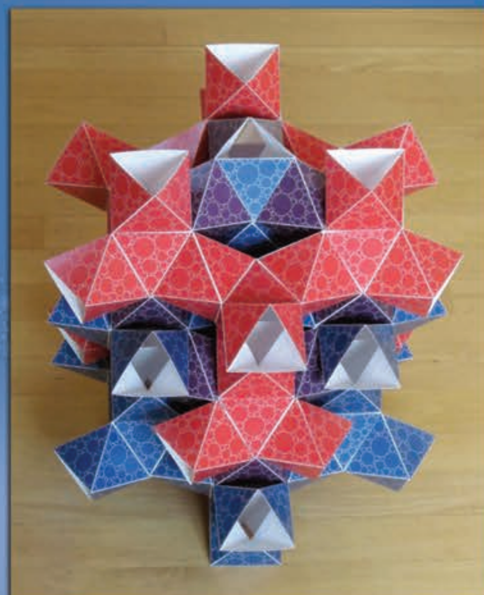
NOTE. See Henry Cohn's Conant Prize-winning cover story on Maryna Viazovska, "A Conceptual Breakthrough in Sphere Packing," in the February 2017 *Notices*. `www.ams.org/publications/journals/notices/201702/rnoti-p102.pdf`.

MATHEMATICAL IMAGERY

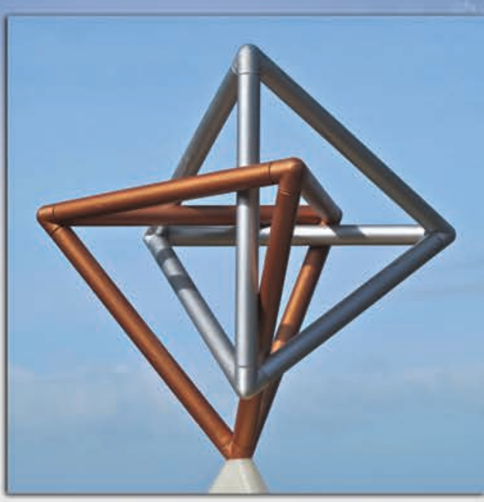
View and share hundreds of images!

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

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



"A Fractal Circle Pattern on the {3,12} Polyhedron," by Doug Dunham, *University of Minnesota - Duluth*



"Linked Tetra Frames," by Carlo Séquin, *University of California, Berkeley*

"Heighway Dragon Tiling," by Larry Riddle, *Agnes Scott College, Decatur, GA*

AMS American Mathematical Society

www.ams.org/mathimagery

Building on a Foundation of Grit: Houston's CHAMP Gives Students Tools for Success in STEM (and Life)

By Elizabeth Platt Hamblin

To Mark Tomforde, Associate Professor of Mathematics at the University of Houston, success in STEM fields is open to anyone and everyone—you just need the right mindset.

This is the basic premise underpinning the Houston-area program CHAMP, which the AMS Committee on the Profession chose as the 2018 winner of the AMS Mathematics Programs That Make a Difference Award. CHAMP, which stands for Cougars and Houston Area Math Program—"Cougars" being the University of Houston mascot—provides middle and high school students from Houston's Third Ward, Sunnyside, and East End neighborhoods with mentoring and math tutoring by volunteer undergraduates from the University of Houston (UH).

While the goals of the Program are to encourage students to graduate high school, attend college, and major in STEM fields (Science, Technology, Engineering, and Mathematics), CHAMP's approach is innovative in that it doesn't focus primarily on teaching the nuts-and-bolts of mathematics. Instead, its methods are centered around the psychology of success, emphasizing real-life applications of knowledge and building students' confidence in their ability to solve problems. At the same time, CHAMP has a significant effect on its undergraduate student volunteers, inspiring them to pursue mathematics at the graduate level and/or mathematics teaching.

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Mark Tomforde, CHAMP program director and founder (far left), with the CHAMP facilitators for this upcoming semester of programs.

Catherine Godfrey, who graduated from UH in 2017, originally planned to major in chemistry and pharmacology. A recruiting email from CHAMP aroused her interest, and she met with Tomforde to discuss a possible role for her as a volunteer. That meeting led to a change in major and a new career path.

For the first time, she realized that there were opportunities to be had in mathematics. "I was always good at math, always liked math, but I never really knew that a career in mathematics was an option," she says. Once she got involved with CHAMP, however, she was infected by the excitement of working with the math students and professors and got a sense of where her interest in math could be put to excellent use. After changing majors and completing her bachelor's degree, Godfrey is now a mathematics graduate student at the University of Nebraska (whose Mathematics Department won the 2009 AMS Award for an Exemplary Program or Achievement in a Mathematics Department).

More generally, of the 40 volunteers participating in CHAMP since its inception in 2013, 15 (9 men, 6 women) enrolled in mathematics graduate programs, and 9 more became math teachers. Of those who became math teachers, 8 are women, and 6 are members of ethnic minorities, increasing the number of greatly needed role models for younger students in groups still underrepresented in mathematics.

A Focus on Grit and Growth

The "process goals" CHAMP outlines on its website are as follows:

> We want the students in CHAMP to develop qualities that will make them more successful in academic pursuits. This includes (1) acquiring Grit, (2) cultivating a Growth Mindset, (3) developing Positive Attitudes Towards Mathematics, and (4) practicing Habits of Mind that aid in critical thinking.

Grit

The concept of grit, simply defined, is the capacity to maintain motivation and determination in the face of setbacks and obstacles. University of Pennsylvania researcher Angela Lee Duckworth and colleagues described it in 2007 as "perseverance and passion for long-term goals" and established a "grit scale" for assessing individuals' level of grit. Tomforde has used Duckworth's grit scale to evaluate the effects of the program on participants.

Tomforde and CHAMP volunteers working with high school students.

Growth Mindset

The CHAMP program takes the position espoused by Stanford professor of psychology Carol Dweck in her 2007 book, *Mindset: The New Psychology of Success*, that an individual's intelligence can be developed and expanded with effort. A "growth mindset" is one that accepts the concept that intelligence is not fixed, and is a factor contributing to students' success. Growth mindset, like grit, is a facet Tomforde has measured in participants as a way of gauging the program's impact.

Positive Attitudes Towards Mathematics

"Math is hard" is a popular meme on social media—but it's not a helpful point of focus for students struggling with math in the academic setting. So CHAMP seeks to replace that thinking with more positive foci: that math is beautiful, powerful, important in everyday life, and open to all. Hard work and making mistakes are highlighted as important tools for learning math—and greater career opportunity is one prize that comes from use of those tools.

Habits of Mind

The end goal is not to have students just be better at math—it's to have students who develop thought processes that make them successful at solving any problem, in the classroom or in real-world situations. "We want students to see math as problem-solving," Tomforde notes in a video summary of CHAMP's impacts. "So we want to get them to think critically, we want them to come up with their own methods of solving problems, we want them to find different ways of solving problems, and we want them to be able to communicate their solutions effectively."

This boils down to a key idea: *Give the students tools they can use in problem solving, and they can apply that knowledge not only to their education, but also to their daily lives*—allowing them to achieve success in whatever path they choose.

That's not to say Tomforde, the program's director and founder, wouldn't prefer to see his students enter STEM fields. The majority of students in the schools participating in CHAMP are African American or Hispanic—and both ethnicities are greatly underrepresented in the sciences and mathematics. Moreover, the area CHAMP serves is by no means an affluent community, and many students in the area's schools aren't likely to consider college as a viable option simply because their families lack financial resources.

Tomforde finds this troubling, pointing out the potential loss, not just to the individuals, but to the world: "What if the next Einstein or the next Steve Jobs or the person capable of curing cancer is born in poverty and attends an under-resourced school in inner city America? Their potential contributions will most likely be lost. It's a frightening thought, and yet surely this must be happening all the time. The fact it happens in our own communities, within miles of where we live in work, should be additionally troublesome[1]."

The Community CHAMP Serves

Houston's Third Ward community has undergone a lot of changes in recent decades. Although it was a thriving, self-sufficient center of African American community, business, and culture in the 1960s and 1970s, it declined during the 1980s as Black families, pushed out by "blockbusting" and other forms of residential discrimination, moved into integrated suburbs of Greater Houston.[2] The deterioration of the oil economy also hit the ward hard; by the early 1990s, it was one of the most dangerous neighborhoods in the city, with rampant crime, unemployment, and poverty. As recently as 2013, two sections of the Third Ward were ranked #6 and #15, respectively, on a list of the twenty-five most dangerous neighborhoods in America,[3] although it should be noted that as of 2016, both were off the list. Even so, the risk of violent crimes such as murder, assault, and robbery are considerably above the national average in the Third Ward.[4]

But the basic facts and figures about demographics in the Third Ward create a stereotypical—and woefully incomplete—picture of a high-crime, low-income city neighborhood that barely scratches the surface of the Third Ward's rich history. The roots of this community are deeply intertwined with Houston's institutions of higher learning (see sidebar 1), civil rights activism, the contributions of cultural centers like the Houston Museum of African American Culture—not to mention being the hometown of music icons ranging from blues legends like "Lightning" Hopkins and Albert Collins to R&B and pop superstar Beyoncé Knowles.[5]

The public schools in the Third Ward serve a largely Black and Hispanic student population. Although the Third Ward was originally a blue-collar neighborhood, recent demographics show that almost 65 percent of families living there now are white-collar professionals, and more than half of the residents have an undergraduate college degree or higher. In part, this transition is a result of gentrification that began in the 1990s. Gentrification is itself a problematic process for the school system, as it brings greater wealth into the district at the expense of some of its poorer residents' ability to retain their homes. Average household income has increased 64 percent since 2000, but this doesn't necessarily reflect greater opportunity in the Third Ward community itself so much as a new "commuter" population that lives in the Third Ward but works elsewhere—one that may have limited interest in the local schools' performance, as only about 20 percent of Third Ward households include children.[6] Another unfortunate outgrowth of this trend is pressure pushing long-term residents with lower incomes out of the community that they have lived in for many years.

1. Higher Education and Civil Rights Activism in Houston's Third Ward

In the decades after the Civil War, the Third Ward drew African American families searching for blue-collar jobs and a better life. Along with the characteristic shotgun houses that dominate the ward, they built churches and schools. By the early 1920s, a number of primary and secondary schools focused on educating Black children had been firmly established, as well as several colleges. One, the Colored Junior College founded in 1927, was to become Texas Southern University (TSU). As the result of a 1947 Supreme Court decision *Sweatt v. Painter* challenging the University of Texas School of Law's decision to deny entry to a Black applicant, the state of Texas created a law school for Black students on the TSU campus. The law school eventually took the name of the celebrated Supreme Court Justice Thurgood Marshall, who was the NAACP's attorney in the *Sweatt v. Painter* case.

At the same time, another university was in its infancy in Houston's Third Ward: The University of Houston began its life as a junior college in 1927, transformed over the next half-decade into a 4-year college, and ultimately moved to a larger campus to serve more students. The two segregated universities coexisted mere blocks from one another in the Third Ward.

It would be another 7 years before *Brown v. Board of Education* overturned the "separate but equal" doctrine in 1954, and another 15 years before the legalized discrimination in public education was entirely dismantled. TSU's students and faculty would take a prominent role in civil rights actions against the Jim Crow laws in Texas in the 1960s. In the meantime, TSU grew quickly from a small college with a few hundred students to a large university with a few thousand students. As of 2018, the student body at TSU is nearly 10,000 students enrolled in over 80 undergraduate, graduate, and professional degree programs. Meanwhile, the battle to fully desegregate UH during the Civil Rights era gradually transformed it into the ethnically diverse institution of higher learning it is today; in 2016–2017, the school tied for second place in the *US News & World Report* Campus Ethnic Diversity ranking with Stanford University with a diversity index of 74%.

[1] *"UH Program Helps High School Students Achieve College Dream," University of Houston,* www.youtube.com/watch?v=qd-CCQcCNMsk.

[2] *K. Duggins, "Third-Ward Rebound," Houston Press November 16, 2000.*

[3] *W. Radley, "Crime hotspots hit home: Two of the most dangerous neighborhoods in the country are in Houston."CultureMap Houston, May 1, 2013.* houston.culturemap.com/news/city-life/05-01-13-crime-hotspots-hit-home-two-of-the-most-dangerous-neighborhoods-in-the-country-are-in-houston/#slide=0.

[4] www.point2homes.com/US/Neighborhood/TX/Houston/Greater-Third-Ward-Demographics.html.

[5] *C. Feidman, "Third Ward: The epicenter of Houston's fight for racial equality," Houston Chronicle August 22, 2014.* www.houstonchronicle.com/life/article/Third-Ward-The-epicenter-of-Houston-s-fight-for-5706658.php.

[6] www.point2homes.com/US/Neighborhood/TX/Houston/Greater-Third-Ward-Demographics.html.

The Stumbling Blocks Impeding Success

In considering the educational opportunities for low-income students in the Third Ward, two facts stand out: First, the historical community environment of the Third Ward is one that values—and is willing to fight for—quality post-secondary education; and second, the resources to provide higher education are abundant and locally available for students who want to obtain a college degree. So, if educational resources are present and available, why are many students not using them?

There is no small irony in the fact that one of the key obstacles keeping many Third Ward students from having the opportunity to further their education is something that originated in an effort to ensure students' success—Texas' annual achievement tests, which go by the acronym STAAR (State of Texas Assessments of Academic Readi-ness). "The biggest obstacle to graduation is scores on the standardized tests in Texas, and it's often the math scores that are the lowest," Tomforde notes.

The STAAR testing system assesses students' readiness to progress to the next grade level, but it has not been without controversy since its initiation in the 2011-2012 school year. One point of contention was the significant increase in high-pressure tests that students must endure, estimated at four times[7] the amount of assessment in place prior to the passage of the amendment that established the STAAR testing protocol. Another: the grading system used to determine students' outcomes, where the test results count as 15 percent of a student's final grade, regardless of classroom performance.[8] The result: even students who were regularly performing well in the classroom were penalized for poor test performance, to the point at which, as early as 2014, many Texas parents were seeking to opt their children out of the testing process.[9]

One possible reason for the difficulty was that the tests were designed in such a way as to require students to exercise specific skills that are not necessarily incorporated into classroom instruction. A 2015 evaluation of the test content in the *Journal of the Effective Schools Project* noted that skills such as visualization, prediction, and inferential reasoning were embedded within the STAAR mathematics tests from fifth grade on, and that the math, science, and social studies tests all have high-level literacy skills embedded within them—meaning, a student who has less advanced reading comprehension or reasoning skills may score poorly on the test (and thus get a lower or failing grade in the subject overall) despite having the subject matter knowledge the tests seek to assess.[10] Such disconnects between students' performance in the classroom and the assessment's findings—which also impacts how a school's overall performance is rated—is discouraging to all concerned, and potentially harmful to students' ability to make progress.

This isn't, of course, a problem unique to Texas: As one Virginia high school teacher argued in a social media post that was later published by the *Washington Post*,[11] "It is also true that many students do poorly on standardized tests even though they may have achieved mastery over the material. The stress of "test anxiety" can be debilitating for many students."

Thus, the problem as encountered by Tomforde in 2012 when he took the first steps toward creating CHAMP, was that many students in Houston's Third Ward faced a complicated social and educational environment that had students struggling—including the (then) brand new STAAR testing protocol.

CHAMP's Genesis

The pivotal moment that led to Tomforde's founding CHAMP came in 2012—the year he was granted tenure by the University of Houston. He'd been aware throughout his education of the underrepresentation of women and minorities in STEM fields, and while it had been on his mind to actively try to address the problem—particularly with respect to reaching out to underserved communities like the Third Ward—time constraints imposed by the rigors of graduate school and, later, the continual need to publish and build a body of research put the idea on hold.

With tenure came a certain freedom to branch out, and Tomforde wasted little time. After doing background research to develop a strategy, he concluded that there was more value in simply "getting out there and doing it" than in seeking grants or institutional support. As he notes in the program's mission statement,

> Mathematics can be taught without expensive equipment, computers, labs, or materials. It is easy to give quality math education with very little funding, and what we do in CHAMP can also be replicated by teachers or administrators in the partnering high schools without requiring them to spend money or purchase additional resources.

And that was an important consideration for Tomforde at the outset, because when he did look for financial inputs, he found that "there wasn't a lot of support available for such a program, and what funding was there didn't seem to fit the project."

"I was more interested in action rather than doing grant admin," Tomforde adds. "My choice was to try to do it as cheaply as possible and rely on volunteers."

There's a secondary rationale to Tomforde's decision, as well. He cites research that shows unpaid volunteers are more effective at accomplishing goals than paid staff,

[7] www.tamsatx.org/uploads/3/1/6/2/3162377/2012-12-05-brief-history-of-staar.pdf.

[8] www.chron.com/news/houston-texas/article/STAAR-s-grading-system-criticized-3646465.php.

[9] www.dallasnews.com/news/news/2016/05/26/hate-the-staar-test-opting-out-is-possible-but-not-easy.

[10] *Fowler TW, Bradley KS, Bradley J, Cude K. Comparison of Process Student Expectations Across Content Area STAAR Examinations. JESP 2015;22:13-16.* www.thejesp.org/index.php/jesp/article/view/9/12.

[11] www.washingtonpost.com/news/answer-sheet/wp/2014/04/22/11-problems-created-by-the-standardized-testing-obsession/?utm_term=.d7995bfbc735.

in part because they invest more of their emotional commitment to the program when given autonomy to help decide how the program is run. Research also shows, he adds, that service learning activities tend to offer the greatest benefit to women and minority volunteers—and in CHAMP's case, the pool of volunteers consists mainly of University of Houston (UH) undergraduate students, many of whom are women and minority students. So, a volunteer-run program to help Third Ward and Sunnyside high school students develop better math skills, he reasoned, could serve double duty by encouraging UH undergrads to explore a career in STEM after graduation.

Tomforde sought out interested students and had them help with putting the program together and raising a group of committed volunteers—students who *wanted* to make a difference in the Third Ward community where the university campus is located.

Then he started approaching area schools to drum up interest—and ran into his first roadblock. "I couldn't even get a meeting or a phone conversation with anybody," Tomforde says ruefully. "No one would listen to me; [CHAMP] was something they didn't want." Finally, some of the student volunteers connected with a small charter school located near the university—called, appropriately, Hope Academy—to pilot the program.

Early Success at Hope Academy

Hope Academy was a small "second chance" charter high school serving students who were considered at risk. The initial cohort of high school students from Hope Academy numbered just fifteen, but the small numbers were intentional; keeping the program small not only allowed volunteers to spend more time one-on-one with the students, it also permitted coordination between the school and CHAMP in transporting students from their school to the university campus. And the curriculum was designed to focus on problem-solving skills, using puzzles and game-like lessons that focused on the mathematics of probability, logic, mathematical reasoning—even a unit on symmetry in poetry, and a trip to a robotics lab. All teaching materials, Tomforde notes, were collected or developed by the CHAMP staff and run in the style of math circles to introduce topics that students don't typically get in the classroom using real-world examples: everything from the number of chicken nuggets in a box from McDonald's to the probability of false positives versus false negatives in disease, exponential growth, credit card debt, interest accumulation, and similar examples.

This focus, as Tomforde details on the program's website, takes advantage of a particularly valuable aspect of mathematics: It "can also be used to teach critical reasoning, problem solving, logic, and general quantitative literacy… [it] helps students to understand how to think and how to learn, and its skills are useful and transferable to many other situations."

The partnership with Hope Academy proved successful for the first two years; students were engaged, and the lessons worked well. Resource constraints, says Tomforde, prevented them from collecting data about the students; "We were working heuristically, so this is not data based," he says, "but what we have seen is that [among] the students that we worked with, more of them are going to college than prior to being involved in CHAMP." What the program did measure, however, was the students' progress in three of the four process goals (grit, growth mindset, and attitudes toward math; see sidebar 2). The surveys showed encouraging results; students made significant progress in all areas after participating in CHAMP.

2. CHAMP uses three surveys that measure Grit, Growth, and Math Attitude. These surveys are given to each participant when they start CHAMP and then again on the last day they participate in the program. The following is a record of how the scores have changed.

