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Notices

of the American Mathematical Society

November 2013 **Volume 60, Number 10**

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Israeli benefits from Palestinian concessions

		Integrity and Unity of Israeli Society Post Agreement	Security	Strengthening the Alliance with the United States	Make Israel more Attractive to Jewish Diaspora and Israelis Citizens	End of Claims	Legitimization of the State of Israel	Stop being Occupiers	Peace, Prosperity and Stability in Region	Maintain the Jewish Majority of Israel Alongside with the Arab Minority	Weakening the Radical Forces in the Middle East Headed by Iran
	Score	.0753	.1636	.0477	.0397	.2216	.0654	.0529	.0959	.1899	.0479
1	Accept mutually agreed upon land swap	0.8905	0.95	0.78	0.49	0.782	0.96	0.98	0.96	0.78	1	0.93
2	Accept settlements under Palestinian sovereignty as residents	0.225	0.54	0.028	0.42	0.252	0.064	0.242	0.274	0.144	0.42	0.242
3	Accept the temporary presence of multinational military monitoring system in Jordan Valley	0.6783	0.372	0.92	0.9	0.84	0.78	0.78	0.88	0.94	0.094	0.94
4	Accept Two-State Solution	0.9591	0.91	0.84	0.94	0.96	1	1	0.98	1	1	0.95
5	Acceptance of a Two-State solution which includes a Non-Contiguous State	0.7275	0.292	0.68	0.91	0.76	0.62	0.78	0.91	0.83	0.88	0.78
6	Acknowledge Israel's Existence as a Jewish State	0.8431	0.98	0.272	0.86	1	1	0.96	0.78	0.95	1	0.78
7	Acknowledge Israel's Existence as an Independent State	0.7769	0.236	0.224	0.78	0.82	1	1	0.73	0.93	1	1
8	Agree to Compromise to the Demand of the Right of Return	0.9645	1	0.91	0.93	0.88	1	0.98	0.93	0.93	1	0.98
9	Agreeing with Palestinian demilitarized state for a limited time period	0.5756	0.26	0.65	0.92	0.78	0.65	0.652	0.71	0.88	0.106	0.96
10	Preserve the Status Quo in the Holy places of Jerusalem	0.6781	0.502	0.172	0.94	0.94	0.94	0.98	0.89	0.98	0.384	0.91
11	Allow Israel to use Palestinian airspace	0.6358	0.7	0.98	0.91	0.76	0.78	0.63	0.45	0.6	0.046	0.94
12	Declare Against Iranian Nuclear Development	0.3827	0.422	0.322	0.94	0.5	0.222	0.83	0.028	0.76	0.046	0.98
13	Denounce & Reign in Violence	0.5935	0.79	0.81	0.94	0.76	0.47	0.89	0.176	0.89	0.126	0.95
14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	0.4791	0.722	0.53	0.94	0.5	0.39	0.84	0.046	0.76	0.046	1
15	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	0.1938	0.076	0.046	0.462	0.334	0.192	0.304	0.124	0.254	0.224	0.194
16	Make Compromise on the Status of Jerusalem	0.8923	0.96	0.5	0.96	0.91	0.96	0.96	0.96	1	0.98	1
17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	0.8238	0.93	0.71	0.89	0.95	0.98	0.98	0.69	0.96	0.53	0.98
18	Refrain and work against any anti-Israel sentiments in Palestinian schools	0.7314	0.65	0.75	0.84	0.79	0.83	0.95	0.68	0.94	0.402	0.83
19	Seek Assistance for a Legitimate Settlement of Refugees Anywhere Except Israel	0.9232	0.94	0.76	0.96	0.96	1	0.95	0.95	0.88	0.98	0.81
20	Sharing of Natural Resources	0.3925	0.028	0.384	0.62	0.29	0.52	0.58	0.57	0.73	0.106	0.272
21	Work Cooperatively and in active engagement w/ Israel	0.7343	0.434	0.84	0.94	0.68	0.86	0.89	0.92	0.94	0.304	0.98