Grit Score (1 = Not at all gritty, 5 = extremely gritty)
Average Before: 2.7
Average After: 3.8

Growth Score (1 = fixed mindset, 5 = growth mindset)
Average Before: 2.4
Average After: 4.1

Math Attitudes Score (answers aligning with positive attitudes)
Average Before: 62%
Average After: 84%

The surveys and their scoring metrics can be found at `www.math.uh.edu/champ/surveys.html`.

Source: Mark Tomforde, University of Houston/CHAMP

Expanding CHAMP's Reach

Within two short years, CHAMP faced a setback of its own when Hope Academy lost its accreditation in 2015 due to administrative issues; Tomforde had to seek elsewhere for partners in the Third Ward. "Through luck," Tomforde says, "I connected with [Rice University professor] Steve Cox, who had in the past run the Worthing Rice Apprentice Program (WRAP) at Rice University. He put me in touch with KIPP Sunnyside High School." It was also Cox who advised Tomforde to expand the program based on the reality that "high school is too late to reach many students, especially girls," so Tomforde went to work on reaching out to middle school students. In addition to KIPP Sunnyside High, CHAMP now serves two middle schools: KIPP Liberation College Prep Middle School and Ryan Middle School, the former a public college-prep charter school and the latter a Third Ward public school that operates in affiliation with Baylor College of Medicine.

The number of students served per school remains limited—the tutoring program, which helps students with homework and reinforces classroom skills, typically serves twenty kids from the participating high school and ten to fifteen from each middle school, Tomforde states. At every level, students are offered tutoring focused on the math section of Texas' annual STAAR exams—targeting the key obstacle to students' ability to continue on to college. For the high school students, the tutoring also assists students preparing for SAT and ACT exams, using test prep samples to help students become familiar with the types of questions included.

Middle schoolers are the focus of two special secondary programs as well. CHAMP runs a middle school math day that can vary from ten to fifty participants. The focus of the math day is to engage the participants in activities that both put mathematics into a physical context—for example, using their math skills for estimating distances on the UH campus (which, not coincidentally, allows students to gain familiarity with a college environment while ensuring they get exercise)—as well as games, such as a math scavenger hunt. CHAMP also runs a summertime "algebra boot camp" open to fifteen to twenty students transitioning into eighth grade to prepare them for algebra in the fall. The goal, says Tomforde, is to "get them mentally primed for going into algebra, get them excited about it, and teach them a few things to hit the ground running."

A group of CHAMP volunteers with local students during a "Middle School Math Day" of activities.

A Multiplier Effect

Tomforde explains that CHAMP is both self-sustaining and self-expanding. "Since we run CHAMP on a small budget and use mostly volunteer effort, the model can be replicated by almost any math department in the US." At the same time, he notes that "It's harder to do things without money." (The Program has received some funding from the MAA's Tensor-SUMMA grant program to pay for things like food and T-shirts, but for the most part it depends on donations.)

In order to help like-minded educators to more easily replicate his efforts, Tomforde has made many details of the Program, including his worksheets, available for all by posting them on the CHAMP website, `https://www.math.uh.edu/champ/index.html`.

For a large number of students, ranging from middle school through college, CHAMP has paved the way to success in further education, and in some cases careers, in mathematics and other STEM fields. The fact that so many of these students come from groups underrepresented in mathematics, makes CHAMP's results even more important. In creating CHAMP and building it into such a successful program, Mark Tomforde has demonstrated both the basic determination and the creativity in problem solving that he continues to instill in the CHAMP students.

Photo Credit

All article photos are courtesy of Mark Tomforde.

See the official AMS 2018 Mathematics Programs That Make a Difference Award citation on page 552.

Call for Nominations

The selection committees for these prizes request nominations for consideration for the 2019 awards, which will be presented at the Joint Mathematics Meetings in Baltimore, MD, in January 2019. Information about past recipients of these prizes may be found at **www.ams.org/prizes-awards**.

LEVI L. CONANT PRIZE

The Levi L. Conant Prize, first awarded in January 2001, is presented annually for an outstanding expository paper published in either the *Notices* or the *Bulletin of the American Mathematical Society* during the preceding five years.

E. H. MOORE RESEARCH ARTICLE PRIZE

This prize was established in 2002 to honor E. H. Moore's extensive contributions to the discipline and to the Society. It is awarded every three years for an outstanding article published in one of the AMS primary research journals (namely, the *Journal of the AMS*, *Proceedings of the AMS*, *Transactions of the AMS*, *Memoirs of the AMS*, *Mathematics of Computation*, *Electronic Journal of Conformal Geometry and Dynamics*, and the *Electronic Journal of Representation Theory*) during the six calendar years ending a full year before the meeting at which the prize is awarded.

OSWALD VEBLEN PRIZE IN GEOMETRY

The Oswald Veblen Prize in Geometry, which was established in 1961 in honor of Professor Veblen, is awarded every three years for a notable research work in geometry or topology that has appeared in the last six years. The work must be published in a recognized, peer-reviewed venue.

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Nominations that reflect the diversity of our profession are encouraged.

NORBERT WIENER PRIZE IN APPLIED MATHEMATICS

The Norbert Wiener Prize was established in 1967 in honor of Professor Wiener and was endowed by a fund from the Department of Mathematics at the Massachusetts Institute of Technology. The prize is awarded every three years for an outstanding contribution to applied mathematics in the highest and broadest sense and is made jointly by the American Mathematical Society and the Society for Industrial and Applied Mathematics. The recipient must be a member of one of these societies.

RUTH LYTTLE SATTER PRIZE IN MATHEMATICS

The Ruth Lyttle Satter Prize is presented every two years in recognition of an outstanding contribution to mathematics research by a woman in the previous six years.

DAVID P. ROBBINS PRIZE

The David P. Robbins Prize, established in 2005 is awarded every three years for a paper with the following characteristics: it shall report on novel research in algebra, combinatorics, or discrete mathematics and shall have a significant experimental component; it shall be on a topic which is broadly accessible and shall provide both a clear statement of the problem and clear exposition of the work.

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

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

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

The nomination period is March 1 through June 30, 2018.

AMS AMERICAN MATHEMATICAL SOCIETY

The MathCEP Programs at the University of Minnesota: A Story of Longevity, Success, and Exemplary Outreach

By Evelyn Lamb

In the late 1970s, Macalester College in St. Paul, Minnesota, started a small accelerated algebra and geometry instruction program for middle- and high-schoolers in the Minneapolis–St. Paul area. After a few years, they asked the University of Minnesota to help them expand the program to calculus, but before they could, Macalester's funding dried up. "I said, naively, 'Let's take the whole thing over,'" says Harvey Keynes, who was the associate head of the mathematics department at the University of Minnesota (UMN) at the time. After consulting with Willard Miller, then department chair, what is now known as the University of Minnesota Talented Youth Mathematics Program or UMTYMP (pronounced "um-tee-ump" by everyone involved) came to the UMN.

"We got the program started, and it was successful beyond belief," Keynes says. In the program's four decade history, it has served about 5,600 middle- and high-school students who have gone on to successful careers in math, yes, but also in other STEM (science, technology, engineering, and math) fields, as well as law, music, and business. This year, about 575 UMTYMP students in sixth through twelfth grade come to the University of Minnesota campus once a week for accelerated math classes. UMTYMP is the flagship program of the University of Minnesota's School of Mathematics Center for Educational Programming, or MathCEP, which hosts a variety of other math outreach and training programs and received the 2018 AMS Award for an Exemplary Program or Achievement in a Mathematics Department.

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Origins

Keynes was part of a cohort of faculty that came to UMN in the late 1960s, mostly from the east coast, where many of them had gone through accelerated public high school programs that had jump-started their careers. Minnesota did not have similar programs, so as faculty members' children grew up and went to school, there was strong support from the faculty to get such a program running. Keynes says the political climate at the time contributed to a post-Vietnam War slump in interest in STEM majors, so faculty were also eager to attract and work with students who were genuinely interested in math and other STEM fields. When the opportunity came, they were ready to support it.

Peter Olver, the current head of the mathematics department, says the program fits perfectly into the mission of the university. UMN is the land-grant university in Minnesota, and with that designation comes a strong feeling that the university should be dedicated to serving the needs of residents of the state. Shortly after the program was founded, the Minnesota state legislature gave it a specific line item in the state budget as a "state special" associated with the university. It is one of only two that are still in the budget.

UMN quickly saw the benefit of the program. "It wasn't the primary reason we started it, but the University of Minnesota loved the graduates," Keynes says. MIT, Stanford, Harvard, and Berkeley are among the most popular schools for UMTYMP graduates, but UMN tops the list. "These were kids who may never have considered coming to the University of Minnesota, but they liked what they saw here in UMTYMP," Keynes says.

There were some concerns early on that the program would hurt local schools, taking some of their strongest math students out of the classroom. "There was a lot of politics involved," Keynes says, in convincing schools and teachers that the program would not be a threat. "It took a lot of time to work it out, but we persisted."

The program is more or less unique in the country. The University of Minnesota has some attributes that make it particularly suited for a program like this. Many states chose to start a new university as their land-grant school, but Minnesota chose not to, so UMN is both the land-grant university and the major public university in the state. It is also in the state's largest population center; about two thirds of Minnesota's population lives in the Twin Cities metropolitan area. "You need a critical mass of students to get such a program running," says Olver. Having a large population to support the main branch of UMTYMP has allowed the school to offer the program at some of the university's other campuses as well, though the vast majority of students go through the Twin Cities program.

When Keynes was looking at retiring, the department planned on hiring a senior mathematician from outside the university to take over. Jonathan Rogness had started teaching at UMTYMP as a graduate student. "I went to a small liberal arts college, and I always thought I was headed back to a place like that after I finished my PhD," he says. But he enjoyed UMTYMP so much he stayed on as a postdoc after graduating, and his years of experience with the program made him a good fit to direct MathCEP and UMTYMP. "I always say this is the only job I would have taken at any large research university," he says. With UMTYMP and MathCEP, he gets to develop close relationships with students over the course of the program.

Former UMTYMP director Harvey Keynes (r) and current director Jonathan Rogness (l) prepare for a lesson on sphere packing.

UMTYMP Today

The first two years of UMTYMP are an accelerated trip through algebra, geometry, and precalculus, completing Minnesota state math requirements for high school graduation. Recently, the median age of students in the program has been decreasing. As the state math curriculum has moved toward emphasizing algebra earlier, more students have been academically ready for the program

Students learn about origami and mathematics in a Saturday enrichment program.

by sixth grade. "There's a little more variability with the sixth graders than the seventh or eighth graders in terms of their ability to handle such a long class," Rogness says. The entrance exam cannot test maturity, so he talks to parents before the program about what to expect and whether their kids are ready for the format of the program.

In the early days, UMTYMP met twice a week after school, but it is currently only once a week to fit more easily into student schedules. The first two years of the program are taught by local teachers, many of whom are master's students in mathematics with an emphasis in math education. Rogness relies on their expertise teaching young students. "I'm not about to start micromanaging," he says. "We hire good teachers who are enthusiastic about math and want to share that with students, and then I get out of their way."

After the first two years, UMTYMP students spend the next three years in an accelerated calculus sequence, covering single-variable calculus, multivariable calculus, and linear algebra. The final semester is a rotating course in combinatorics, number theory, or some other advanced topic. Taking these rigorous math content courses allows UMTYMP students to start their college careers with more advanced math classes and try more different things while they have a chance in college. Students who enter UMTYMP as sixth- or seventh-graders finish the program before their senior year of high school. Many of them take advanced math classes at UMN after graduating from the program.

Creating An Ideal Environment

UMTYMP's history is marked by great care to create a good environment for helping students have a positive experience as they took on challenging math courses. "They were so thoughtful about the efforts to build that program and learn at every step," says Theresa Wise, retired Chief Information Officer of Delta Airlines and the first female student to graduate from UMTYMP [See sidebar on page

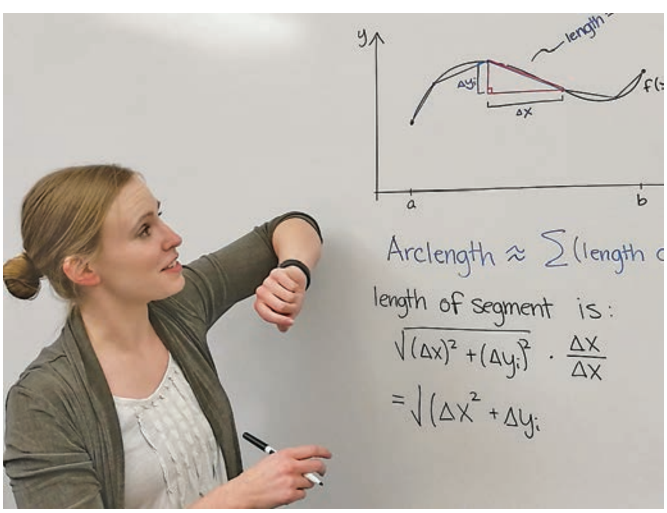
581.]. Several other girls started the program with Wise, but attrition rates, for both boys and girls, were higher at that time, and Wise was the only girl to graduate in her class. Since Wise was a student, the program has consistently worked to get a more even gender balance in the program and increase retention rates for all students.

In 1988, UMTYMP was awarded a grant from the Bush Foundation to increase the number of girls in the program and improve their experiences during the program. "A lot of things they did have become part of the overall program for everybody," Rogness says.

Today, about 35 to 40 percent of admitted students are girls. In order to keep classrooms from being dominated by boys, if there is a class that has a large gender imbalance, UMTYMP creates an all-boys section to maintain a more balanced gender ratio in the other sections so no girls will be in classes where they will feel isolated. Rogness says the practice is based on research that shows that girls feel more comfortable in classes when there is a critical mass of female students in the room.

About 35 to 40 percent of admitted students are girls.

UMTYMP also started an informal mentor network for girls, where older students are paired up with younger ones to help them when they suddenly come to a concept that really stumps them or get that first low test grade. They have a few girls-only UMTYMP events each year, with fun activities such as a screening of the movie Hidden Figures, to help girls develop friendships and supportive relationships with other girls in the program.



MathCEP postdoc and former UMTYMP student Melissa Lynn teaches calculus.

The program incorporates active learning and group work, encouraging students to see math as a cooperative endeavor. "In my normal high school life, I would downplay how much I liked math, especially as a girl" says Melissa Lynn, an UMTYMP alumna who is now a MathCEP postdoc. Group work in UMTYMP allowed her to work on math collaboratively with other students who were just as excited about math.

In addition to typical problem sets, UMTYMP calculus sequence students present some "professional" problems, often proof-based, with more thorough written explanations. "I think learning mathematical writing through that helped me go into proofs-based classes later on," Lynn says. "Seeing other students in my classes, and later as a grader, I learned that not everyone comes into higher-level math classes with the ability to write proofs like that." As an instructor who has worked with many students both in and outside of UMTYMP, she appreciates how unusual it is for young students to learn to write math well. "It's incredible how good these students are at writing math," she says.

Brooke Ullery, an UMTYMP alumna, says the program prepared her for a career in math research by teaching her how to work hard on math problems. She is currently a postdoc in mathematics at Harvard University. As a teacher, she sees that many students don't know how to work on problems that aren't the same as problems they've already seen before. "They have to learn how to think about different strategies, to do problems in a lot of different steps," she says. "That's one of the biggest leaps people have to do going into advanced math, and it's something UMTYMP forced me to do earlier on."

MathCEP

UMTYMP is the best known program of the broader MathCEP center, which offers enrichment events for students from fourth grade through high school, along with teacher training and postdoctoral positions.

Some of the most widely attended programs are the department's Saturday morning math enrichment events. Offered about once a quarter, they bring students, teachers, and families from around the area to the university for math activities led by MathCEP and UMN graduate students, postdocs, and faculty members.

One recent event focused on topology and graph theory. Students began by looking at Euler's classical Bridges of Königsberg puzzle: Was it possible to cross over all the bridges in Königsberg exactly once? Euler proved it was impossible, and after exploring the situation and figuring out why it was impossible in eighteenth-century Königsberg, students looked at an example closer to home, studying the topology of the bridges of Nicollet Island, situated in the Mississippi River a few short miles from the UMN campus in Minneapolis.

MathCEP also sponsors a Girls Excel in Math (GEM) program for 4th–6th grade girls. GEM and the Saturday morning enrichment programs originally started as a way to prepare and encourage students who might someday apply for UMTYMP, but the aim is to help students encoun-

A Girls Excel in Math student deciphers a message during a cryptography lesson.

ter interesting math in a fun environment, whether or not the students decide to focus on math as they get older.

Recently, MathCEP has offered summer camps for high school students, including a math modeling camp run jointly by the Institute for Mathematics and its Applications, also located at UMN. "For most of them, it's their first experience with a really open-ended problem," Rogness says. One year, the program opened with a challenge to design the best recycling program for a city. Students' first instinct was to start searching for a cut and dried answer on the internet. "Thirty-five minutes later they start to wonder, what does best really mean?" Rogness says. These open-ended problems, on topics from recycling to white-nose syndrome in bats to Twin Cities area bike-share programs, help students understand the importance of math modeling in everyday life.

The UMN Master of Math with an emphasis in math education program is not officially under the MathCEP umbrella, but Rogness is the faculty advisor for the program, and students in the program often teach at UMTYMP and other MathCEP activities. In the past few years, MathCEP has been able to hire postdocs as well.

Continued Growth

Mike Weimerskirch is the MathCEP Director of Educational Innovation, and since joining the department a few years ago, he has been working on easing the transition from high school to college for students in entry-level math classes. "We've got all these good things at the K–12 level with students and teachers, and then there's the master's program and the MathCEP postdocs, but there was sort of this gap at the undergraduate level," Rogness says.

Weimerskirch's first mission was to improve retention rates in introductory math courses. He overhauled the university's precalculus sequence, replacing lecture-style classes with more of an active learning approach. He has been training teachers to teach the new courses and creating a video textbook for students in the class. As the university has transitioned to the new approach, retention rates in the sequence have improved, and more students are continuing from those courses into calculus. Beyond the retention numbers, though, he sees an attitude difference in students in the active learning classrooms compared to the traditional lectures. "They're used to the fact that they have some skills to try some stuff, and it may or may not work, but they're willing to engage in mathematics," he says.

High school calculus teachers have a lot of training in education and pedagogy but sometimes little math background past calculus; college calculus teachers tend to know a lot of math beyond calculus but often have little preparation for the classroom. "I really see this as an opportunity to bring the high school community and the college community together to work on things," says Weimerskirch, who taught high school math before coming to UMN. Educators at both levels have a lot to offer each other. Weimerskirch hopes that he and his colleagues can create materials that will improve precalculus and calculus classes in both high schools and colleges.

Recently, Weimerskirch started collaborating with faculty members at several universities around the country to develop open educational resources for both precalculus and calculus classes. It started when Weimerskirch was trying to choose an online homework system for calculus classes at UMN. After finally coming to a decision, he started to get emails from colleagues at other universities about other possibilities and potential collaborations. "It just spread, and suddenly I had people from Nebraska writing to me: 'Hey, this is a great workshop. When are we doing it?' I didn't know I had volunteered to organize a nationwide workshop, but apparently I did." The group, which calls itself the Collaboration for the Advancement of Learning Calculus, or CALC, has members at about a dozen schools and has met twice so far to exchange ideas and share resources for teaching precalculus and calculus.

Lasting Impacts

With 5,600 UMTYMP alumni and even more students and teachers who have participated in other enrichment and training programs, MathCEP has a prominent place in the mathematics community, especially in Minnesota. "It's one of the great things about the University of Minnesota, and particularly the math department," Olver says.

"One of Harvey's favorite things to tell people is that 110 percent of our students earn degrees in STEM fields," Rogness says. There are enough alumni that double major in multiple STEM fields or get advanced degrees that if you take the number of STEM degrees and divide it by the number of students, you do get a number larger than one. Historically, about 28 percent of UMTYMP student major in engineering and 18 percent in math. Computer science, physics, and other STEM majors are also high on the list, though many students go into law, music, or other disciplines as well.

The students in the program are interested in math, but they are also involved in theater, music groups, and many other interests, like any group of motivated high school students. "It's nice to see these ordinary kids do extraordinary things," Keynes says.

An indication of how positive the experience is for students is the number of UMTYMP students, like Melissa Lynn, who end up coming back to teach in the program. Lynn completed UMTYMP in her junior year of high school and took an abstract algebra class at UMN during her senior year. She went to college at the University of Chicago with the intention of eventually going to graduate school to be a math professor. "I felt like I was set up to succeed there," she says. She went to UCLA for graduate school in math. "About halfway through the program, I started re-evaluating," she says. "I was more excited about the teaching activities than the research." After getting her PhD she wanted a teaching-focused job, and ideally she would be able to move back to the Twin Cities to be closer to her family. The MathCEP postdoc was a good fit for her, and she is now teaching there.

"MathCEP seems like the ideal preparation for me," Lynn says, as she looks to prepare herself for teaching-focused tenure-track jobs. During graduate school, she didn't have many opportunities to be the primary instructor in a course, and at UMN she teaches both UMTYMP and other UMN courses. "It's not a super heavy teaching load, so we can really focus on doing it well." MathCEP provides support and resources for experimenting with different teaching formats. She is currently involved in revamping the UMTYMP multivariable calculus class, replacing the current textbook with an online, interactive resource.

Outside of teaching, MathCEP postdocs have a lot of latitude in the activities they work on, from continuing their own research to participating in other outreach activities to supervising student research projects. Lynn has been especially involved in the latter, working with both UMN undergraduates and UMTYMP students on research projects in knot theory and number theory. She is also an editor for the *Minnesota Journal of Undergraduate Mathematics*, an undergraduate research journal the school recently started publishing.

Few top-tier research universities like UMN have such a strong commitments to intensive and extensive educational programming, and Olver says it's a draw for the department. MathCEP and UMTYMP make it easy for UMN faculty to plug into an already thriving, well-supported outreach program. "Whenever we're recruiting tenure track faculty, this is one of the main things I mention," Olver says.

MathCEP has had an enormous impact on math education in the Twin Cities for 40 years, and Rogness is proud of the environment the program fosters. "It's not that every single day is perfect," he says, "but there are a lot of times when you walk in, and it's just so much fun to be with all these kids who really like math."

Photo Credits

Sidebar photo courtesy of Theresa Wise.
Article photos courtesy of University of Minnesota.

See the official AMS 2018 Award for an Exemplary Program or Achievement in a Mathematics Department citation on page 550.

An UMTYMP Alumna's Flight Path

UMTYMP alumna Theresa Wise.

Theresa Wise was an eighth grade UMTYMP student in 1980, the first year the program was held at UMN. She went to public school, and no one in her family had yet graduated from college. She was a good student in her math classes and liked puzzles as a kid but didn't have any exposure to math as a creative, living subject. UMTYMP changed that. "What this opened was absolutely irreplaceable," she says. She still remembers taking the entrance exam, which tested reasoning skills and a few computational concepts but no advanced math content. She likely would not have gotten into the program if it required anything beyond typical middle school math, and she appreciates the fact that Keynes and others involved with UMTYMP thought carefully about how to find kids who would thrive in the program, whether or not they had already been accelerated in math classes.

After becoming the first girl to complete the full UMTYMP cycle (from grades 8-12), Wise went to St. Olaf College as a premed student and earned a bachelor's degree with a double major in chemistry and math. "When I got to college I wanted to try a bunch of different things, but because I had that rooting in mathematics to begin with, it was natural to continue math as I explored other things," she says. By the time she graduated, she realized that she wanted to continue in math rather than becoming a doctor. She was still interested in medicine, though, and started a PhD program in applied math at Cornell University, intending to do math modeling with medical applications. Along the way, she ended up doing an internship with Northwest Airlines and getting interested in understanding the logistical challenges of the airline industry. Her first job after graduating with a PhD was doing mathematical modeling for the airline industry, and she ended up staying in the field. Eventually she saw that the largest logistical challenges in the airline industry required more than math modeling; they also required significant advances in information technology, and she expanded her focus to include IT problems as well. She was Chief Information Officer for Delta Airlines, also responsible for Operations Research, until her retirement.

Wise sees UMTYMP as a huge factor in her future educational and career successes. "It's so hard to know how things would look without that experience," she says, but she doubts she would have ended up in a math career without it. She believes one of the reasons is that it kept her challenged and engaged. She says there are several points in the standard math course sequence where bright students can lose interest in math and related fields. The accelerated UMTYMP program can keep students from hitting those points of boredom when they are young, and by the time they're in college, they they are ready for a broader array of interesting advanced classes. "If the first college experiences with math are really fascinating experiences, that inspiration is there to keep going," she says.

Aside from the math itself, though, the program fostered good attitudes towards learning and hard work. "I think it's amazingly good for kids in middle school or high school to be in a situation in which they are academically challenged and not necessarily number one," she says. Sometimes, high-achieving students get used to the "reward" of always getting an A and are discouraged when when they get to a level where they no longer get that reward on a regular basis. "One of my only "B's" through high school or college was given to me by Harvey Keynes," Wise says. "How good to learn at that pretty young age that it's just about learning. It was a lesson about being stretched and not being afraid of being stretched."

OPINION

The PCMI Workshop for Mentors: A Weeklong Workshop on Diversity?

Angelynn R. Alvarez, Malena Español, Adel Faridani, Cynthia V. Flores, Alison Marr, Jenny McNulty, Elaine Newman, Rebecca Nugent, Alice Seneres, Martha Shott, William Y. Vélez, and Erica Walker

Note: The opinions expressed here are not necessarily those of Notices.

ABSTRACT. In what follows, the participants from the five-day workshop for mentors share their perspectives and lessons learned from the workshop. Participants and facilitators alike offer final thoughts in the form of recommendations for mathematics mentoring.

Before the workshop I wondered how one could spend an entire week talking about diversity in mathematics. During the course of the week I realized that we could actually only scratch the surface, that the topic is very complex and raises very similar questions to those that arise when thinking about overcoming prejudices and achieving equity and inclusion in society at large.

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Figure 1. Participants in the Workshop on Increasing Minority Participation in Undergraduate Mathematics at the 2017 IAS/Park City Mathematics Institute. Back row: Rafe Mazzeo (Director), Adel Faridani, Alice Seneres, Rebecca Nugent, Alison Marr, Malena Español, Angelynn Alvarez. Front row: Jenny McNulty, Cynthia Flores, Elaine Newman, William Vélez (Workshop Facilitator), Martha Shott, Erica Walker (Workshop Facilitator).

The weeklong workshop for mentors has been part of the three-week Park City Mathematics Institute (PCMI) since 2013. Facilitated by William Vélez and Erica Walker this year, the workshop had ten participants; see Figure 1.

Workshop activities included presentations, panels, and readings. In addition, participants developed action plans to address diversity and equity at their institutions and crafted letters to incoming students to attract them to the major. During its three-week duration, PCMI runs several different programs at the same time,[1] aimed at different sectors of the mathematical community. Throughout PCMI, efforts are made to establish communication between the different groups:

> During the week that our group was at PCMI, there were a couple of lunches that the conference organizers "socially engineered" to get people from the different groups to mingle. After getting my food, I sat down at the randomly assigned table and introduced myself to the others: I told them my name, my institution, and that I was a part of the Diversity workshop. Their eyes would flicker with interest. "That workshop sounds really fascinating," they'd say, or perhaps, "I really want to attend that workshop one of these years." And then, after the initial excitement, they would flounder a bit. "So...what do you all talk about in that workshop?"
>
> These introductions speak to the fact that other mathematicians are hungry for information about the challenges that underrepresented students face, and how to best support them—but as is often the case, we (as a community) often make the choice to postpone the discussion for another day in lieu of something that may "better serve our careers" at the current time (e.g., participating in a research group focused on our particular branch of mathematics).

Conversations about diversity are a rarity in mathematics departments, and often minority mathematicians may be reluctant to openly discuss their experiences in the mathematical enterprise. Several of these discussions naturally came up during our workshop.

> I, as a majority white mathematician, feel that I am inviting students in to the mathematics community when I encourage them to become mathematics majors. But some of our minority students may feel that to join the mathematics higher-education community, they will need to leave behind their home community. My minority students may not want to be "just like me"! We need to let them know that there are many diverse ways to be a mathematician.

> We learned about several examples where minority mathematicians either felt subtly excluded or felt pressure to assimilate. For example, upon entering the classroom on the first day of classes, being asked: "Are you sure you are in the right room? This is a PDE seminar." My interactions with every student will be approached with a greater degree of humility and openness.

> Many mathematicians are puzzled when the issue of diversity is brought up. "Math does not discriminate, it is black and white with no in-between," they counter. The issue isn't math, it's people. Our students are not all the same, they come to us with their own set of skills, hopes, dreams and issues—many of which are formed by our society. Do we think our society is equitable? Some students won't even get to attend college because of where they are born, regardless of their skill. How many Ramanujans might be out there? How many Dorothy Vaughans (*Hidden Figures*) have gone unrecognized and underappreciated?

> As a faculty member working with Native American students, I am cognizant of many similarities and differences. Many of our students have grown up on a reservation and have had similar issues to that of author Sherman Alexie,[2] who as a young child learned to cope with alcoholic parents. Other students have grown up in a culturally rich, family-centric supportive home. Yet both of these groups of students feel like outsiders when they attend

[1] *See* pcmi.ias.edu *for details.*

[2] *Alexie wrote, for example,* The Absolutely True Diary of a Part Time Indian (2007).

> university; they are from a different culture. What are we doing about this?
>
> Students are best served by seeing the conscious work and effort of an entire department reaching out to help them. The work to serve the students can't be marginalized or compartmentalized. Our university tenure and promotion policies must explicitly recognize the value of the intensive work involved in the outreach to underserved and under-represented minority students.

An early activity of the workshop was to create a letter of invitation to incoming students informing them of the importance of mathematics in their studies and inviting them to become mathematics majors. All participants crafted letters, though sometimes they targeted different audiences. In addition to the letters participants were asked to craft "action plans" (see Figure 2).

Figure 2. Participants drafted letters to prospective majors and crafted action plans.

> One of the most valuable components of this workshop is that I walked away with immediate action items for my university that were zero cost. The email letters we drafted for incoming students is an easy no-cost item. We also read many relevant and engaging articles related to diversity that could be used as a topic at a faculty meeting, math club, or as part of a classroom conversation. We also discussed making updates to our departmental website to have more information about our graduates, more diverse photos and videos of our current faculty and students, and clearer information about our majors. All three of these action items would help in the recruitment and retention of a more diverse undergraduate math population, yet can be done with little to no financial cost.
>
> While it is easy to think that it is not necessary to email every prospective student, because a student who is truly interested will self-identify, in truth there are many reasons a student may be hesitant to reach out or simply not even consider themselves a good match for the field. Many, many things in life are decided due to the external influence—positive or negative—of society, family, or friends. An email inviting students to consider a certain course of study is adding another voice.
>
> An invitation that focuses on missing populations may seem unnecessary, but change won't happen overnight. It will be challenging to hold the door open when you don't see someone approaching. If you are willing to be an agent of change, join a network of faculty who share your philosophy.

There is evidence that committed faculty (in particular, department chairs) with a willingness to engage and support students can result in substantial success of minority students (see, for example, [5]). But the results of diversity initiatives may take years to appear and support for these initiatives should be viewed as long-term commitments. As one participant stated:

> While we exchanged many good ideas that can be implemented quickly and will do some good right away, there are also deeper issues that appear to require the rethinking of long-held assumptions, and consistent efforts by a dedicated and growing group of people, exerted over a long period of time, in order to be resolved. This became particularly evident to me when we read and discussed the 1996 article "The Challenge of Diversity" by Etta Falconer, which examined the reasons for the persistent under-representation of African Americans, Hispanics, and Native Americans in mathematics. Falconer acknowledged that since the 1960s extraordinary efforts had been made to increase the participation of minori-

"There are deeper issues that appear to require the rethinking of longheld assumptions."

ties and women in the scientific and technical workforce, and that the advocates of this movement in the 1960s could not have imagined that after 30 years [by 1997] this massive disparity would still exist. Our group felt that it would be very interesting to see a current update of the data that Falconer presented. Our initial impression was that most likely not much has changed in the additional 20 years since the article appeared. Falconer attributed the disparity to "the existence of unfavorable conditions in American society and in the culture and actions of the mathematics community." While some of these unfavorable conditions are obvious to many, others may not be, and their recognition may require an opportunity for reflection such as this workshop provided for our group.

In the latest report of doctoral recipients [4] it was reported that 56 out of 1,901 doctorates in the mathematical sciences in 2014–2015 were minorities. That is less than 3%! After so many years of addressing diversity in this country, 4 American Indian or Alaska Native, 20 Black or African American, 26 Hispanic or Latino, and 6 Native Hawaiian or Other Pacific Islander survived the rigors of graduate education in the mathematical sciences. Graduate programs complain that there is a paucity of minority applicants. Yet we discovered that there were 3,100 bachelors degrees in mathematics awarded to minorities and it was estimated that, of these, 192 were accepted into graduate school [1]. There is no lack of interest in the minority community for mathematics but there appears to be a lack of attention to them from the mathematical sciences graduate programs.

Are we unintentionally turning off certain populations from our discipline? What are those micro-aggressions [see, for example, [2]] that lead large groups of people to turn to other disciplines? Are we reinforcing a culture that values individual efforts and not community efforts?

The title, *Workshop for Mentors*, gives importance to the interaction between instructor and student, and this topic was pervasive in our conversations throughout the week.

First, I've learned that increasing minority student representation in mathematics majors and careers requires aggressive hands-on advising and mentoring. During the PCMI, a panel of [undergraduate and] graduate students talked with us about why they persisted in studying mathematics and why they chose the particular graduate programs they did. As undergraduates, a faculty mentor encouraged them to do research projects and attend REUs or other programs in the summers. The students told us that they picked graduate programs because of the special attention of the graduate chair of that department.

I initially wondered: does it take special skills to do this kind of mentoring? We had the opportunity to have a Skype conversation with Leticia Williams at the NOAA Center for Atmospheric Sciences, and Talitha Washington of Howard University. Williams counseled us to let students know they have an ally in us, to verbalize specific things that a student does well, and to make a contract with students that includes long-term goals or even time spent on homework. I left the workshop realizing that I had to be more assertive about reaching out to students, instead of waiting for them to come to me.

"From now on I am going to be extremely proactive in reaching out to students."

Several of the mathematicians that we heard from via readings or conference calls alluded to the fact that most minority students do not take full advantage of office hours, tutoring services, etc., because they may not feel entitled to those services, and/or they may not feel comfortable in those environments. So from now on, I am going to be extremely proactive in reaching out to students, whether they are obviously struggling or not, to discuss their study habits and encourage them to seek help as often as they need.

There were issues that minority students often face when they arrive at college. As we all know, students who are not prepared for college level mathematics must take remedial or development courses. These courses can present barriers to STEM careers.

I learned that many students in underrepresented groups that were placed in developmental math might see math as a "dead end" and end up not taking more math classes. It would be constructive for faculty to send the message that such courses are not dead-end courses, and that when one takes more math in college, they start opening doors to careers.

Recommendations

1. Make action plans to promote diversity.
2. Design all mathematics classes to encourage students to “take the next math course” [3].
3. Write to students inviting them to become mathematics majors.
4. Make the mathematics major relevant to the career goals of students.
5. Improve advising and mentoring beyond standard office hours.

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Angelynn R. Alvarez earned her PhD in May 2016 from the University of Houston in Houston, Texas. Her research interests lie in the fields of differential geometry, algebraic geometry, and complex analysis. She enjoys baking, traveling, eating spicy foods, and enjoying the great outdoors of upstate NY.

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Malena Español’s research interests are in numerical analysis, numerical linear algebra, and applied and computational mathematics. Her research consists of designing and analyzing numerical methods for problems arising in materials science and image processing. When she is not doing math, she enjoys playing with her husband, Agustin, and their son Sebastian.

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Adel Faridani studied physics and applied mathematics in Germany before joining Oregon State University in 1989. His research interests include computed tomography and Shannon sampling theory.

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Cynthia V. Flores completed her PhD in PDEs at UC Santa Barbara in 2014 then joined the faculty at CSU Channel Islands, where she enjoys teaching differential equations and supervising undergraduate research. She is dedicated to continuing the efforts of her inspirational mentors in creating opportunities for diversity within the mathematics community.

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Alison Marr has been at Southwestern University since 2007 and is currently Chair of the Mathematics and Computer Science Department. She enjoys teaching mathematics at all levels including more interdisciplinary courses like her First-Year Seminar on television game shows. In her free time, she enjoys playing saxophone and traveling.

Jenny McNulty

Jenny McNulty is a combinatorist who uses her mathematical problem-solving skills in a variety of ways in her role as an academic administrator. When not at work, she enjoys the outdoors of Montana—the rivers, mountains, and ice hockey rinks.

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Elaine Newman received her PhD in probability theory from UCLA. In addition to her passion for teaching and learning mathematics and statistics, she is chapter president of her union, the California Faculty Association, at Sonoma State.

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Rebecca Nugent received her Bachelor's in Mathematics, Statistics, and Spanish from Rice University, her Master's in Statistics from Stanford University, and her PhD in Statistics from the University of Washington. Her research is primarily in clustering and classification methodology development. She is also very active in statistics and data science curriculum and program development.

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Alice Seneres earned her PhD in Mathematics Education, and her previous careers include being a mechanical engineer and teaching college mathematics. She oversees the Learning Assistant Program at Rutgers University, and her research interests are peer education and active learning.

Martha Shott

Martha Shott's primary research interests are in mathematical models of freeway traffic flow and in interdisciplinary STEM education at the undergraduate level. Outside of academia, she enjoys running, cooking plant-based meals, and playing soccer.

William Y. Vélez

William Y. Vélez is soon to be emeritus.

Erica Walker

Erica Walker earned her doctorate in education from Harvard University in 2001. The author of two books, one of which is a study of mathematicians in the United States (*Beyond Banneker: Black Mathematicians and the Paths to Excellence,* published by SUNY Press), she is fond of museums and finding mathematics in everyday and unusual spaces.

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Members of the Thomas S. Fiske Society have made a provision for the AMS in their estate plans. In 2017 the AMS was honored to receive gifts from the estates of Cathleen S. Morawetz and Franklin P. Peterson. Their legacy gifts will positively impact mathematicians for years to come.

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Photo of the Director of the AMS Office of Government Relations Karen Saxe by Kate Awtrey, Atlanta Convention Photography.
Photo of Mathematics Research Community participants courtesy of AMS staff.

This report reflects contributions received January 1, 2017, through December 31, 2017. Accuracy is important to us and we apologize for any errors. Please bring discrepancies to our attention by calling AMS Development at 401.455.4111 or emailing `development@ams.org`. Thank you.

Inside the AMS

Congressional Briefing Highlights Cryptography

Dr. Shafi Goldwasser

The American Mathematical Society (AMS) cosponsored a congressional briefing with the Mathematical Sciences Research Institute (MSRI) on December 6, 2017, in Washington, DC. The briefing presenter was Dr. Shafi Goldwasser, the RSA Professor of Electrical Engineering and Computer Science at MIT. Dr. Goldwasser took up a new post on January 1, 2018, as director of the Simons Institute for the Theory of Computing at the University of California Berkeley. The briefing, titled "Cryptography: How to Enable Privacy in a Data-Driven World," was held for members of Congress and their staff at the US Capitol. The Simons Institute made a film of Dr. Goldwasser's experience with Congress, which can be viewed at `bit.ly/2GBaL5y`.

Dr. Goldwasser's pioneering work in the field of cryptography examines how we share and receive information. In the last forty years, cryptography has shown how to use basic mathematics to enable secure electronic commerce. The enormous amount of data currently collected offers great opportunities to achieve medical breakthroughs, smart infrastructure, economic growth through consumer targeting, and surveillance for national security. This data collection, however, seems to stand in contradiction to patients' rights, consumers' privacy, unfair pricing, and the "Basic Right to be Left Alone." The question is, can mathematics and technology make it possible to maintain privacy and make progress at the same time? Dr. Goldwasser's presentation addressed how modern encryption methods, zero-knowledge proofs, and multi-party secure computation go a long way to get the best of both worlds.