Matrix of values of relative importance assigned by Israeli participants

		1	2	3	4	5	6	7	8	9	10
1	Integrity and unity of Israel post agreement	1	1/8,1/3,1/4,1/5,3	3,5,5,1,1	3,5,4,1/2,3	1/8,1,1,1/7,1/3	1,5,1,1/3,1	2,5,5,1/4,1/5	2,1,2,1/5,1	1/6,1/7,1/3,1/7,3	1/3,5,3,1/5,5
2	Security		1	2,3,5,2,5	2,7,7,4,2	1/4,1,1/2,1/3,1/2	7,9,1,5,1	7,7,7,4,1	1,2,1/3,1,3	1/3,1,1,2,2	1,9,4,4,5
3	Strengthening the alliance with the United States			1	2,1,1,1,4	1/8,1/3,1/8,1/9,5	1,3,1/5,2,1/5	3,3,3,1,1/5	2,1/3,1/4,1/5,1/3	1/5,1/7,1/3,1/4,1/5	1/2,1,1,1/5,1
4	Making Israel more attractive to Jewish diaspora and Israeli citizens				1	1/6,1/7,1/8,1/8,1/3	2,3,1/2,1/8,1	2,3,2,1/2,1/5	1/4,1/5,1/3,1/6,1	1/5,1/6,1/2,3,1	5,9,6,9,3
5	Ending claims					1	4,9,1,5,1	3,9,7,5,3	3,2,2,3,5	1/4,1/3,1/2,3,1	5,9,6,9,3
6	Legitimization of the State of Israel						1	1,1,1,1/3,1	1,1/7,1,1,3	1/3,1/3,1/2,1/3,3	1,1/2,5,1,1/3
7	Stop being occupiers							1	1/2,1,1/4,1,5	1,1/7,1/7,1/4,1	1/4,1,1/5,2,5
8	Peace, prosperity, and stability in the region								1	1/3,1,1/4,1/2,1	2,5,2,4,1
9	Maintaining the Jewish majority in Israel alongside the Arab minority									1	7,7,3,5,5
10	Weakening the radical forces in the Middle East headed by Iran										1

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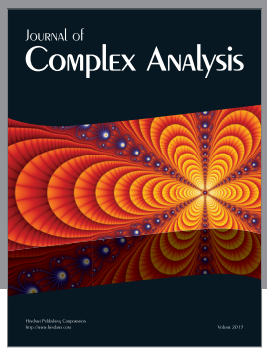
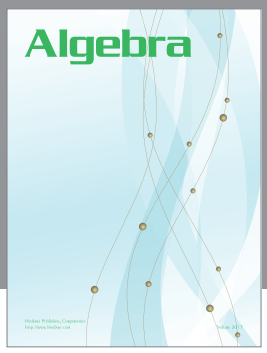
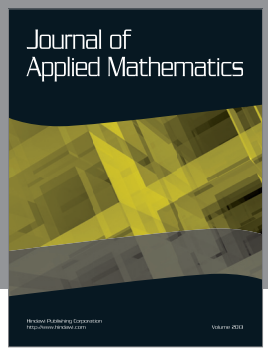
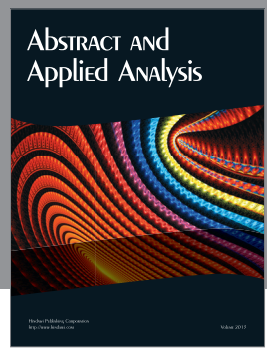
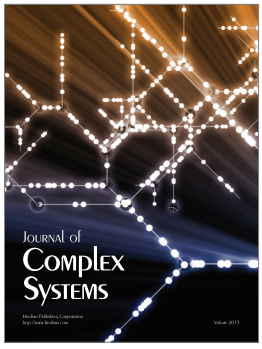
About the cover: Can mathematics help resolve serious conflicts? (see page 1343)