House Minority Leader Nancy Pelosi and Representatives Jerry McNerney (CA) and Daniel Lipinski (IL) were on hand to give remarks and provide their support for the mathematical sciences and federal funding of basic scientific research.

In years past, the AMS has hosted an annual congressional briefing as a means to communicate information to policymakers. Speakers discuss the importance of mathematics research and present their work to Congressional staff as a way to inform members of Congress on how mathematics impacts today's important issues. In 2017, the AMS joined forces with MSRI to offer Congressional briefings twice per year.

—AMS Office of Government Relations

AMS Holds Department Chairs Workshop

The AMS holds an annual Department Chairs Workshop just prior to the Joint Mathematics Meetings. This year's workshop was held on January 9, 2018, in San Diego, California. More than forty-five department leaders from across the country participated in the workshop, which focused this year on improving students' experience; building effective internal and external partnerships; and responsibilities, duties and expectations that deans, provosts, and other chief academic officers have for their department chairs.

The workshop was led by Malcolm Adams, University of Georgia; Krista Maxson, University for Science and Arts of Oklahoma; Irina Mitrea, Temple University; and Douglas Mupasiri, University of Northern Iowa.

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

The next AMS Department Chairs Workshop will be held January 15, 2019, in Baltimore, Maryland. Information on next year's workshop will be sent to department chairs via email and published in the *Notices* in the fall.

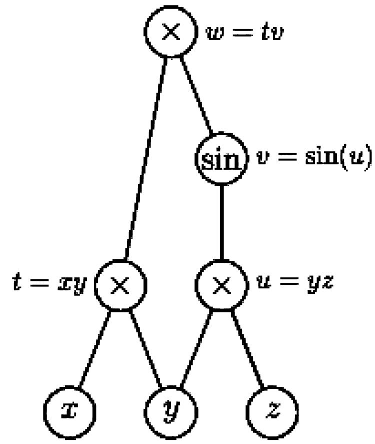
—AMS Office of Government Relations

NEWS

From the AMS Public Awareness Office

Recent Feature Columns

See some recent AMS Feature Columns—including “Jakob Bernoulli’s Zoo” by Bill Casselman, “How to Differentiate with a Computer” by David Austin (see illustration), “Regular-Faced Polyhedra: Remembering Norman Johnson” by Joe Malkevitch, and “The Early History of Calculus Problems, II” by Tony Phillips—and access others at `www.ams.org/publicoutreach/feature-column/fc-browse`.



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

Image Credits

Photo of Dr. Shafi Goldwasser courtesy of Allison O'Brien Photography.

"How to Differentiate with a Computer" illustration courtesy of David Austin.

Mathematics People

Nguyen Awarded 2018–2019 Centennial Fellowship


Toan T. Nguyen

The AMS has awarded its Centennial Fellowship for 2018–2019 to Toan T. Nguyen of Pennsylvania State University. Nguyen's research interests are analysis of partial differential equations, fluid dynamics, kinetic theory of gases, nonlinear waves, boundary layers, and weak turbulence. He will use the Fellowship for full support for the academic year 2018–2019.

Nguyen received his PhD in mathematics from Indiana University in 2009 under the direction of Kevin Zumbrun. He was a research postdoctoral fellow at the Université Pierre et Marie Curie Paris VI from 2009 to 2010 and Prager Assistant Professor at Brown University from 2010 to 2012 before joining the Penn State faculty in 2013.

Nguyen provided the following information to the *Notices*: "I grew up as a coffee farmer in a small village back in Vietnam, but it was quite natural for me to study mathematics. Indeed, mathematics is my given name at birth (Toán in Vietnamese). My parents believed math and science are the future. In fact, I also have a physics sister (Lý) and a chemistry brother (Hoá). While most of the kids in my village ended up dropping out of school due to poverty at the time, we all went on to Vietnam National University in Saigon for an undergraduate degree. I then got a well-paid and trending job at a technology company, which I actually quit after a few months, when they ordered me to stop bringing math books to work.

"I went back to the university to work as a teaching assistant, and met D. Le (UTSA), who gave me a paper to read. After I extended the work in his paper, he asked me to come to America and work with him. Two years later, I went to Indiana University for my PhD.... I ended up graduating in my third year in the program, with several postdoctoral offers from Chicago, Michigan, Brown, and the like.

"My recent work with E. Grenier (ENS Lyon) proves that, for a certain class of initial data, the classical boundary layer theory proposed by L. Prandtl in 1904 is false in describing the behavior of fluids at a very high Reynolds number near a boundary. We are currently writing a book on the subject. I also disseminate new research on my blog: 'Snapshots in Mathematics!' I believe that persistence is the key to success."

The Centennial Fellowship carries a stipend of US$93,000, a travel expense allowance of US$9,300, and a complimentary Society membership for one year. The award was made at the recommendation of the Centennial Fellows Selection Committee. The primary selection criterion is the excellence of the candidate's research.

Please note: Information about the competition for the 2019–2020 AMS Centennial Fellowships will be published in the "Mathematics Opportunities" section of an upcoming issue of the *Notices*.

—*Elaine Kehoe*

Beck Awarded Birman Fellowship


Margaret Beck

Margaret Beck of Boston University has been awarded the AMS Joan and Joseph Birman Fellowship for Women Scholars for the academic year 2018–2019 in recognition of her "exceptional research on stability problems in partial differential equations (PDEs) and spatially extended dynamical systems." Her primary research interest is determining the nonlinear stability and large-time behavior of solutions to dissipative partial differential equations, such as reaction-diffusion equations and viscous conservation laws. This includes studying nonlinear waves such as traveling waves and spatially and/or temporally periodic patterns. She typically views these PDEs as infinite-dimensional dynamical systems and analyzes them using a variety of mathematical techniques, for example, invariant manifolds, similarity variables, geometric singular perturbation theory, exponential dichotomies, and pointwise estimates. She will use the Fellowship for a full-year sabbatical and to partially fund travel to Sydney, Australia, where she will visit the University of Sydney during 2019.

Beck received her PhD from Boston University in 2006 under the direction of Tasso J. Kaper and C. Eugene Wayne. She has held postdoctoral positions at the Mathematical Sciences Research Institute, the University of Surrey, and Brown University. She became assistant professor at Boston University in 2009 and was a lecturer at Heriot-Watt University in Edinburgh, Scotland, from 2011 to 2013. Since 2015 she has been associate professor at Boston University. She held an NSF Mathematical Sciences Postdoctoral Research Fellowship from 2006 to 2009 and was selected a Sloan Research Fellow for 2012 to 2014.

The fellowship seeks to give exceptionally talented women extra research support during their mid-career years. The fellowship was established in 2017 with a generous gift from Joan and Joseph Birman. The primary selection criterion for the Birman Fellowship is the excellence of the candidate's research. The award carries a stipend of US$50,000. Joan Birman explains her decision to establish the prize with AMS as follows: "I feel that my choice to give money to the AMS rather than to some other worthy organization was the right decision. When I proposed the Satter Prize, Bill Browder (then AMS president) and others asked me thoughtful questions that led to small but important changes in its structure. The proposal for the Fellowship was similar in that excellent questions were asked by people I respect and it was shaped with the help of thoughtful colleagues. I know many good organizations, but no other where I could feel the same trust that my money will be used well for its intended purpose of helping more women mathematicians to develop their creative voices."

—Elaine Kehoe

2018 AWM Awards

The Association for Women in Mathematics (AWM) presented several awards at the Joint Mathematics Meetings in San Diego, California, in January 2018.

Lillian Pierce

Lillian Pierce of Duke University was awarded the 2018 AWM Sadosky Research Prize "in recognition of her outstanding contributions to harmonic analysis and analytic number theory." According to the prize citation, "Pierce is one of the most talented, original and visionary analysts of her generation. Her research spans and connects a broad spectrum of problems ranging from character sums in number theory to singular integral operators in Euclidean spaces. She has made far-reaching contributions to the study of discrete analogs of harmonic-analytic integral operators, taking inspiration in classical Fourier analysis, but drawing also on methods from analytic number theory such as the circle method and diophantine approximation." She received her PhD from Princeton University in 2009 and has been the recipient of a Marie Curie Fellowship, an NSF Mathematical Sciences Postdoctoral Research Fellowship, and an NSF CAREER award. She has also been awarded an Alfred P. Sloan Foundation Fellowship for 2018.

Kristin L. Umland

Kristin L. Umland of Illustrative Mathematics (IM) has been chosen to receive the 2018 Louise Hay Award for Contributions to Mathematics Education. The prize citation reads in part: "Umland's work has exemplified a passion for engaging learners in worthwhile mathematics while seeking to enhance and support their instruction. She has revamped mathematics courses for non-mathematics majors and for prospective teachers, led collaborative professional development projects for K-12 teachers in New Mexico, and investigated the impact of Math Teachers' Circles. Recently Umland has been instrumental in the development of Illustrative Mathematics, a heavily used, online mathematics resource that advances improvement in mathematics education through a rich, coherent collection of over 1,200 vetted instructional tasks, as well as assessment items, lesson plans, and professional development modules." Umland received her PhD from the University of Illinois at Chicago under the direction of Stephen D. Smith. She served on the faculty of the University of New Mexico until 2016, when she became vice president of IM Product Development. She received the AMS Award for Impact on the Teaching and Learning of Mathematics in 2017.

Erica Flapan

Erica Flapan of Pomona College is the recipient of the 2018 M. Gweneth Humphreys Award for Mentorship of Undergraduate Women in Mathematics. According to the prize citation, "Flapan's dedication to her students is exceptional, and she has received awards for teaching and advising at her home institution as well as at the national level. She has also devoted many of her summers to teaching in mathematics programs and institutes, most often at the Summer Math Program for Women at Carleton College. She has served as a mentor to more than sixty female undergraduates, many of whom have gone on to receive their doctorates and have careers in mathematics." She received her PhD from the University of Wisconsin—Madison in 1983. She was awarded the Deborah and Franklin Tepper Haimo Award of the MAA in 2011, and she is a Fellow of the AMS. Her areas of research interest are low-dimensional topology and knot theory. Flapan will become editor in chief of the *Notices of the AMS* in January 2019.

Melanie Matchett Wood of the University of Wisconsin—Madison has been awarded the 2018 AWM-Microsoft Research Prize in Algebra and Number Theory "in recognition of her exceptional research achievements in number theory and algebraic geometry." According to the prize

Melanie Matchett Wood

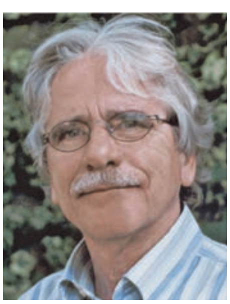
citation, "Wood has made deep and influential contributions to number theory and algebraic geometry. She excels at drawing connections between different areas of mathematics. Her work is a truly remarkable synthesis of number theory, algebraic geometry, topology, and probability." Wood received her PhD from Princeton University in 2009 under the direction of Manjul Bhargava and has held appointments at the American Institute of Mathematics, Stanford University, and the Mathematical Sciences Research Institute. She won the AMS Morgan Prize in 2004 and an NSF CAREER Award in 2017. She is a Fellow of the AMS.

—From AWM announcements

2018 MAA Awards

The Mathematical Association of America (MAA) awarded several prizes at the Joint Mathematics Meetings in San Diego, California, in January 2018.

Roland van der Veen



Jan van de Craats

Roland van der Veen of Leiden University and Jan van de Craats of the University of Amsterdam have been awarded the 2018 Beckenbach Book Prize for their book *The Riemann Hypothesis: A Million Dollar Problem* (MAA Press, 2015). According to the prize citation, the authors "take us on a remarkably compact and efficient journey from primes and their distribution to the Riemann hypothesis. Along the way we are introduced to infinite series, infinite products and complex variables and functions." Van de Craats received his PhD from Leiden University and is now professor emeritus at the University of Amsterdam. For many years he was trainer and leader of the Dutch International Mathematical Olympiad team and is "much appreciated for his skills in explaining mathematics to a general public." Van der Veen received his PhD from the University of Amsterdam in 2010. His research focuses on the interplay of low-dimensional topology, representation theory, and mathematical physics. He enjoys exploring new ways of popularizing mathematics. He also enjoys ballroom dancing; in fact, van der Veen gave a dance presentation during his PhD defense.

Daniel J. Velleman of Amherst College and the University of Vermont has been awarded the Chauvenet Prize for his article "The Fundamental Theorem of Algebra: A Visual

Daniel J. Velleman

Approach," *The Mathematical Intelligencer* **37** (2015), no. 4, in which he applies "a colorful method for visualizing a complicated assertion: that every nonconstant polynomial with complex coefficients has at least one root in the complex numbers." Velleman received his PhD from the University of Wisconsin—Madison in 1980. He is the author of *How to Prove It, Which Way Did the Bicycle Go?* (with Joe Konhauser and Stan Wagon), *Philosophies of Mathematics* (with Alexander George), and *Calculus: A Rigorous First Course*. He was the editor of the *American Mathematical Monthly* from 2007 through 2011 and is currently associate editor of the *Notices*. In his spare time, he enjoys singing and playing volleyball.

Matt Parker

Matt Parker has been awarded the Euler Book Prize for *Things to Make and Do in the Fourth Dimension* (Farrar, Straus and Giroux, 2014). The prize citation reads in part: "Parker's book takes readers on a fascinating mathematical journey that includes puzzles, paradoxes, and even 4D space monsters. … Although the unifying theme in the book is geometry, it also incorporates ideas from a variety of other fields, including number theory, graph theory, and knot theory. … With the use of witty humor and quirky hand-drawn illustrations, Parker achieves the astounding goal of bringing everyday relevance to high-level mathematical concepts in a fun and interactive way. Most importantly, the book presents the beauty and fun of mathematics in a way that attracts even the most math phobic of readers." Parker is a stand-up comedian and mathematics communicator who appears regularly on TV and online; his YouTube videos have been viewed over fifty million times. Originally trained as a high school teacher, he now visits schools around the world to talk to students about mathematics as part of the Think Maths organization he founded. Parker is also a recipient of the 2018 Joint Policy Board for Mathematics Communications Award.

David Bressoud

David Bressoud of Macalester College is the recipient of the 2018 Gung and Hu Award for Distinguished Service to Mathematics "for his prolific service to many professional mathematical societies, including the Mathematical Association of America, for his influential leadership in exploring the role of calculus in our schools and our nation, and for a laudable career that has been rich in mathematical research, mathematics education, and mathematical exposition." He is currently the director


Gary Gordon


Hortensia Soto


Ronald Taylor, Jr.

of the Conference Board of Mathematical Sciences. He received his PhD from Temple University in 1977 under Emil Grosswald.

The Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching of Mathematics were awarded to the following: GARY GORDON of Lafayette College; HORTENSIA SOTO of the University of Northern Colorado; and RONALD TAYLOR, JR. of Berry College. Gordon was recognized "for his record of exemplary mathematics teaching," including leading the Lafayette REU program and as an advocate of educational equity and inclusion. He received his PhD from the University of North Carolina in 1983. He is the faculty mentor for Lafayette's baseball team and teaches a first-year seminar on baseball.

Soto was recognized as an "innovative and caring teacher and an inspiring mentor." She was born in a sod home built by her dad in Belen del Refujio, Jalisco, Mexico. They migrated to western Nebraska, where she was raised on a farm and learned the meaning of work. She spent her summers working in the fields and thus loved when August rolled around because it meant it was time to go back to school. She enjoys practicing yoga, meditating, cooking for others, hiking in Colorado where she lives, and walking her dog Coco Butter, but her "most favorite thing" is spending time with her son, Miguel, who is a sophomore in college. Soto received her PhD from the University of Northern Colorado.

Taylor "brings a unique blend of student-centered learning, creativity, and tireless dedication that both inspires and enables" his students to pursue mathematics. He has had a nationwide effect on the teaching of mathematics through his work supporting Inquiry Based Learning instruction. He has taught at a summer camp for middle school girls and a summer math course to minority students. He also holds summer workshops for in-service teachers. He received his PhD from Bowling Green State University. He taught martial arts at Berry College and has had roles with Berry's athletic department and the local minor league baseball team, "where he has been lucky enough to be paid to sit and watch sports."

—From MAA announcements

Ball Awarded Faisal Prize


Sir John M. Ball

SIR JOHN M. BALL of the University of Oxford has been awarded the 2018 King Faisal Prize for Science for his "fundamental and groundbreaking contributions to nonlinear partial differential equations, the calculus of variations, and dynamical systems." His recent work on the Landau–de Gennes theory "has greatly stimulated the worldwide study of the mathematics of liquid crystals." Ball received his DPhil in mechanical engineering from the University of Sussex. He is Sedleian Professor of Natural Philosophy at Oxford, director of its Centre for Nonlinear Partial Differential Equations, and Fellow of Queen's College. Ball received the Theodore von Kármán Prize in 1999 with Stuart S. Antman and the Sylvester Medal in 2009. He was elected an inaugural Fellow of the AMS and a Fellow of the Royal Society of Edinburgh. He has served as president of the London Mathematical Society (1996–1998) and the International Mathematical Union (2003–2006).

—From a King Faisal Foundation announcement

Harutyunyan Awarded Emil Artin Junior Prize


Davit Harutyunyan

DAVIT HARUTYUNYAN of the University of California Santa Barbara has been awarded the 2018 Emil Artin Junior Prize in Mathematics. Harutyunyan was chosen for his paper "Gaussian Curvature as an Identifier of Shell Rigidity," *Archive for Rational Mechanics and Analysis* **226** (2017).

Established in 2001, the Emil Artin Junior Prize in Mathematics carries a cash award of US$1,000 and is presented usually every year to a student or former student of an Armenian educational institution under the age of thirty-five for outstanding contributions to algebra, geometry, topology, and number theory—the fields in which Emil Artin made major contributions. The prize committee consisted of A. Basmajian, Y. Movsisyan, and V. Pambuccian.

—Victor Pambuccian
New College, Arizona State University

2018 Sloan Fellows Announced

The Alfred P. Sloan Foundation has announced the names of the recipients of the 2018 Sloan Research Fellowships. Each year the foundation awards fellowships in the fields of mathematics, chemistry, computational and evolutionary molecular biology, computer science, economics, neuroscience, physics, and ocean sciences. Grants of US$60,000 for a two-year period are administered by each Fellow's institution. Once chosen, Fellows are free to pursue whatever lines of inquiry most interest them, and they are permitted to employ Fellowship funds in a wide variety of ways to further their research aims.

Following are the names and institutions of the 2018 awardees in the mathematical sciences.

- Jennifer Balakrishnan, Boston University
- Afonso S. Bandeira, New York University
- Tamara Broderick, Massachusetts Institute of Technology
- Joan Bruna Estrach, New York University
- Yaiza Canzani, University of North Carolina, Chapel Hill
- Melody Chan, Brown University
- Tristan Collins, Harvard University
- Marcelo Disconzi, Vanderbilt University
- Robert Haslhofer, University of Toronto, Scarborough
- Miranda Holmes-Cerfon, New York University
- Tye Lidman, North Carolina State University
- Joe Neeman, University of Texas, Austin
- Andrei Neguț, Massachusetts Institute of Technology
- Lillian Pierce, Duke University
- Arul Shankar, University of Toronto
- Stefan Steinerberger, Yale University
- Giulio Tiozzo, University of Toronto
- Thomas Walpuski, Michigan State University
- Lutz Warnke, Georgia Institute of Technology
- Yihong Wu, Yale University

—From a Sloan Foundation announcement

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Photo of Davit Harutyunyan courtesy of Davit Harutyunyan.

Mathematics Opportunities

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

*NSF Postdoctoral Research Fellowships

The National Science Foundation (NSF) awards Mathematical Sciences Postdoctoral Research Fellowships in all areas of the mathematical sciences, including applications to other disciplines. Awards are either Research Fellowships or Instructorships. The Research Fellowship provides full-time support for any eighteen academic-year months in a three-year period. The Research Instructorship provides either two academic years of full-time support or one academic year of full-time and two academic years of half-time support. The deadline for proposals is **October 17, 2018**. See www.nsf.gov/funding/pgm_summ.jsp?pims_id=5301&org=NSF.