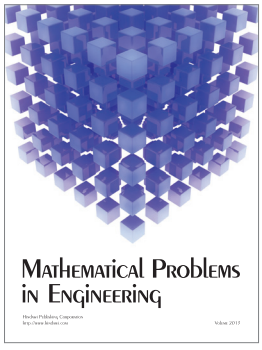


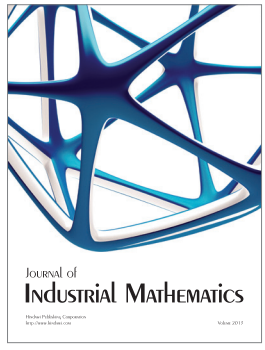


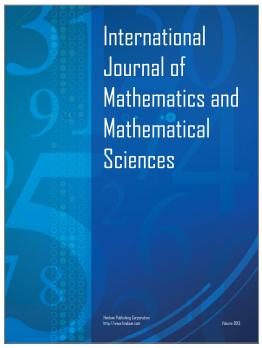


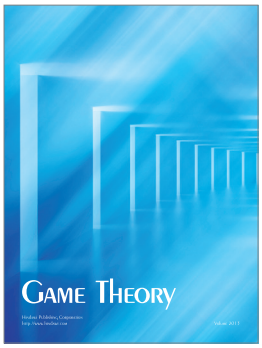


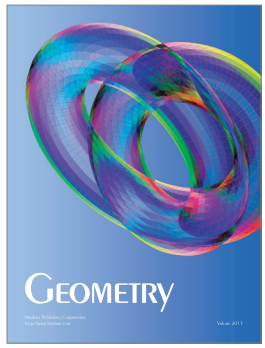


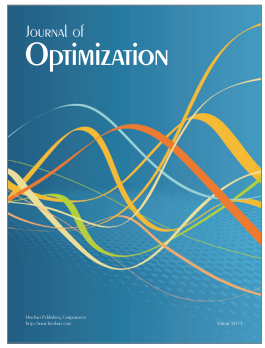


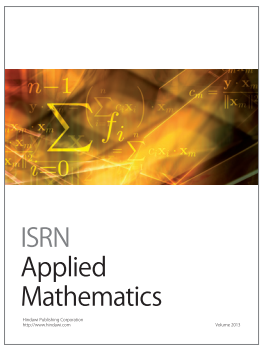


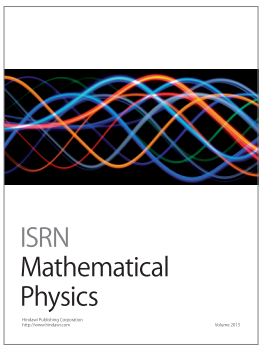


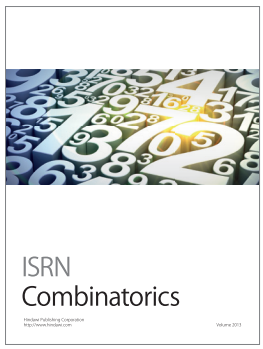


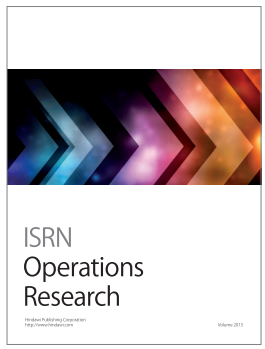


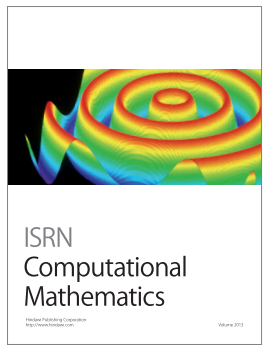












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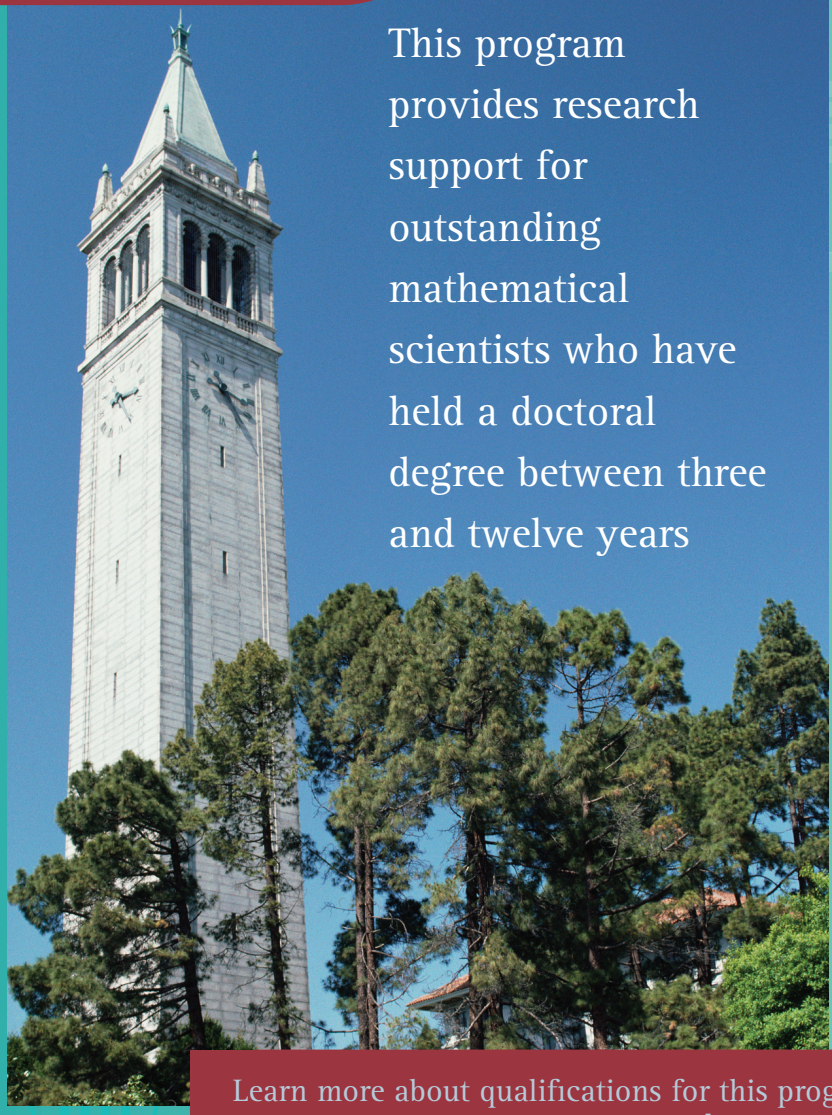
AMS Centennial Research Fellowship Program



This program provides research support for outstanding mathematical scientists who have held a doctoral degree between three and twelve years

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$$t \ln t \frac{dr}{dt} + r = 7te^t$$

$$r = \frac{7e^t + C}{\ln t}$$

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November 2013

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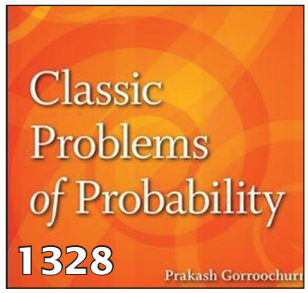

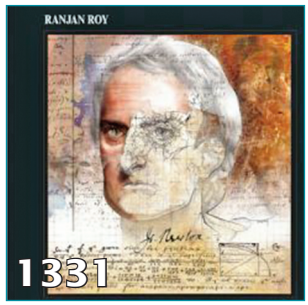

The November issue features several articles bearing on math education. These include a *Doceamus* on moving from the routine to the nonroutine in problem solving, a piece on the structure of U.S. elementary school mathematics, and an article on what secondary preservice math teachers need to know. In a historical direction, we have an article about the role of Cauchy's mean value theorem in the history of analytic rigor. Finally, there is an unusual article about the application of mathematical principles to the negotiation of peace in the Middle East.

—Steven G. Krantz, Editor