—NSF announcement

*Research Training Groups in the Mathematical Sciences

The National Science Foundation (NSF) Research Training Groups in the Mathematical Sciences program provides funds for the training of US students and postdoctoral associates through structured research groups that include vertically integrated activities spanning the entire spectrum of educational levels from undergraduate through postdoctoral. The deadline for full proposals is **June 5, 2018**. See www.nsf.gov/funding/pgm_summ.jsp?pims_id=5732.

—NSF announcement

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.

International Mathematics Competition for University Students

The Twenty-Fifth International Mathematics Competition for University Students will be held July 22–28, 2018, at American University in Blagoevgrad, Bulgaria. Students completing their first, second, third, or fourth years of university education are eligible. See www.imc-math.org.uk.

—John Jayne, University College London

SAMSI and the Mathematical Sciences Institutes Diversity Initiative (MSIDI) Announces Modern Math Workshop Deadline

MSIDI holds a Modern Math Workshop (MMW) prior to the SACNAS National Conference each year. The 2018 MMW will be hosted by SAMSI at the Henry B. Gonzalez Convention Center, San Antonio, Texas, October 10–11, 2018. This workshop is intended to encourage undergraduates, graduate students and recent PhDs from underrepresented minority groups to pursue careers in the mathematical sciences and build research and mentoring networks.

- Funding Applications are due: **June 30, 2018**.

For details, visit: https://www.samsi.info/mmw-2018.

—Rick Scoggins
The Statistical and Applied Mathematical Science Institute

Classical Topics in Mathematics

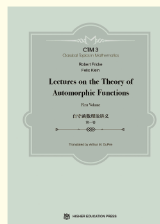
The Classical Topics in Mathematics series, published by Higher Education Press, presents classic books that have withstood the test of time, all written by leading experts.

Lectures on the Theory of Elliptic Modular Functions: First Volume

Felix Klein and **Robert Fricke**

Translated by Arthur M. DuPre.

Classical Topics in Mathematics, Volume 1; 2017; 639 pages; Hardcover; ISBN: 978-7-04-047872-3; List US$89; AMS members US$71.20; Order code CTM/1



Lectures on the Theory of Automorphic Functions: First Volume

Felix Klein and **Robert Fricke**

Translated by Arthur M. DuPre.

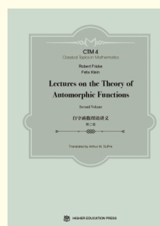
Classical Topics in Mathematics, Volume 3; 2017; 539 pages; Hardcover; ISBN: 978-7-04-047840-2; List US$89; AMS members US$71.20; Order code CTM/3

Lectures on the Theory of Elliptic Modular Functions: Second Volume

Felix Klein and **Robert Fricke**

Translated by Arthur M. DuPre.

Classical Topics in Mathematics, Volume 2; 2017; 589 pages; Hardcover; ISBN: 978-7-04-047837-2; List US$89; AMS members US$71.20; Order code CTM/2



Lectures on the Theory of Automorphic Functions: Second Volume

Felix Klein and **Robert Fricke**

Translated by Arthur M. DuPre.

Classical Topics in Mathematics, Volume 4; 2017; 563 pages; Hardcover; ISBN: 978-7-04-047839-6; List US$89; AMS members US$71.20; Order code CTM/4

The first volumes of this series consist of an annotated version of Klein's masterpiece Lectures on the icosahedron and the solution of equations of the fifth degree, and the first English translation of Klein and Fricke's four volumes on modular functions and automorphic functions. All books in the series reflect Klein's vision of the grand unity of mathematics.

The Bochner Technique in Differential Geometry

Hung-Hsi Wu, *University of California, Berkeley*

This monograph is a detailed survey of an area of differential geometry surrounding the Bochner technique.

Classical Topics in Mathematics, Volume 6; 2017; 214 pages; Hardcover; ISBN: 978-7-04-047838-9; List US$59; AMS members US$47.20; Order code CTM/6

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CHINA

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

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

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

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

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

Please send your resume to `mathjobs@tju.edu.cn`. For more information, please visit `cam.tju.edu.cn` or contact Ms. Erica Liu at `mathjobs@tju.edu.cn`, telephone: 86-22-2740-6039.

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

The 2018 rate is $3.50 per word with a minimum two-line headline. No discounts for multiple ads or the same ad in consecutive issues. For an additional $10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

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

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

Upcoming deadlines for classified advertising are as follows: June/July 2018—April 27, 2018; August 2018—June 6, 2018; September 2018—June 28, 2018; October 2018—July 27, 2018; November 2018—August 29, 2018; December 2018—September 21, 2018.

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

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photo by Kyle Newell-Groshong

2017–2018 Centennial Fellowship recipient — Shuichiro Takeda
Associate Professor of Mathematics at University of Missouri. Research interests include automorphic forms and representations of *p*-adic groups, especially from the point of view of the Langlands program

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- a. 43
- b. 50
- c. 75
- d. 106

Answer: d. 106 recipients, as of 2016.

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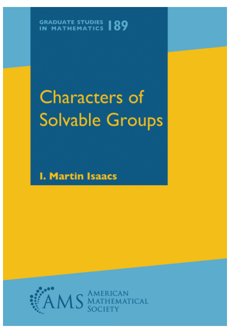
Algebra and Algebraic Geometry



Characters of Solvable Groups

I. Martin Isaacs, *University of Wisconsin, Madison, WI*

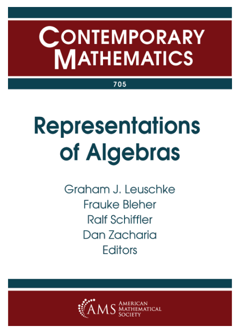
This book, which can be considered as a sequel of the author's famous book *Character Theory of Finite Groups*, concerns the character theory of finite solvable groups and other groups that have an abundance of normal subgroups. It is subdivided into three parts: π-theory, character correspondences, and M-groups. The π-theory section contains an exposition of D. Gajendragadkar's π-special characters, and it includes various extensions, generalizations, and applications of his work. The character correspondences section proves the McKay character counting conjecture and the Alperin weight conjecture for solvable groups, and it constructs a canonical McKay bijection for odd-order groups. In addition to a review of some basic material on M-groups, the third section contains an exposition of the use of symplectic modules for studying M-groups. In particular, an accessible presentation of E. C. Dade's deep results on monomial characters of odd prime-power degree is included.

Very little of this material has previously appeared in book form, and much of it is based on the author's research. By reading a clean and accessible presentation written by the leading expert in the field, researchers and graduate students will be inspired to learn and work in this area that has fascinated the author for decades.

Contents: *π-theory:* π-separable groups and character theory background; π-special characters; Partial characters; The nucleus and B_π-characters; $\mathbf{B}_\pi(G)$ and $\mathbf{I}_\pi(G)$; *Character counts and correspondences:* The Okuyama–Wajima argument; Fully ramified abelian sections; Fully ramified sections and character correspondences; *M-groups:* M-groups and monomial characters; Symplectic modules and character theory; Bibliography; Index.

Graduate Studies in Mathematics, Volume 189

May 2018, 384 pages, Hardcover, ISBN: 978-1-4704-3485-4, LC 2017047819, 2010 *Mathematics Subject Classification:* 20C15; 20C20, 20D10, 20D35, 20F16, 20F14, **AMS members US$75.20**, List US$94, Order code GSM/189



Representations of Algebras

Graham J. Leuschke, *Syracuse University, NY*, **Frauke Bleher**, *University of Iowa, Iowa City, IA*, **Ralf Schiffler**, *University of Connecticut, Storrs, CT*, and **Dan Zacharia**, *Syracuse University, NY*, Editors

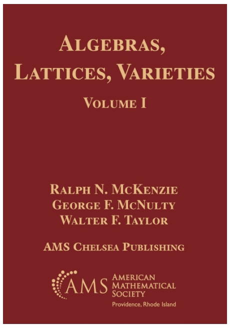
This volume contains the proceedings of the 17th Workshop and International Conference on Representations of Algebras (ICRA 2016), held from August 10–19, 2016, at Syracuse University, Syracuse, NY.

Included are three survey articles based on short courses in the areas of commutative algebraic groups, modular group representation theory, and thick tensor ideals of bounded derived categories. Other articles represent contributions to areas in and related to representation theory, such as noncommutative resolutions, twisted commutative algebras, and upper cluster algebras.

Contents: M. Brion, Commutative algebraic groups up to isogeny. II; **R.-O. Buchweitz**, **E. Faber**, and **C. Ingalls**, Noncommutative resolutions of discriminants; **J. Fei**, Polyhedral models for tensor product multiplicities; **E. L. Green** and **S. Schroll**, Special multiserial algebras, Brauer configuration algebras and more: A survey; **G. Jasso** and **J. Külshammer**, Nakayama-type phenomena in higher Auslander-Reiten theory; **R. Kinser**, K-polynomials of type A quiver orbit closures and lacing diagrams; **R. Laking**, Krull-Gabriel dimension and the Ziegler spectrum; **H. Lenzing**, On the K-theory of weighted projective curves; **M. Linckelmann**, Finite-dimensional algebras arising as blocks of finite group algebras; **C. M. Ringel**, Kronecker modules generated by modules of length 2; **S. V Sam**, Noetherian properties in representation theory; **R. Takahashi**, Thick tensor ideals of right bounded derived categories of commutative rings; **H. Thomas**, Stability, shards, and preprojective algebras; **A. Touzé**, Computations and applications of some homological constants for polynomial representations of GL_n.

Contemporary Mathematics, Volume 705

May 2018, 296 pages, Softcover, ISBN: 978-1-4704-3576-9, 2010 *Mathematics Subject Classification:* 13D09, 13F60, 14K02, 14E16, 16E10, 16G10, 16T30, 18E35, 18F30, 20G07, 20G10, 30F10, **AMS members US$93.60**, List US$117, Order code CONM/705



Algebras, Lattices, Varieties

Volume I

Ralph N. McKenzie, *Vanderbilt University, Nashville, TN*, **George F. McNulty**, *University of South Carolina, Columbia, SC*, and **Walter F. Taylor**, *University of Colorado, Boulder, CO*

This book presents the foundations of a general theory of algebras. Often called "universal algebra", this theory provides a common framework for all algebraic systems, including groups, rings, modules, fields, and lattices. Each chapter is replete with useful illustrations and exercises that solidify the reader's understanding.

The book begins by developing the main concepts and working tools of algebras and lattices, and continues with examples of classical algebraic systems like groups, semigroups, monoids, and categories. The essence of the book lies in Chapter 4, which provides not only basic concepts and results of general algebra, but also the perspectives and intuitions shared by practitioners of the field. The book finishes with a study of possible uniqueness of factorizations of an algebra into a direct product of directly indecomposable algebras.

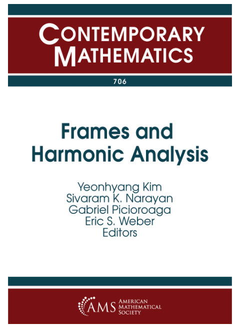
There is enough material in this text for a two semester course sequence, but a one semester course could also focus primarily on Chapter 4, with additional topics selected from throughout the text.

Contents: Basic concepts; Lattices; Unary and binary operations; Fundamental algebraic results; Unique factorization; Bibliography; Additional bibliography; List of errata; Table of notation; Index of names; Index of terms.

AMS Chelsea Publishing, Volume 383

June 2018, 368 pages, Hardcover, ISBN: 978-1-4704-4295-8, 2010 *Mathematics Subject Classification:* 08Axx, 08Bxx, 03C05, 06Bxx, 06Cxx, **AMS members US$42.40**, List US$53, Order code CHEL/383.H

Analysis



Frames and Harmonic Analysis

Yeonhyang Kim, *Central Michigan University, Mount Pleasant, MI*, **Sivaram K. Narayan**, *Central Michigan University, Mount Pleasant, MI*, **Gabriel Picioroaga**, *University of South Dakota, Vermillion, SD*, and **Eric S. Weber**, *Iowa State University, Ames, IA*, Editors

This volume contains the proceedings of the AMS Special Sessions on Frames, Wavelets and Gabor Systems and Frames, Harmonic Analysis, and Operator Theory, held from April 16–17, 2016, at North Dakota State University in Fargo, North Dakota.

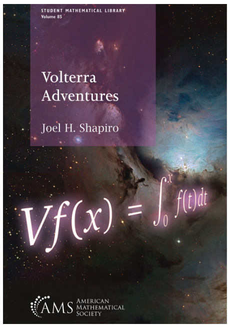
The papers appearing in this volume cover frame theory and applications in three specific contexts: frame constructions and applications, Fourier and harmonic analysis, and wavelet theory.

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

Contents: **P. G. Casazza**, **J. Cahill**, **J. I. Haas**, and **J. C. Tremain**, Constructions of biangular tight frames and their relationships with equiangular tight frames; **S. Botelho-Andrade**, **P. G. Casazza**, **D. Cheng**, **J. Haas**, **T. T. Tran**, **J. C. Tremain**, and **Z. Xu**, Phase retrieval by hyperplanes; **D. Ellis**, **E. Hayashi**, and **S. Li**, Tight and full spark Chebyshev frames with real entries and worst-case coherence analysis; **R. Aceska**, **J.-L. Bouchot**, and **S. Li**, Fusion frames and distributed sparsity; **M. Bownik**, The Kadison-Singer problem; **A. G. Baskakov** and **I. A. Krishtal**, Spectral properties of an operator polynomial with coefficients in a Banach algebra; **X. Chen**, Kaczmarz algorithm, row action methods, and statistical learning algorithms; **R. Balan**, **M. Singh**, and **D. Zou**, Lipschitz properties for deep convolutional networks; **M. Begué** and **K. A. Okoudjou**, Invertibility of graph translation and support of Laplacian Fiedler vectors; **J.-P. Gabardo**, Weighted convolution inequalities and Beurling density; **L. De Carli** and **P. Vellucci**, p-Riesz bases in quasi shift invariant spaces; **D. E. Dutkay** and **I. Kraus**, On spectral sets of integers; **I. Long**, Spectral fractal measures associated to IFS's consisting of three contraction mappings; **J. E. Herr**, **P. E. T. Jorgensen**, and **E. S. Weber**, A matrix characterization of boundary representations of positive matrices in the Hardy space; **M. Mohammad** and **E.-B. Lin**, Gibbs effects using Daubechies and Coiflet tight framelet systems; **Y. H. Kim**, Conditions on shape preserving of stationary polynomial reproducing subdivision schemes; **D. Alpay**, **P. E. T. Jorgensen**, and **I. Lewkowicz**, W-Markov measures, transfer operators, wavelets and multiresolutions.

Contemporary Mathematics, Volume 706

May 2018, 360 pages, Softcover, ISBN: 978-1-4704-3619-3, LC 2017044766, 2010 *Mathematics Subject Classification:* 15Axx, 41Axx, 42Axx, 42Cxx, 43Axx, 46Cxx, 47Axx, 94Axx, **AMS members US$93.60**, List US$117, Order code CONM/706



Volterra Adventures

Joel H. Shapiro, *Portland State University, OR*

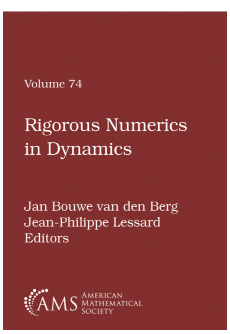
This book introduces functional analysis to undergraduate mathematics students who possess a basic background in analysis and linear algebra. By studying how the Volterra operator acts on vector spaces of continuous functions, its readers will sharpen their skills, reinterpret what they already know, and learn fundamental Banach-space techniques—all in the pursuit of two celebrated results: the Titchmarsh Convolution Theorem and the Volterra Invariant Subspace Theorem. Exercises throughout the text enhance the material and facilitate interactive study.

Contents: *From Volterra to Banach:* Starting out; Springing ahead; Springing higher; Operators as points; *Travels with Titchmarsh:* The Titchmarsh convolution theorem; Titchmarsh finale; *Invariance through duality:* Invariant subspaces; Digging into duality; Rendezvous with Riez; V-invariance: Finale; Uniform convergence; ℂomplex primer; Uniform approximation by polynomials; Riemann-Stieltjes primer; Bibliography; Index.

Student Mathematical Library, Volume 85

May 2018, 248 pages, Softcover, ISBN: 978-1-4704-4116-6, 2010 *Mathematics Subject Classification:* 46-01, 45-01, **All Individuals US$41.60**, List US$52, Institutional member US$41.60, Order code STML/85

Applications



Rigorous Numerics in Dynamics

Jan Bouwe van den Berg, *VU Universiteit Amsterdam, The Netherlands*, and **Jean-Philippe Lessard**, *McGill University, Montreal, Quebec, Canada*, Editors

This volume is based on lectures delivered at the 2016 AMS Short Course "Rigorous Numerics in Dynamics", held January 4–5, 2016, in Seattle, Washington.

Nonlinear dynamics shapes the world around us, from the harmonious movements of celestial bodies, via the swirling motions in fluid flows, to the complicated biochemistry in the living cell. Mathematically these phenomena are modeled by nonlinear dynamical systems, in the form of ODEs, PDEs and delay equations. The presence of nonlinearities complicates the analysis, and the difficulties are even greater for PDEs and delay equations, which are naturally defined on infinite dimensional function spaces. With the availability of powerful computers and sophisticated software, numerical simulations have quickly become the primary tool to study the models. However, while the pace of progress increases, one may ask: just how reliable are our computations? Even for finite dimensional ODEs, this question naturally arises if the system under study is chaotic, as small differences in initial conditions (such as those due to rounding errors in numerical computations) yield wildly diverging outcomes. These issues have motivated the development of the field of rigorous numerics in dynamics, which draws inspiration from ideas in scientific computing, numerical analysis and approximation theory.

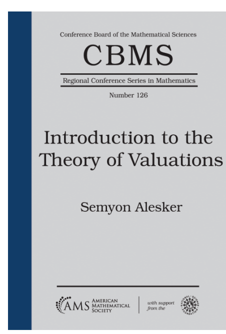
The articles included in this volume present novel techniques for the rigorous study of the dynamics of maps via the Conley-index theory; periodic orbits of delay differential equations via continuation methods; invariant manifolds and connecting orbits; the dynamics of models with unknown nonlinearities; and bifurcations diagrams.

Contents: **J. B. van den Berg**, Introduction to rigorous numerics in dynamics: General functional analytic setup and an example that forces chaos; **J. D. Mireles James**, Validated numerics for equilibria of analytic vector fields; Invariant manifolds and connecting orbits; **J.-P. Lessard**, Continuation of solutions and studying delay differential equations via rigorous numerics; **T. Wanner**, Computer-assisted bifurcation diagram validation and applications in materials science; **S. Day**, Dynamics and chaos for maps and the Conley index; **K. Mischaikow**, Rigorous computational dynamics in the context of unknown nonlinearities.

Proceedings of Symposia in Applied Mathematics, Volume 74

June 2018, 224 pages, Hardcover, ISBN: 978-1-4704-2814-3, 2010 *Mathematics Subject Classification:* 37M99, 65G99, 37B30, 65L99, 35B32, 65N25, 34K13, **AMS members US$88**, List US$110, Order code PSAPM/74

Geometry and Topology



Introduction to the Theory of Valuations

Semyon Alesker, *Tel Aviv University, Israel*

Theory of valuations on convex sets is a classical part of convex geometry which goes back at least to the positive solution of the third Hilbert problem by M. Dehn in 1900. Since then the theory has undergone a multifaceted development. The author discusses some of Hadwiger's results on valuations on convex compact sets that are continuous in the Hausdorff metric. The book also discusses the Klain-Schneider theorem as well as the proof of McMullen's conjecture, which led subsequently to many further applications and advances in the theory. The last section gives an overview of more recent developments in the theory of translation-invariant continuous valuations, some of which turn out to be useful in integral geometry.