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Opinion

MOOCs and the Future of Mathematics

Calculus pedagogy and online courses are well-trod fields of war. I write with care, given the wide array of opinions strongly held.

In 2012 I created a calculus MOOC (massive open online course) for Penn's partnership with Coursera. The course ran in the spring of 2013 and again in summer 2013. You are welcome to view the materials for this course (and other free courses) on Coursera's website.

Contrary to apocalyptic fears, this is not the end of calculus instruction. Rather, this and other open-access online courses herald a time of experimentation and rapid improvement in how we communicate mathematics to the world.

I volunteered to build this MOOC to give a proof-of-concept for a different approach to calculus and calculus education. Over the course of a year, I designed, drew, animated, and recorded a complete second-semester calculus course. Two dedicated graduate students and two postdocs helped generate assessments and write a free Wiki-based text. The work was difficult; the impact on grateful learners across the world redeemed that difficulty in full.

Before turning to the question of MOOCs and their future, I wish to note that MOOCs are more than a translation of an existing course to a video format: they represent a novel means of rapid innovation in how we present mathematics. A few particulars of my MOOC should illustrate this point.

1) The video lectures are hand drawn and animated. Students gain a visually dynamic understanding of series, surfaces, moments, and more. Many find it fun, an adjective not normally applied to calculus texts.

2) The ordering is novel (apologies to Euler), beginning with Taylor series. The initial emphasis on their mechanics draws in those students of AP calculus who grasp derivatives without depth. The course then turns to limits, derivatives, integrals, and applications, drawing conceptual insight from Taylor expansions throughout. Sequences and a more rigorous approach to series are part of "discrete calculus"—recapitulating calculus for functions with discrete input and analog output (i.e., sequences).

3) Connections to deeper ideas in mathematics and applications are repeatedly drawn. The nonthreatening nature of comic-book-style animations lets me foreshadow commutative diagrams, generating functions, and network topology without overwhelming students. Asymptotic notation (big-O) is used throughout, and an emphasis on contemporary applications empowers students for future courses in the sciences.

Some will view these changes as refreshing; others will find them misguided. Whatever the value of this particular offering, it demonstrates the degree of innovation possible with MOOCs. The rise of low-cost platforms for putting our courses online is a liberation from the publishing bureaucracy that has made the calculus education of today look almost identical to that of the 1980s and earlier (in every respect save price).

This course is one example of the creative possibilities for MOOCs. The reader can imagine what could be done with higher-level material. The potential advances arising from modular cross-linked content, collaborative development, and improvement based on data-mining student performance are profound. Though only a handful of MOOCs in mathematics have been developed, the optimism surrounding this platform is justified.

There are many open questions concerning MOOCs: what do they portend for our profession? our students? our community?

I wish to sidestep the more hyperbolic criticisms (such as meaningless completion rates or conspiracy theories of venture-capitalist plots) and instead address realistic risks and rewards. MOOCs certainly have the potential to do harm: harm to our students if regulations or laziness lead to entertaining pabulum catering to the lowest common denominator, harm to faculty if we are robbed of our freedom of creative expression in the classroom. However, the potential returns, especially to those without ready access to the best schools, are so compelling as to demand experimentation and investment.

The future of MOOCs is uncertain. I have learned this past year from my inaccuracy in predicting six months ahead that it is folly to predict a decade hence. I have also learned from the last century of mathematics research (not infrequently funded by the U.S. Department of Defense) that an innovation that can be imagined as being turned to evil almost always ends up being turned to an unimagined good. I am optimistic about MOOCs, especially in mathematics.

"What will MOOCs change?" is not the ultimate question. "Why do mathematicians exist?" is the critical question that we must answer—persuasively—with skillful exposition to all those we serve: students, parents, scientists, deans, and lawmakers. If we do not provide a comprehensible and compelling answer, others will answer the question for us. If we do not build high-quality expositions that demonstrate why mathematics is to be loved, others will build expositions communicating that mathematics is to be feared or endured. To us is given the gift of seeing the beauty and art in our discipline, a beauty that is not grasped without great effort. The rise of MOOCs is our profession's moment of opportunity to communicate its truths skillfully and artfully and to promote our core insights and modes of thought to an eager worldwide audience through this medium of rapid innovation.

—Robert Ghrist
Andrea Mitchell University Professor
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Letters to the Editor

On "Two Views: How Much Math Do Scientists Need?"

The *Notices*, August 2013, reprints E. O. Wilson's *Wall Street Journal* piece "Great Scientist ≠ Good at Math" and Edward Frenkel's spirited response in *Slate*, "Don't Listen to E. O. Wilson".

I agree with Frenkel, but a professor of mathematics is the least convincing person to advocate for students of other sciences taking more math courses. In fact, if the only people vigorously promoting math for scientists were mathematicians, I would have serious fears for the future of our profession!

I am convinced that this is not the case. Many eminent biologists can rebut Wilson's piece with personal stories of how their own breakthroughs were made possible by their mathematical educations. I will ask some of my colleagues in the so-called nonmathematical sciences to read Wilson's and Frenkel's essays and send responses to me, and I encourage other members of the AMS to do the same. I will share these with the editor of the *Notices*; I guarantee they will be extremely interesting reading.