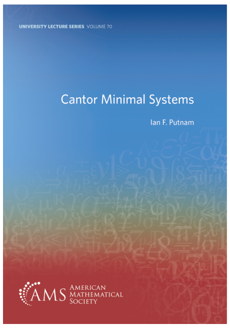
This book grew out of lectures that were given in August 2015 at Kent State University in the framework of the NSF CBMS conference "Introduction to the Theory of Valuations on Convex Sets". Only a basic background in general convexity is assumed.

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

Contents: Basic definitions and examples; McMullen's decomposition theorem; Valuations on the line; McMullen's description of $(n-1)$-homogeneous valuations; The Klain-Schneider characterization of simple valuations; Digression on the theory of generalized functions on manifolds; The Goodey-Weil imbedding; Digression on vector bundles; The irreducibility theorem; Further developments; Bibliography.

CBMS Regional Conference Series in Mathematics, Number 126

June 2018, 88 pages, Softcover, ISBN: 978-1-4704-4359-7, 2010 *Mathematics Subject Classification:* 52B45, 52A39, **AMS members US$41.60**, List US$52, Order code CBMS/126



Cantor Minimal Systems

Ian F. Putnam, *University of Victoria, BC, Canada*

Within the subject of topological dynamics, there has been considerable recent interest in systems where the underlying topological space is a Cantor set. Such systems have an inherently combinatorial nature, and seminal ideas of Anatoly Vershik allowed for a combinatorial model, called the Bratteli-Vershik model, for such systems with no non-trivial closed invariant subsets. This model led to a construction of an ordered abelian group which is an algebraic invariant of the system providing a complete classification of such systems up to orbit equivalence.

The goal of this book is to give a statement of this classification result and to develop ideas and techniques leading to it. Rather than being a comprehensive treatment of the area, this book is aimed at students and researchers trying to learn about some surprising connections between dynamics and algebra. The only background material needed is a basic course in group theory and a basic course in general topology.

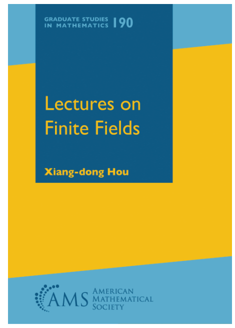
This item will also be of interest to those working in analysis.

Contents: An example: A tale of two equivalence relations; Basics: Cantor sets and orbit equivalence; Bratteli diagrams: Generalizing the example; The Bratteli-Vershik model: Generalizing the example; The Bratteli-Vershik model: Completeness; Étale equivalence relations: Unifying the examples; The D invariant; The Effros-Handelman-Shen theorem; The Bratteli-Elliott-Krieger theorem; Strong orbit equivalence; The D_m invariant; The absorption theorem; The classification of AF-equivalence relations; The classification of $\mathbb{Z}$-actions; Examples; Bibliography; Index of terminology; Index of notation.

University Lecture Series, Volume 70

June 2018, 184 pages, Softcover, ISBN: 978-1-4704-4115-9, 2010 *Mathematics Subject Classification:* 37B05, 20F60, **AMS members US$35.20**, List US$44, Order code ULECT/70

Number Theory



Lectures on Finite Fields

Xiang-dong Hou, *University of South Florida, Tampa, FL*

The theory of finite fields encompasses algebra, combinatorics, and number theory and has furnished widespread applications in other areas of mathematics and computer science. This book is a collection of selected topics in the theory of finite fields and related areas. The topics include basic facts about finite fields, polynomials over finite fields, Gauss sums, algebraic number theory and cyclotomic fields, zeros of polynomials over finite fields, and classical groups over finite fields. The book is mostly self-contained, and the material covered is accessible to readers with the knowledge of graduate algebra; the only exception is a section on function fields. Each chapter is supplied with a set of exercises. The book can be adopted as a text for a second year graduate course or used as a reference by researchers.

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

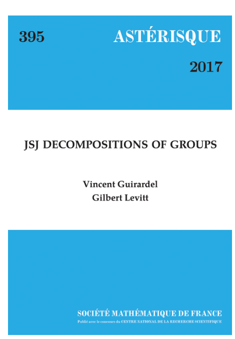
Contents: Polynomials over finite fields; Gauss sums; Algebraic number theory; Zeros of polynomials over finite fields; Classical groups; Bibliography; List of notation; Index.

Graduate Studies in Mathematics, Volume 190

July 2018, 240 pages, Hardcover, ISBN: 978-1-4704-4289-7, 2010 *Mathematics Subject Classification:* 11-01, 11Exx, 11Rxx, 11Txx, **AMS members US$66.40**, List US$83, Order code GSM/190

New AMS-Distributed Publications

Algebra and Algebraic Geometry



JSJ Decompositions of Groups

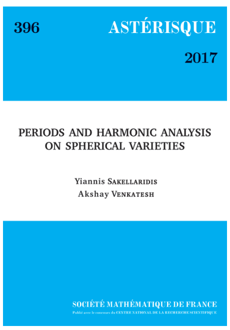
Vincent Guirardel, *Université de Rennes 1, France*, and **Gilbert Levitt**, *Université de Rennes 1, France*

JSJ decompositions of finitely generated groups are a fundamental tool in geometric group theory, encoding all splittings of a group over a given class of subgroups. The authors give a unified account of this theory with complete proofs and many examples. They introduce a simple and general definition of JSJ decompositions, the natural object being a deformation space of actions on trees, similar to outer space. In many cases of interest, this deformation space contains a canonical JSJ tree, which is invariant under automorphisms.

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 395

January 2018, 165 pages, Softcover, ISBN: 978-2-85629-870-1, 2010 *Mathematics Subject Classification:* 20E08, 20E34, 20F65, 20F67, 57M07, 20E06, **AMS members US$48**, List US$60, Order code AST/395



Periods and Harmonic Analysis on Spherical Varieties

Yiannis Sakellaridis, *Rutgers University, Newark, NJ*, and **Akshay Venkatesh**, *Stanford University, CA*

This volume elaborates the idea that harmonic analysis on a spherical variety X is intimately connected to the Langlands program. In the local setting, the key conjecture is that the spectral decomposition of $L^2(X)$ is controlled by a dual group attached to X. Guided by this, the authors develop a Plancherel formula for $L^2(X)$, formulated in terms of simpler spherical varieties which model the geometry of X at infinity. This local study is then related to global conjectures—namely, conjectures about period integrals of automorphic forms over spherical subgroups.

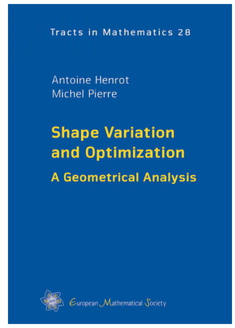
This item will also be of interest to those working in number theory.

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 396

February 2018, 360 pages, Softcover, ISBN: 978-2-85629-871-8, 2010 *Mathematics Subject Classification:* 22E50; 11F70, **AMS members US$72**, List US$90, Order code AST/396

Analysis



Shape Variation and Optimization

A Geometrical Analysis

Antoine Henrot, *Université de Lorraine, Vandoeuvre-lès-Nancy, France*, and **Michel Pierre**, *ENS Cachan Bretagne, Bruz, France*

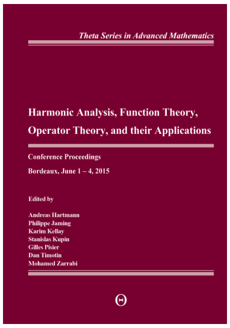
Optimizing the shape of an object to make it the most efficient, resistant, streamlined, lightest, noiseless, stealthy or the cheapest is clearly a very old task. But the recent explosion of modeling and scientific computing has given this topic new life. Many new and interesting questions have been asked. A mathematical topic was born—shape optimization (or optimum design).

This book provides a self-contained introduction to modern mathematical approaches to shape optimization. The book assumes only an undergraduate-level understanding of the subject matter but tackles open questions in this vibrant field. The analytical and geometrical tools and methods for the study of shapes are developed. In particular, the text presents a systematic treatment of shape variations and optimization associated with the Laplace operator and the classical capacity. Emphasis is also put on differentiation with respect to domains and a FAQ on the usual topologies of domains is provided. The book ends with geometrical properties of optimal shapes, including the case where they do not exist.

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

EMS Tracts in Mathematics, Volume 28

March 2018, 379 pages, Hardcover, ISBN: 978-3-03719-178-1, 2010 *Mathematics Subject Classification:* 49Q10, 49Q05, 49Q12, 49K20, 49K40, 53A10, 35R35, 35J20, 58E25, 31B15, 65K10, 93B27, 74P20, 74P15, 74G65, 76M30, **AMS members US$67.20**, List US$84, Order code EMSTM/28



Harmonic Analysis, Function Theory, Operator Theory, and Their Applications

Conference Proceedings, Bordeaux, June 1-4, 2015

Philippe Jaming, **Andreas Hartmann**, **Karim Kellay**, **Stanislas Kupin**, *University of Bordeaux, France*, **Gilles Pisier**, *Université Pierre et Marie Curie, Paris, France, and Texas A & M University, College Station, TX*, and **Dan Timotin**, *Romanian Academy, Institute of Mathematics, Bucharest, Romania*, Editors

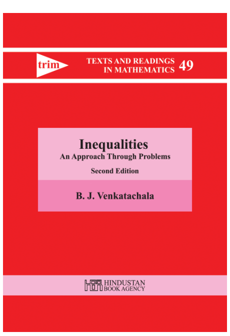
The volume contains the proceedings of an international conference in honor of Jean Esterle, held from June 1–4, 2015, in Bordeaux. Most of the papers present original work in harmonic analysis, function theory, operator theory, and their applications; others review known results and put them in a new perspective.

Among the subjects covered are: operators on spaces of holomorphic functions; Hankel and Toeplitz operators; Carleson measures for various spaces; spectral problems for differential operators; geometry of Banach spaces; linear dynamics; interpolation of functions; idempotents in Banach algebras; and magnetic distributions on thin plates.

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

International Book Series of Mathematical Texts

February 2018, 267 pages, Hardcover, ISBN: 978-606-8443-08-9, 2010 *Mathematics Subject Classification:* 00B25, 30-06, 42-06, 47-06, **AMS members US$55.20**, List US$69, Order code THETA/22



Inequalities: An Approach through Problems

Second Edition

B. J. Venkatachala, *Homi Bhabha Centre for Science Education, Mumbai, India*

This book is an introduction to basic topics in inequalities and their applications. These include the arithmetic mean-geometric mean inequality, Cauchy-Schwarz inequality, Chebyshev inequality, rearrangement inequality, convex and concave functions and Muirhead's theorem. More than 400 problems are included in the book and their solutions are explained. A chapter on geometric inequalities is a special feature of this book. Most of these problems are from International Mathematical Olympiads and from many national mathematical olympiads.

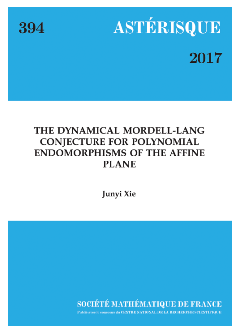
The book is intended to help students who are preparing for various mathematical competitions. It is also a good source book for graduate students in consolidating their knowledge of inequalities and their applications.

The author has been involved in training Indian students for mathematical olympiads for more than 25 years.

A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Hindustan Book Agency

March 2018, 532 pages, Softcover, ISBN: 978-93-86279-68-2, 2010 *Mathematics Subject Classification:* 26D20; 97U40, **AMS members US$57.60**, List US$72, Order code HIN/75



The Dynamical Mordell-Lang Conjecture for Polynomial Endomorphisms of the Affine Plane

Junyi Xie, *Université de Rennes 1, France*

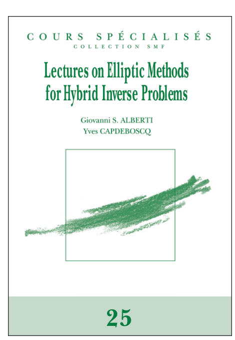
In this paper, the author proves the Dynamical Mordell-Lang Conjecture for polynomial endomorphisms of the affine plane over the algebraic numbers. More precisely, f let be an endomorphism of the affine plan over the algebraic numbers. Let x be a point in the affine plan and C be a curve. If the intersection of C and the orbits of x is infinite, then C is periodic.

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 394

January 2018, 110 pages, Softcover, ISBN: 978-2-85629-869-5, 2010 *Mathematics Subject Classification:* 37P05; 37P50, **AMS members US$48**, List US$60, Order code AST/394

Differential Equations



Lectures on Elliptic Methods for Hybrid Inverse Problems

Giovanni S. Alberti, *University of Genoa*, and **Yves Capdeboscq**, *University of Oxford*

In recent years, several new imaging modalities have been developed in order to be able to detect physical parameters simultaneously at a high spatial resolution and with a high sensitivity to contrast. These new approaches typically rely on the interaction of two physical imaging methods, and the corresponding mathematical models are the so-called hybrid, or coupled-physics, inverse problems. The combination of two physical modalities poses new mathematical challenges: the analysis of this new class of inverse problems requires the use of various mathematical tools, often of independent interest.

This book intends to provide a first comprehensive course on some of these tools (mainly related to elliptic partial differential equations) and on their applications to hybrid inverse problems. For certain topics, such as the observability of the wave equation, the generalization of the Rad-Kneser-Choquet Theorem to the conductivity equation, complex geometrical optics solutions and the Runge approximation property, the authors review well-known results.

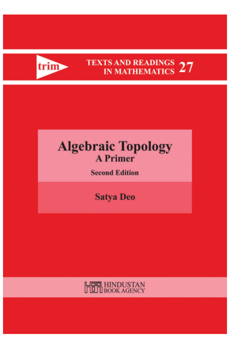
The material is presented with a clear focus on the intended applications to inverse problems. On other topics, including the regularity theory and the study of small-volume perturbations for Maxwell's equations, scattering estimates for the Helmholtz equation and the study of non-zero constraints for solutions of certain PDE, the authors discuss several new results. The authors then show how all these tools can be applied to the analysis of the parameter reconstruction for some hybrid inverse problems: acousto-electric tomography, current density impedance imaging, dynamic elastography, thermoacoustic and photoacoustic tomography.

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.

Cours Spécialisés—Collection SMF, Number 25

January 2018, 226 pages, Hardcover, ISBN: 978-2-85629-872-5, 2010 *Mathematics Subject Classification:* 35R30, 35Q93, 35B65, 35B30, 35J25, 35Q61, 35P25, 35J05, **AMS members US$53.60**, List US$67, Order code COSP/25

Geometry and Topology



Algebraic Topology

A Primer (Second Edition)

Satya Deo, *Harish-Chandra Research Institute, Allahabad, India*

This is the second (revised and enlarged) edition of the book originally published in 2003. It introduces the first concepts of algebraic topology such as general simplicial complexes, simplicial homology theory, fundamental groups, covering spaces and singular homology theory in detail. The text has been designed for undergraduate and beginning graduate students of mathematics. It assumes a minimal background of linear algebra, group theory and topological spaces.

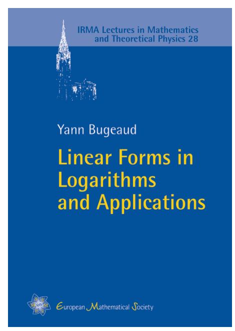
The author deals with the basic concepts and ideas in a very lucid manner, giving suitable motivations and illustrations. As an application of the tools developed in this book, some classical theorems such as Brouwer's fixed point theorem, the Lefschetz fixed point theorem, the Borsuk-Ulam theorem, Brouwer's separation theorem, and the theorem on invariance of domain are proved and illustrated. Most of the exercises are elementary, but some are more challenging and will help readers with their understanding of the subject.

A publication of Hindustan Book Agency; distributed within the Americas by the American Mathematical Society. Maximum discount of 20% for all commercial channels.

Hindustan Book Agency

March 2018, 358 pages, Softcover, ISBN: 978-93-86279-67-5, 2010 *Mathematics Subject Classification:* 55Nxx; 54Dxx, **AMS members US$41.60**, List US$52, Order code HIN/74

Number Theory



Linear Forms in Logarithms and Applications

Yann Bugeaud, *Université de Strasbourg, France*

The aim of this book is to serve as an introductory text to the theory of linear forms in the logarithms of algebraic numbers, with a special emphasis on a large variety of its applications. The author intends to help students and researchers to learn what is hidden inside the blackbox "Baker's theory of linear forms in logarithms" (in complex or in p-adic logarithms) and how this theory applies to many Diophantine problems, including the effective resolution of Diophantine equations, the *abc*-conjecture, and upper bounds for the irrationality measure of some real numbers.

Written for a broad audience, this accessible and self-contained book can be used for graduate courses (some 30 exercises are supplied). Specialists will appreciate the inclusion of over 30 open problems and the rich bibliography of over 450 references.

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

IRMA Lectures in Mathematics and Theoretical Physics, Volume 28

May 2018, 240 pages, Softcover, ISBN: 978-3-03719-183-5, 2010 *Mathematics Subject Classification:* 11-02, 11J86, 11Dxx; 11B37, 11D25, 11D41, 11D59, 11D61, 11D75, 11D88, 11J25, 11J81, 11J82, **AMS members US$38.40**, List US$48, Order code EMSILMTP/28

MEETINGS & CONFERENCES OF THE AMS

MAY TABLE OF CONTENTS

The Meetings and Conferences section of the Notices gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Information in this issue may be dated.

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

Important Information About AMS Meetings: Potential organizers, speakers, and hosts should refer to page 88 in the January 2018 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts: Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset in LaTeX. Visit **www.ams.org/cgi-bin/abstracts/abstract.pl/**. Questions about abstracts may be sent to `abs-info@ams.org`. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

MEETINGS IN THIS ISSUE

See `www.ams.org/meetings/` *for the most up-to-date information on the meetings and conferences that we offer.*

ASSOCIATE SECRETARIES OF THE AMS

Central Section: Georgia Benkart, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388; email: benkart@math.wisc.edu; telephone: 608-263-4283.

Eastern Section: Steven H. Weintraub, Department of Mathematics, Lehigh University, Bethlehem, PA 18015-3174; email: 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, email: 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; email: 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 .

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
Issue of *Abstracts*: Volume 39, Issue 2

Deadlines

For organizers: Expired
For abstracts: Expired

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

Invited Addresses

Jian Ding, University of Pennsylvania, *Random walk, random media and random geometry*.

Edward Frenkel, University of California, Berkeley, *Imagination and knowledge* (Einstein Public Lecture in Mathematics).

Valentino Tosatti, Northwestern University, *Metric limits of Calabi-Yau manifolds*.

Maryna Viazovska, École Polytechnique Fédérale de Lausanne, *The sphere packings and modular forms*.

Algebraic Number Theory, **Michael Bush**, Washington and Lee University, **Farshid Hajir**, University of Massachusetts, and **Christian Maire**, Université Bourgogne Franche-Comté.

Algebraic Statistics, **Kaie Kubjas** and **Elina Robeva**, Massachusetts Institute of Technology.

Algebraic, Geometric, and Topological Methods in Combinatorics, **Florian Frick**, Cornell University, and **Pablo Soberón**, Northeastern University.

Algorithmic Group Theory and Applications, **Delaram Kahrobaei**, City University of New York, and **Antonio Tortora**, University of Salerno.

Analysis and Geometry in Non-smooth Spaces, **Nageswari Shanmugalingam** and **Gareth Speight**, University of Cincinnati.

Arithmetic Dynamics, **Jacqueline M. Anderson**, Bridgewater State University, **Robert Benedetto**, Amherst College, and **Joseph H. Silverman**, Brown University.

Arrangements of Hypersurfaces, **Graham Denham**, University of Western Ontario, and **Alexander I. Suciu**, Northeastern University.

Combinatorial Aspects of Nilpotent Orbits, **Anthony Iarrobino**, Northeastern University, **Leila Khatami**, Union College, and **Juliana Tymoczko**, Smith College.

Combinatorial Representation Theory, **Laura Colmenarejo**, York University, **Ricky Liu**, North Carolina State University, and **Rosa Orellana**, Dartmouth College.