—Bruce Bayly
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(Received August 5, 2013)

Frenkel Misreads Wilson

Reading E. O. Wilson's essay and Edward Frenkel's response to it [*Notices*, August 2013], I thought Frenkel mischaracterized Wilson's views. Wilson's point was that fear of mathematics was driving away potential scientists and that it need not do so. It seems to me that this point is hard to disagree with. In no way was Wilson arguing that potential scientists should not learn mathematics. Frenkel points out that Wilson is "octogenarian". How is this relevant? The only point I can see of making this statement is to insinuate that Wilson is too old to have a valid opinion. Frenkel also says that Wilson believes fear of math is justified and most scientists don't need math. Wilson does not say that in his article, and I would be very surprised if he believed it. Frenkel says that Wilson's thesis is that "great scientists don't need math," in quotation marks. The quotation marks lead one to believe that this is a quote from Wilson's article, but no such quote appears in the article. Furthermore, I don't think that is Wilson's thesis. In all, Frenkel's essay is of much lower quality than Wilson's, and I think the *Notices* should have thought twice before publishing it.

—Mark Hovey
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(Received August 2, 2013)

Wilson's Misguided Headline

Both articles speak for themselves, so I shall only respond to Mark Hovey's comment that the quote "great scientists don't need math" does not appear in E. O. Wilson's article. In fact, this was the headline under which Wilson's article was published online on the *Wall Street Journal* website, and under which it was distributed on social media, such as Twitter.

—Edward Frenkel
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(Received August 12, 2013)

Do Scientists Need Math?

The disagreement in the essays by Wilson and Frenkel in the August issue of the *Notices* seems, on first reading, to be fundamental and sharp. But it can be made moot simply by qualifying the overly broad term "scientist". The biological and social sciences are very different from the physical sciences. It is not controversial that physicists and chemists need quite a bit of math, but it may well be a defensible position that at the current state of their science many biological and social scientists do not need much mathematics beyond statistics.

And, by the way, other differences between the biological and physical sciences occasionally show up. It is no longer surprising that when "scientific" fraud makes it into the newspaper, the science is usually biomedical. Also, most popular disbelief or distrust in "science" concerns biology, such as evolution and the efficacy of vaccines; very few people refuse to use airplanes due to distrust of aerodynamics.

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(Received August 22, 2013)

Authors, Editors, and Referees

I would like to add a comment to Neal Koblitz's letter on "Errors in Papers" (*Notices*, August 2013).

Even the most talented mathematicians make errors that were not detected by referees and ended up published. Nowadays, authors and referees are under pressure, as Koblitz points out, but editors also deserve criticism.

Let me describe a recent case. Professor X wrote a paper on a subject originally investigated by A and B, two bright, talented, and inspiring mathematicians. Professor X built on results by A and B, whom he duly quoted in his manuscript. However, he noticed an error in the first page of one of the numerous papers written by A and B: an equivalence between two definitions given by A and B was wrong, and he decided to investigate the two structures associated with the nonequivalent definitions. He submitted the manuscript to the same journal where A and B had published, among many others, the paper with the error.

He got a rejection, in a computer-generated letter, stating only that the journal applies the highest standard and has a broad readership. No answer to his polite and tactful cover letter (in fact, Professor A had meanwhile passed away), no referee's report, nothing! Such an editor's message is indeed ridiculous, to say the least. Highest standard, but an error was published and a correction was denied.

Is such an editor acting in a rational way?

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(Received August 6, 2013)

Can *Bulletin* Papers Be Made More Readable?

My purpose in writing is to raise the question: Is there a better format for some of the papers in the *Bulletin of the AMS*—better meaning, more likely to achieve the goal of the *Bulletin* as implied by the statement on the inside of its front cover: The *Bulletin* publishes expository articles on contemporary mathematics research written in a way that gives insight to mathematicians who may not be experts in the particular topic.

This question was motivated by the paper in the July 2013 issue of the *Bulletin*, "Chern-Weil Forms and Abstract Homotopy Theory". Let me hasten to say that I have no doubt the paper describes research results that are an important contribution to the relevant field. I am raising a question about format, not content.

In particular, the question was motivated by my realization, soon after I began attempting to read the paper, that I had no chance of understanding most of it. It seemed to me to be a paper written for specialists. And so I began asking myself the following questions:

(1) What are the criteria that the editorial staff uses to determine if a paper is likely to give insight to mathematicians who may not be experts in the particular topic?

(2) Does the staff conduct tests on randomly-selected members of the readership to determine to what degree the goal of the *Bulletin* is being met?

(3) What is the minimum knowledge that the staff assumes that any reader should have?