Connections Between Trisections of 4-manifolds and Low-dimensional Topology, **Jeffrey Meier**, University of Georgia, and **Juanita Pinzon-Caicedó**, North Carolina State University.

Discretization in Geometry and Dynamics, **Richard Kenyon**, **Wai Yeung Lam**, and **Richard Schwartz**, Brown University.

Dynamical systems, Geometric Structures and Special Functions, **Alessandro Arsie**, University of Toledo, and **Oksana Bihun**, University of Colorado, Colorado Springs.

Effective Behavior in Random Environments, **Jessica Lin**, McGill University, and **Charles Smart**, University of Chicago.

Ergodic Theory and Dynamics in Combinatorial Number Theory, **Stanley Eigen** and **Daniel Glasscock**, Northeastern University, and **Vidhu Prasad**, University of Massachusetts, Lowell.

Extremal Graph Theory and Quantum Walks on Graphs, **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, **Tara Holm**, Cornell University, **Jo Nelson**, Columbia University, and **Jonathan Weitsman**, Northeastern University.

Geometries Defined by Differential Forms, **Mahir Bilen Can**, Tulane University, **Sergey Grigorian**, University of Texas Rio Grande Valley, and **Sema Salur**, University of Rochester.

Geometry and Analysis of Fluid Equations, **Robert McOwen** and **Peter Topalov**, Northeastern University.

Geometry of Moduli Spaces, **Ana-Marie Castravet** and **Emanuele Macrí**, Northeastern University, **Benjamin Schmidt**, University of Texas, and **Xiaolei Zhao**, Northeastern University.

Global Dynamics of Real Discrete Dynamical Systems, **M. R. S. Kulenović** and **O. Merino**, University of Rhode Island.

Harmonic Analysis and Partial Differential Equations, **Donatella Danielli**, Purdue University, and **Irina Mitrea**, Temple University.

Homological Commutative Algebra, **Sean Sather-Wagstaff**, Clemson University, and **Oana Veliche**, Northeastern University.

Hopf Algebras, Tensor Categories, and Homological Algebra, **Cris Negron**, Massachusetts Institute of Technology, **Julia Plavnik**, Texas A&M, and **Sarah Witherspoon**, Texas A&M University.

Mathematical Perspectives in Quantum Information Theory, **Aram Harrow**, Massachusetts Institute of Technology, and **Christopher King**, Northeastern University.

Mathematical Problems of Relativistic Physics: Classical and Quantum, **Michael Kiessling** and **A. Shadi Tahvildar-Zadeh**, Rutgers University.

Modeling of Biological Processes, **Simone Cassani** and **Sarah Olson**, Worcester Polytechnic Institute.

New Developments in Inverse Problems and Imaging, **Ru-Yu Lai**, University of Minnesota, and **Ting Zhou**, Northeastern University.

Noncommutative Algebra and Representation Theory, **Van C. Nguyen**, Hood College, and **Alex Martsinkovsky** and **Gordana Todorov**, Northeastern University.

Nonlinear Reaction-Diffusion Equations and Their Applications, **Nsoki Mavinga** and **Quinn Morris**, Swarthmore College.

Nonlinear and Stochastic Partial Differential Equations and Applications, **Nathan Glatt-Holtz** and **Vincent Martinez**, Tulane University, and **Cecilia Mondaini**, Texas A&M University.

Numerical Methods and Applications, **Vera Babenko**, Ithaca College.

Optimization Under Uncertainty, **Yingdong Lu** and **Mark S. Squillante**, IBM Research.

Polytopes and Discrete Geometry, **Gabriel Cunningham**, University of Massachusetts, Boston, **Mark Mixer**, Wentworth Institute of Technology, and **Egon Schulte**, Northeastern University.

Regularity of PDEs on Rough Domains, **Murat Akman**, University of Connecticut, and **Max Engelstein**, Massachusetts Institute of Technology.

Relations Between the History and Pedagogy of Mathematics, **Amy Ackerberg-Hastings**, and **David L. Roberts**, Prince George's Community College.

Singularities of Spaces and Maps, **Terence Gaffney** and **David Massey**, Northeastern University.

The Analysis of Dispersive Equations, **Marius Beceanu**, University at Albany, and **Andrew Lawrie**, Massachusetts Institute of Technology.

The Gaussian Free Field and Random Geometry, **Jian Ding**, University of Pennsylvania, and **Vadim Gorin**, Massachusetts Institute of Technology.

Topics in Qualitative Properties of Partial Differential Equations, **Changfeng Gui**, University of Texas at San Antonio, **Changyou Wang**, Purdue University, and **Jiuyi Zhu**, Louisiana State University.

Topics in Toric Geometry, **Ivan Martino**, Northeastern University, and **Emanuele Ventura**, Texas A&M University.

Topology of Biopolymers, **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
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: Expired
For abstracts: May 10, 2018

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, *An overview of unconstrained optimization.*

Kenneth A. Ribet, University of California, Berkeley, *The Eisenstein ideal and the arithmetic of modular curves and their Jacobians.*

Richard M. Schoen, University of California, Irvine, *Geometry and general relativity.*

Sijue Wu, University of Michigan, *On the motion of water waves with angled crests.*

Chenyang Xu, Peking University, *Compact moduli spaces.*

Jiangong You, Nankai University, *Quasi-periodic Schrödinger operators.*

Special Sessions

Additive Combinatorics including its Interplay with Factorization Theory (SS 1), **Weidong Gao**, Nankai University, **Alfred Geroldinger**, University of Graz, and **David J. Grynkiewicz**, University of Memphis.

Algebraic Geometry (SS 3), **Davesh Maulik**, Massachusetts Institute of Technology, and **Chenyang Xu**, Peking University.

Algebraic Geometry (SS 21A, **Emily Clader**, San Francisco State University, **Dustin Ross**, San Francisco State University, and **Mark Shoemaker**, Colorado State University.

Algebraic and Geometric Topology (SS 2), **Michael Hill**, University of California at Los Angeles, **Zhi Lü** and **Jiming Ma**, Fudan University, and **Yifei Zhu**, Southern University of Science and Technology.

Asymptotically Hyperbolic Einstein Manifolds and Conformal Geometryb (SS 4), **Jie Qing**, University of California Santa Cruz and Beijing International Center for Mathematical Research, **Mijia Lai** and **Fang Wang**, Shanghai Jiao Tong University, and **Meng Wang**, Zhejiang University.

Complex Geometry and Several Complex Variables (SS 5), **Qingchun Ji**, Fudan University, **Min Ru**, University of Houston, and **Xiangyu Zhou**, Chinese Academy of Sciences.

Computer Science (SS 6), **Erich Kaltofen**, North Carolina State University, and **Lihong Zhi**, Academy of Mathematics and Systems Science, Chinese Academy of Sciences.

Cybernetics (SS 7), **Alberto Bressan**, Pennsylvania State University, and **Xu Zhang**, Sichuan University.

Geometric Models and Methods in Quantum Gravity (SS 8), **Peng Wang**, Sichuan University, and **P. P. Yu**, Westminster College.

Geometric Representation Theory and the Langlands Program (SS 9), **Dihua Jiang**, University of Minnesota, **Yiqiang Li**, State University of New York at Buffalo, **Peng Shan**, Tsinghua University, and **Binyong Sun**, Academy of Mathematics and Systems Science, Chinese Academy of Sciences.

Geometry (SS 10), **Jiayu Li**, University of Science and Technology of China, and **Jie Qing**, University of California Santa Cruz and Beijing International Center for Mathematical Research.

Harmonic Analysis and Partial Differential Equations (SS 11), **Hong-Quan Li**, Fudan University, and **Xiaochun Li**, UIUC.

Harmonic Maps and Related Topics (SS 12), **Yuxin Dong**, Fudan University, **Ye-Lin Ou**, Texas A&M University-Commerce, **Mei-Chi Shaw**, University of Notre Dame, and **Shihshu Walter Wei**, University of Oklahoma.

Inverse Problems (SS 13), **Gang Bao**, Zhejiang University, and **Hong-Kai Zhao**, University of California at Irvine.

Mathematics of Planet Earth: Natural Systems and Models (SS 14), **Daniel Helman**, Ton Duc Thang University, and **Huaiping Zhu**, York University.

Noncommutative Algebra and Related Topics (SS 15), **Quanshui Wu**, Fudan University, and **Milen Yakimov**, Louisiana State University.

Nonlinear Analysis and Numerical Simulations (SS 16), **Jifeng Chu**, Shanghai Normal University, **Zhaosheng Feng**, University of Texas-Rio Grande Valley, and **Juntao Sun**, Shandong University of Technology.

Nonlinear Dispersive Equations (SS 17), **Marius Beceanu**, University at Albany SUNY, and **Chengbo Wang**, Zhejiang University.

Nonlocal PDEs via Harmonic Analysis (SS 20A), **Tadele Mengesha**, University of Tennessee, Knoxville, and **Armin Schikorra**, University of Pittsburgh.

Number Theory (SS 18), **Hourong Qin**, Nanjing University, and **Wei Zhang**, Columbia University.

Numerical Analysis (SS 19), **Jin Cheng**, Fudan University, and **Jie Shen**, Purdue University.

Operations Research (SS 20), **Yanqin Bai**, Shanghai University, **Yu-Hong Dai**, Academy of Mathematics and Systems Science, Chinese Academy of Sciences, and **Jiming Peng**, University of Houston.

Ordinary Differential Equations and Dynamical Systems (SS 21), **Jiangong You**, Nankai University, and **Kening Lu**, Brigham Young University.

Partial Differential Equation–Elliptic and Parabolic (SS 22), **Xinan Ma**, University of Science and Technology of China, and **Lihe Wang**, University of Iowa.

Partial Differential Equations–Hyperbolic (SS 23), **Hongjie Dong**, Brown University, and **Zhen Lei**, Fudan University.

Probability (SS 24), **Zhenqing Chen**, University of Washington, and **Zenghu Li**, Beijing Normal University.

Quantum Algebras and Related Topics (SS 25), **Yun Gao**, York University, **Naihuan Jing**, North Carolina State University, and **Honglian Zhang**, Shanghai University.

Recent Advances in Numerical Methods in Partial Differential Equations (SS 26), **Ying Li**, Shanghai University, and **Jia Zhao**, Utah State University.

Recent Advances in Stochastic Dynamical Systems and their Applications (SS 27), **Xiaofan Li**, Illinois Institute of Technology, and **Yanjie Zhang**, Huazhong University of Science and Technology.

Singularities in Geometry, Topology, and Algebra (SS 28), **Rong Du**, East China Normal University, **Yongqiang Liu**, KU Leuven, and **Laurentiu Maxim** and **Botong Wang**, University of Wisconsin.

Social Change In and Through Mathematics and Education (Code: SS 19A), **Federico Ardila**, San Francisco State University, **Matthias Beck**, San Francisco State University, **Jamylle Carter**, Diablo Valley Community College, and **Kimberly Seashore**, San Francisco State University.

Statistics (SS 29), **Jianhua Guo**, Northeastern Normal University, and **Xumin He**, University of Michigan.

Symplectic Geometry (SS 30), **Qile Chen**, Boston College, **Huijun Fan**, Peking University, and **Yongbin Ruan**, University of Michigan.

Toplogical Thinking about Mathematics of Data and Complex Information (SS 31), **Amir Assadi**, University of Wisconsin and Beijing Institute of Technology, **Dan Burghelea**, Ohio State University, **Huafei Sun**, Beijing Institute of Technology, and **Yazhen Wang**, University of Wisconsin.

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
Issue of *Abstracts*: Volume 39, Issue 3

Deadlines

For organizers: Expired
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*.

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 Numerical Approximation of Partial Differential Equations (Code: SS 8A), **Constantin Bacuta** and **Jingmei Qiu**, University of Delaware.

Applied Algebraic Topology (Code: SS 2A), **Chad Giusti**, University of Delaware, and **Gregory Henselman**, Princeton University.

Billiard Dynamics: Standard and Alternative Collision Models (Code: SS 15A), **Tim Chumley**, Mount Holyoke College, **Chris Cox**, University of Delaware, and **Renato Feres**, Washington University in St. Louis.

Commutative Algebra (Code: SS 19A), **Ela Celikbas**, West Virginia University, **Sema Gunturkun**, University of Michigan, and **Oana Veliche**, Northeastern University.

Convex Geometry and Functional Inequalities (Code: SS 3A), **Mokshay Madiman**, University of Delaware, **Elisabeth Werner**, Case Western Reserve University, and **Artem Zvavitch**, Kent State University.

Fixed Point Theory with Application and Computation (Code: SS 7A), **Clement Boateng Ampadu**, Boston, MA, **Penumarthy Parvateesam Murthy**, Guru Ghasidas Vishwavidyalaya, Bilaspur, India, **Naeem Saleem**, University of Management and Technology, Lahore, Pakistan, **Yaé Ulrich Gaba**, Institut de Mathématiques et de Sciences Physiques (IMSP), Porto-Novo, Bénin, and **Xavier Udo-utun**, University of Uyo, Uyo, Nigeria.

Graph Theory (Code: SS 12A), **Sebastian M. Cioabă**, University of Delaware, **Brian Kronenthal**, Kutztown University of Pennsylvania, **Felix Lazebnik**, University of Delaware, and **Wing Hong Tony Wong**, Kutztown University of Pennsylvania.

Interplay between Analysis and Combinatorics (Code: SS 5A), **Mahya Ghandehari** and **Dominique Guillot**, University of Delaware.

Modern Quasiconformal Analysis and Geometric Function Theory (Code: SS 6A), **David Herron**, University of Cincinnati, and **Yuk-J Leung**, University of Delaware.

Nonlinear Water Waves and Related Problems (Code: SS 9A), **Philippe Guyenne**, University of Delaware.

Numerical Methods for Partial Differential Equations and Applications (Code: SS 17A), **Wenrui Hao**, **Quingguo Hong**, and **Jinchao Xu**, Pennsylvania State University.

Operator and Function Theory (Code: SS 4A), **Kelly Bickel**, Bucknell University, **Michael Hartz**, Washington University, St. Louis, **Constanze Liaw**, University of Delaware, and **Alan Sola**, Stockholm University.

Probability, Combinatorics, and Statistical Mechanics (Code: SS 18A), **Nayantara Bhatnagar** and **Douglas Rizzolo**, University of Delaware.

Quantum Correlation Sets in Quantum Information Theory (Code: SS 13A), **Elie Alhajjar** and **Travis B. Russell**, US Military Academy.

Recent Advances in Nonlinear Schrödinger Equations (Code: SS 1A), **Alexander Pankov**, Morgan State University, **Junping Shi**, College of William and Mary, and **Jun Wang**, Jiangsu University.

Recent Analytic and Numeric Results on Nonlinear Evolution Equations (Code: SS 10A), **Xiang Xu**, Old Dominion University, and **Wujun Zhang**, Rutgers University.

Representations of Infinite Dimensional Lie Algebras and Applications (Code: SS 16A), **Marco Aldi**, Virginia Commonwealth University, **Michael Penn**, Randolph College, and **Juan Villarreal**, Virginia Commonwealth University.

Stochastic Processes in Mathematical Biology (Code: SS 14A), **Yao Li**, University of Massachusetts Amherst, and **Abhyudai Singh**, University of Delaware.

The Mathematics of Swimmers and Active Particles (Code: SS 11A), **Louis Rossi**, University of Delaware.

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
Issue of *Abstracts*: Volume 39, Issue 4

Deadlines

For organizers: Expired
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 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.

Advances in Commutative Algebra (Code: SS 15A), **Jack Jeffries**, University of Michigan, **Linquan Ma**, Purdue University, and **Karl Schwede**, University of Utah.

Advances on Analytical and Geometric Aspects of Differential Equations (Code: SS 24A), **Alessandro Arsie**, **Chunhua Shan**, and **Ekaterina Shemyakova**, University of Toledo.

Analytical and Numerical Aspects of Turbulent Transport (Code: SS 23A), **Michele Coti Zelati**, Imperial College London, and **Ian Tobasco** and **Karen Zaya**, University of Michigan.

Aspects of Geometric Mechanics and Dynamics (Code: SS 13A), **Anthony M Bloch** and **Marta Farre Puiggali**, University of Michigan.

Bio-inspired Mechanics and Propulsion (Code: SS 16A), **Silas Alben**, University of Michigan, and **Longhua Zhao**, Case Western Reserve University.

Canonical Operators in Several Complex Variables and Related Topics (Code: SS 21A), **David Barrett** and **Luke Edholm**, University of Michigan, and **Yunus Zeytuncu**, University of Michigan, Dearborn.

Cell Motility: Models and Applications (Code: SS 20A), **Magdalena Stolarska**, University of St. Thomas, and **Nicoleta Tarfulea**, Purdue University Northwest.

Cluster Algebra, Poisson Geometry, and Related Topics (Code: SS 9A), **Eric Bucher**, Michigan State University, and **Maitreyee Kulkarni** and **Bach Nguyen**, Louisiana State University.

Combinatorics in Algebra and Algebraic Geometry (Code: SS 14A), **Zachary Hamaker**, **Steven Karp**, and **Oliver Pechenik**, University of Michigan.

Commutative Algebra and Complexity (Code: SS 32A), **Harm Derksen**, **Francesca Gandini**, and **Visu Makam**, University of Michigan.

Commutative Ring Theory (Code: SS 22A), **Joe Stickles**, Millikin University, and **Darrin Weber**, University of Evansville.

Ergodic and Topological Quantum Systems (Code: SS 28A), **Matthew Cha**, **Ilya Kachkovskiy**, and **Shiwen Zhang**, Michigan State University.

Extensions-Interpolation-Shape Matching in R^d, Symmetry-Invariance, Algorithms and Related Topics (Code: SS 11A), **Steven Damelin**, American Mathematical Society, and **Nir Sharon**, Princeton University.

From Hyperelliptic to Superelliptic Curves (Code: SS 6A), **Tony Shaska**, Oakland University, **Nicola Tarasca**, Rutgers University, and **Yuri Zarhin**, Pennsylvania State University.

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 University, **Kayvan Najarian** and **Reza Soroushmehr**, University of Michigan, and **Alexander Wood**, CUNY Graduate Center.

Large Cardinals and Combinatorial Set Theory (Code: SS 10A), **Andres E. Caicedo**, Mathematical Reviews, and **Paul B. Larson**, Miami University.

Mathematics of the Genome (Code: SS 30A), **Anthony Bloch**, **Daniel Burns**, and **Indika Rajapakse**, University of Michigan.

Modern Trends in Integrable Systems (Code: SS 12A), **Deniz Bilman**, **Peter Miller**, **Michael Music**, and **Guilherme Silva**, University of Michigan.

Multiplicities and Volumes: An Interplay Among Algebra, Combinatorics, and Geometry (Code: SS 19A), **Federico Castillo**, University of Kansas, and **Jonathan Montaño**, New Mexico State University.

New Trends in Numerical Methods for Partial Differential Equations: Theory and Applications (Code: SS 17A), **Mahboub Baccouch**, University of Nebraska at Omaha, and **Fatih Celiker**, Wayne State University.

Nonlocality in Models for Kinetic, Chemical, and Population Dynamics (Code: SS 25A), **Christopher Henderson**, University of Chicago, **Stanley Snelson**, Florida Institute of Technology, and **Andrei Tarfulea**, University of Chicago.

Probabilistic Methods in Combinatorics (Code: SS 7A), **Patrick Bennett** and **Andrzej Dudek**, Western Michigan University, and **David Galvin**, University of Notre Dame.

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.

Recent Advances in Nonlinear PDE (Code: SS 31A), **Jessica Lin**, McGill University, and **Russell Schwab**, Michigan State University.

Recent Developments in Mathematical Analysis of Some Nonlinear Partial Differential Equations (Code: SS 18A), **Mimi Dai**, University of Illinois at Chicago.

Recent Developments in the Mathematics of Tomography and Scattering (Code: SS 26A), **Shixu Meng**, University of Michigan, and **Yang Yang**, Michigan State University.

Recent Trends on Local, Nonlocal and Fractional Partial Differential Equations (Code: SS 27A), **Pablo Raúl Stinga**, Iowa State University, **Peiyong Wang**, Wayne State University, and **Jiuyi Zhu**, Louisiana State University.

Representations of Reductive Groups over Local Fields and Related Topics (Code: SS 8A), **Anne-Marie Aubert**, Institut Mathématiques de Jussieu, Paris Rive Gauche, **Jessica Fintzen**, IAS, University of Michigan, University of Cambridge, and **Camelia Karimianpour**, 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.

Structured Homotopy Theory (Code: SS 5A), **Thomas Fiore**, University of Michigan, Dearborn, **Po Hu** and **Dan Isaksen**, Wayne State University, and **Igor Kriz**, University of Michigan.

The Mathematics of Decisions, Elections, and Games (Code: SS 29A), **Michael A. Jones**, Mathematical Reviews, and **David McCune**, William Jewell College.

Topics in Graph Theory, Hypergraphs and Set Systems (Code: SS 33A), **John Engbers**, Marquette University, and **Cliff Smyth**, University of North Carolina, Greensboro.

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
Issue of *Abstracts*: Volume 39, Issue 4

Deadlines

For organizers: Expired
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, *Derivatives, Derivations, and Hochschild Cohomology.*

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`.

Advances in Operator Theory, Operator Algebras, and Operator Semigroups (Code: SS 14A), **Asuman G. Aksoy**, Claremont McKenna College, **Michael Hartglass**, Santa Clara University, **Zair Ibragimov**, California State University, Fullerton, and **Marat Markin**, California State University, Fresno.

Analysis and Geometry of Fractals (Code: SS 7A), **Kyle Hambrook**, University of Rochester, **Chun-Kit Lai**, San Francisco State University, and **Sze-Man Ngai**, Georgia Southern University.

Applied Harmonic Analysis: Frame Theory and Applications (Code: SS 9A), **Chun-Kit Lai** and **Shidong Li**, San Francisco State University.

Big Data and Statistical Analytics (Code: SS 17A), **Tao He**, **Mohammad Kafai**, and **Alexandra Piryatinska**, San Francisco State University.

Combinatorial and Categorical Aspects of Representation Theory (Code: SS 10A), **Nicholas Davidson** and **Jonathan Kujawa**, University of Oklahoma, and **Robert Muth**, Tarleton State University.

Coupling in Probability and Related Fields (Code: SS 3A), **Sayan Banerjee**, University of North Carolina, Chapel Hill, and **Terry Soo**, University of Kansas.

Geometric Analysis (Code: SS 8A), **Ovidiu Munteanu**, University of Connecticut, and **David Bao**, San Francisco State University.

Geometric Methods in Hypercomplex Analysis (Code: SS 13A), **Paula Cerejeiras**, Universidade de Aveiro, **Matvei Libine**, Indiana University, Bloomington, and **Mihaela B. Vajiac**, Chapman University.

Geometric and Analytic Inequalities and their Applications (Code: SS 4A), **Nicholas Brubaker**, **Isabel M. Serrano**, and **Bogdan D. Suceavă**, California State University, Fullerton.

Homological Aspects in Commutative Algebra and Representation Theory (Code: SS 5A), **Srikanth B. Iyengar**, University of Utah, and **Julia Pevtsova**, University of Washington.

Homological Aspects of Noncommutative Algebra and Geometry (Code: SS 2A), **Dan Rogalski**, University of California San Diego, **Sarah Witherspoon**, Texas A&M University, and **James Zhang**, University of Washington, Seattle.

Markov Processes, Gaussian Processes and Applications (Code: SS 18A), **Alan Krinik** and **Randall J. Swift**, California State Polytechnic University.

Mathematical Biology with a focus on Modeling, Analysis, and Simulation (Code: SS 1A), **Jim Cushing**, The University of Arizona, **Saber Elaydi**, Trinity University, **Suzanne Sindi**, University of California, Merced, and **Abdul-Aziz Yakubu**, Howard University.

Noncommutative Geometry and Fundamental Applications (Code: SS 12A), **Konrad Aguilar**, Arizona State University, and **Frederic Latremoliere**, University of Denver.

Probabilistic and Statistical Problems in Stochastic Dynamics (Code: SS 16A), **Tao He**, **Mohammad Kafai**, and **Alexandra Piryatinska**, San Francisco State University.

Research in Mathematics by Early Career Graduate Students (Code: SS 11A), **Michael Bishop**, **Marat Markin**, **Jenna Tague**, and **Khang Tran**, California State University, Fresno.

Statistical and Geometrical Properties of Dynamical Systems (Code: SS 6A), **Joanna Furno** and **Matthew Nicol**, University of Houston, and **Mariusz Urbanski**, University of North Texas.

Topics in Operator Theory (Code: SS 15A), **Anna Skripka** and **Maxim Zinchenko**, University of New Mexico.

Fayetteville, Arkansas

University of Arkansas

November 3–4, 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
Issue of *Abstracts*: Volume 39, Issue 3

Deadlines

For organizers: Expired
For abstracts: September 4, 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, Brown 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`.

Commutative Algebra (Code: SS 3A), **Alessandro De Stefani**, University of Nebraska-Lincoln, **Paolo Mantero**, University of Arkansas, and **Thomas Polstra**, University of Utah.

Groups in Low-dimensional Topology and Dynamics (Code: SS 7A), **Matt Clay**, University of Arkansas, and **Kathryn Mann**, Brown University.

Interactions Between Contact and Symplectic Geometry and Low-dimensional Topology (Code: SS 5A), **Jeremy Van Horn-Morris**, University of Arkansas, and **David Shea Vela-Vick**, Louisiana State University.

Partial Differential Equations in Several Complex Variables (Code: SS 2A), **Phillip Harrington** and **Andrew Raich**, University of Arkansas.

Recent Advances in Mathematical Fluid Mechanics (Code: SS 1A), **Zachary Bradshaw**, University of Arkansas.

Recent Developments on Fluid Turbulence (Code: SS 6A), **Eleftherios Gkioulekas**, University of Texas Rio Grande Valley.

Validation and Verification Strategies in Multiphysics Problems (Code: SS 4A), **Tulin Kaman**, University of Arkansas.

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: November 1, 2018.

Issue of *Abstracts*: Volume 40, Issue 1

Deadlines

For organizers: Expired
For abstracts: September 25, 2018

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: January 31, 2019
Issue of *Abstracts*: Volume 40, Issue 2

Deadlines

For organizers: August 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`.

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`.

Developments in Commutative Algebra (Code: SS 1A), **Eloísa Grifo**, University of Michigan, and **Patricia Klein**, University of Kentucky.

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: February 7, 2019
Issue of *Abstracts*: Volume 40, Issue 2

Deadlines

For organizers: May 15, 2018
For abstracts: January 29, 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, *Analysis of Geometric Nonlinear Partial Differential Equations.*

Deanna Needell, University of California, Los Angeles, *Simple approaches to complicated data analysis.*

Katherine Stange, University of Colorado, Boulder, *Title to be announced.*

Andrew Suk, University of California, San Diego, *Title to be announced.*

Hartford, Connecticut

University of Connecticut Hartford (Hartford Regional Campus)

April 13–14, 2019

Saturday – Sunday

Meeting #1148

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: February 21, 2019
Issue of *Abstracts*: Volume 40, Issue 2

Deadlines

For organizers: September 13, 2018
For abstracts: February 5, 2019

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

Special Sessions

If you are volunteering to speak in a Special Session, you should send your abstract as early as possible via the abstract submission form found at `www.ams.org/cgi-bin/abstracts/abstract.pl`.

Analysis, Geometry, and PDEs in Non-smooth Metric Spaces (Code: SS 1A), **Vyron Vellis**, University of Connecticut, **Xiaodan Zhou**, Worcester Polytechnic Institute, and **Scott Zimmerman**, University of Connecticut.

Quy Nhon City, Vietnam

Quy Nhon University

June 10–13, 2019
Monday – Thursday

Meeting #1149
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: N/A
Issue of *Abstracts*: N/A

Deadlines
For organizers: November 30, 2018
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

Henry Cohn, Microsoft Research, *To be announced.*

Robert Guralnick, University of Southern California, *To be announced.*

Le Tuan Hoa, Hanoi Institute of Mathematics, *To be announced.*

Nguyen Dong Yen, Hanoi Institute of Mathematics, *To be announced.*

Zhiwei Yun, Massachusetts Institute of Technology, *To be announced.*

Nguyen Tien Zung, Toulouse Mathematics Institute, *To be announced.*

Madison, Wisconsin

University of Wisconsin–Madison

September 14–15, 2019
Saturday – Sunday

Meeting #1150
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: July 23, 2019
Issue of *Abstracts*: Volume 40, Issue 3

Deadlines
For organizers: February 14, 2019
For abstracts: July 16, 2019

Binghamton, New York

Binghamton University

October 12–13, 2019
Saturday – Sunday

Meeting #1151
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: August 29, 2019
Issue of *Abstracts*: Volume 40, Issue 3

Deadlines
For organizers: March 12, 2019
For abstracts: August 20, 2019

Gainesville, Florida

University of Florida

November 2–3, 2019
Saturday – Sunday

Meeting #1152
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: September 19, 2019
Issue of *Abstracts*: Volume 40, Issue 4

Deadlines
For organizers: April 2, 2019
For abstracts: September 10, 2019

Riverside, California

University of California, Riverside

November 9–10, 2019
Saturday – Sunday

Meeting #1153
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: September 12, 2019
Issue of *Abstracts*: Volume 40, Issue 4

Deadlines
For organizers: April 9, 2019
For abstracts: September 3, 2019

Denver, Colorado

Colorado Convention Center

January 15–18, 2020
Wednesday – Saturday

Meeting #1154
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
Issue of *Abstracts*: To be announced

Deadlines
For organizers: April 1, 2019
For abstracts: To be announced

Washington, District of Columbia

Walter E. Washington Convention Center

January 6–9, 2021
Wednesday – Saturday
Joint Mathematics Meetings, including the 127th Annual Meeting of the AMS, 104th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: October 2020
Program first available on AMS website: November 1, 2020
Issue of *Abstracts*: To be announced

Deadlines
For organizers: April 1, 2020
For abstracts: To be announced

Grenoble, France

Université Grenoble Alpes

July 5–9, 2021
Monday – Friday
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: To be announced
For abstracts: To be announced

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AMS AMERICAN MATHEMATICAL SOCIETY

Buenos Aires, Argentina

The University of Buenos Aires

July 19–23, 2021
Monday – Friday
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

Seattle, Washington

Washington State Convention Center and the Sheraton Seattle Hotel

January 5–8, 2022
Wednesday – Saturday
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2021
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

Boston, Massachusetts

John B. Hynes Veterans Memorial Convention Center, Boston Marriott Hotel, and Boston Sheraton Hotel

January 4–7, 2023
Wednesday – Saturday
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: October 2022
Program first available on AMS website: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

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THE BACK PAGE

"When I began working on Navier-Stokes, I felt like I was a child because I did all the mistakes you do in the beginning. That is something absolutely fantastic."—*Yves Meyer (See interview, page 526.)*

Yves Meyer:

Number of Students: **37**

Number of Descendants: **145**

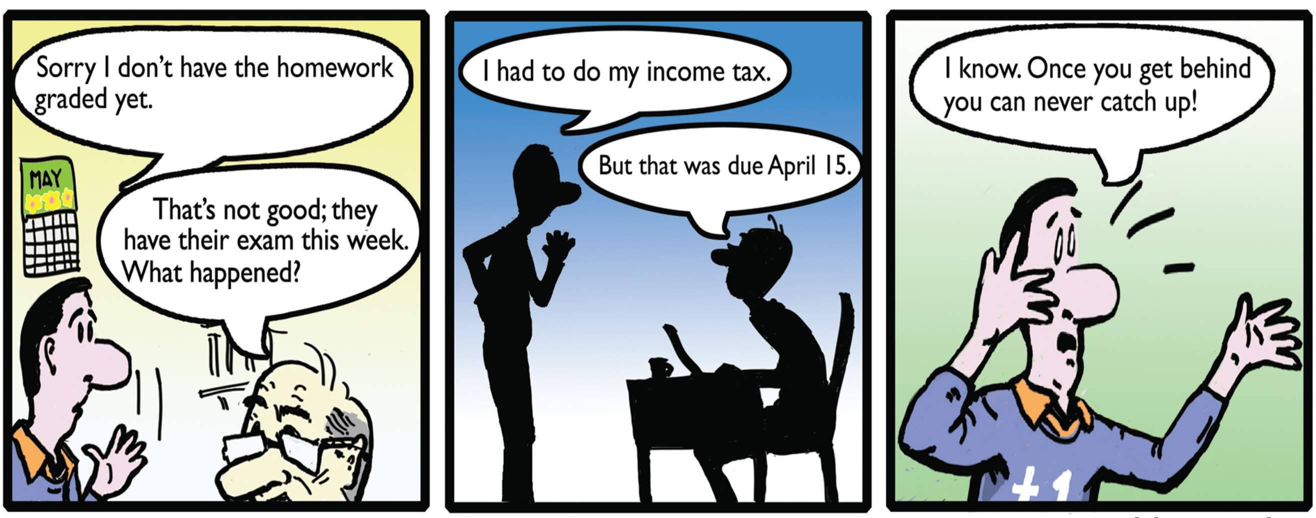
Number of publications: **207**

Two most cited works:

1. **With 550 citations** Meyer, Yves. *Wavelets and operators*. Translated from the 1990 French original by D. H. Salinger. Cambridge Studies in Advanced Mathematics, 3W7. Cambridge University Press, Cambridge, 1992. **MR1228209**.
2. **With 416 citations** Coifman, Ronald R.; Meyer, Yves. *Au deldes opateurs pseudo-diffentiels*. (French)[Beyond pseudodifferential operators] With an English summary. *Astisque*, 57. SociMathatique de France, Paris, 1978. **MR0518170**.

Source: MathSciNet® as of 3/30/18.

MY TA



Artwork by Sam White.

A recent panel selected Fields Medalist Terry Tao as Princeton's most influential graduate alum.
—*from* Princeton Alumni Weekly, *January 10, 2018.*

What crazy things happen to you? Readers are invited to submit original short amusing stories, math jokes, cartoons, and other material to: **noti-backpage@ams.org**.

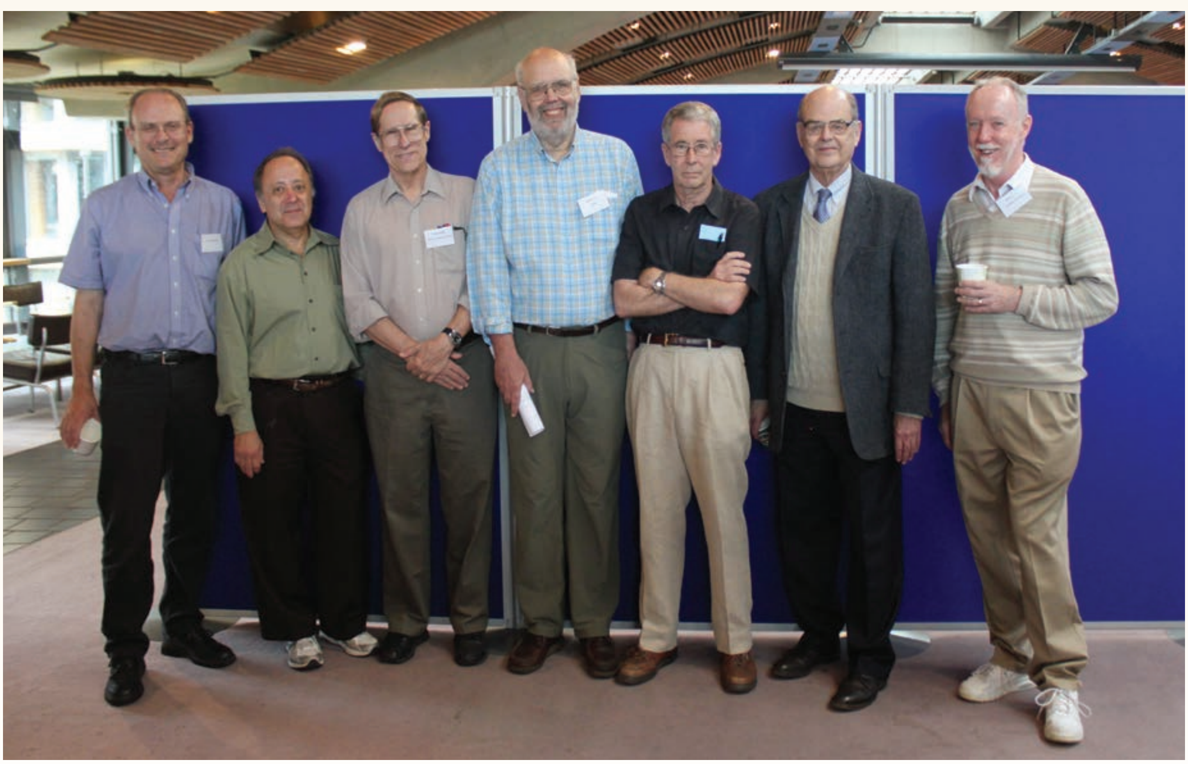
IN THE NEXT ISSUE OF NOTICES

JUNE/JULY 2018

In 1981, the monumental project to classify all of the finite simple groups appeared to be nearing its conclusion. Danny Gorenstein had dubbed the project the "Thirty Years' War."

Gorenstein and Richard Lyons agreed that it would be desirable to write a series of volumes that would contain the complete proof of this Classification Theorem, modulo a short and clearly specified list of background results. As the existing proof was scattered over hundreds of journal articles...there was consensus that this was indeed a worthwhile project, and the American Mathematical Society agreed to publish this series of twelve volumes.

In tribute to Volume 7 of this series recently being published and Volume 8 due out within a year, series contributor Ronald Solomon provides a progress report on the GLS Project.



Some of those who have worked on the Classification Project. Left to right: David Goldschmidt, Ronald Solomon, Stephen D. Smith, Richard Lyons, Michael Aschbacher, John G. Thompson, and Richard Foote.

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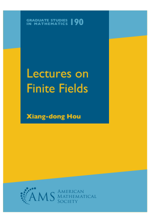
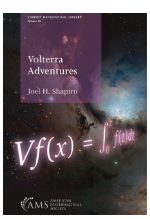


Lectures on Finite Fields

Xiang-dong Hou, *University of South Florida*

This accessible and mostly self-contained book is a collection of selected topics in the theory of finite fields and related areas.

Graduate Studies in Mathematics, Volume 190; 2018; 240 pages; Hardcover; ISBN: 978-1-4704-4289-7; List US$83; MAA members US$74.70; AMS members US$66.40; Order code GSM/190

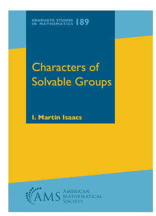


Volterra Adventures

Joel H. Shapiro, *Portland State University, OR*

Enhanced with exercises that facilitate active study, this book introduces functional analysis to undergraduate mathematics students who possess a basic background in analysis and linear algebra.

Student Mathematical Library, Volume 85; 2018; 248 pages; Softcover; ISBN: 978-1-4704-4116-6; List US$52; All individuals US$41.60; Order code STML/85

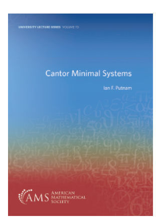


Characters of Solvable Groups

I. Martin Isaacs, *University of Wisconsin*

This book, which can be considered as a sequel of the author's famous book Character *Theory of Finite Groups*, concerns the character theory of finite solvable groups and other groups that have an abundance of normal subgroups.

Graduate Studies in Mathematics, Volume 189; 2018; 384 pages; Hardcover; ISBN: 978-1-4704-3485-4; List US$94; MAA members US$84.60; AMS members US$75.20; Order code GSM/189



Cantor Minimal Systems

Ian F. Putnam, *University of Victoria, BC, Canada*

Rather than being a comprehensive treatment of Cantor minimal dynamics, this book is aimed at students and researchers trying to learn about some surprising connections between dynamics and algebra.

University Lecture Series, Volume 70; 2018; 184 pages; Softcover; ISBN: 978-1-4704-4115-9; List US$44; MAA members US$39.60; AMS members US$35.20; Order code ULECT/70

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