It seems to me that some policies that might improve readability are: (A) written specification, for use by editorial staff, of the minimum level of knowledge assumed for any reader; (B) in each paper containing terms outside this minimum level, an index, with specific references to definitions or brief informal explanations of terms in the paper; (C) structured proofs (à la structured programs) so readers could read proofs top down, hence only to the depth of detail they were interested in; (D) a statement at the beginning of each paper as to why it was chosen for the readership—what is important about it, etc.

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(Received August 9, 2013)

Reply to Letter of Spencer Bloch

Thanks to Professor Bloch for his thoughtful comments (Letter to the Editor from Spencer Bloch, *Notices*, October 2013). It is nice to know that my article was read and stimulated some reactions. Actually I am pleased to have heard from a number of mathematics departments in institutions nationally and internationally that are engaged in discussing teaching practices for their mathematics classes.

I agree with Professor Bloch that evaluating teaching is a challenging task. What particular teaching style works for some students may not work for others. Therefore any generalizations about teaching practices must be offered with caution. Having said that, I think the pioneering work that Carl Wieman (Nobel Prize in Physics in 2001) has done in science education is worthy of careful study and discussion by faculty members in mathematics departments. Much of the innovation in teaching being advocated in science education is based on evidence-based teaching practices. While successful evidence-based teaching practices may differ among the sciences, indeed even among teachers, it seems that any mathematics department seriously discussing teaching practices would want to engage in some self examination.

The goal of a departmental self-study would not necessarily be to identify a particular teaching approach, but rather to learn more about what kinds of teaching practices work best in what specific mathematics classes with what types of students. This research involves multiple variables, many of which are difficult if not impossible to control. Such research is generally considered in the mathematics education domain, but more mathematicians are needed in this effort. Research of this type is complex, always messy, and may be excruciating to the researchers engaged in this effort. I am reminded of the book *Mathematics Education Research: A Guide for the Research Mathematician*, by C. McKnight, A. Magid, T. Murphy, and M. McKnight (AMS, 2000), which identifies some of the challenges faced. This book might provide a nice starting point.

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(Received September 3, 2013)

"AMS to Launch New Open Access Research Journals": A Step in the Wrong Direction!

I firmly believe that offering two new gold open access journals is not in the best interest of the average member of the AMS; see *Notices*, August 2013, p. 873. The "author-pays model" [1] is not even in the best interests of the most talented mathematicians: it will introduce a filter that pre-selects among mathematicians of similar quality only those who are able and willing to spend money for their publications, even before any referee is able to evaluate their results. The attempt to equate the quality of research with money is a step in the wrong direction that will sooner or later backfire. From an ethical perspective, it looks even worse than impact factor manipulation.

[1] Pisanski, Tomaž, Open access—Who pays?, *Newsl.-Eur. Math. Soc.*, June 2013 **88**, 54–56. http://www.ems-ph.org/journals/newsletter/pdf/2013-06-88.pdf

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(Received August 23, 2013)

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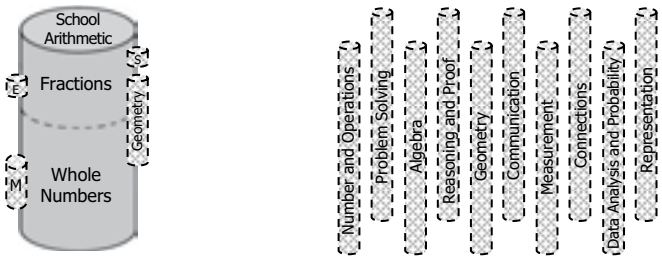
A Critique of the Structure of U.S. Elementary School Mathematics

Liping Ma

Research in mathematics education can be partitioned in many ways. If research in elementary mathematics education is partitioned into just two categories, content and method, this article may seem to belong only to the latter. It argues that consideration of the way in which the content of elementary mathematics is organized and presented is worthwhile for both U.S. and Chinese elementary mathematics educators. But, as illustrated in this article, organizing structure may affect the content that is presented.

Two distinguishing features of organizing structures for elementary mathematics are categorizations of elementary mathematics content and the nature of the relationship among the categories. These features are illustrated by the two examples in Figure 1 below.

Example A has a "core-subject structure". The large gray cylinder in the center represents school arithmetic. Its solid outline indicates that it is a "self-contained subject". (The next section of this article elaborates the meaning of this term.) School arithmetic consists of two parts: whole numbers (nonnegative integers) and fractions (nonnegative rational numbers). Knowledge of whole numbers is the foundation upon which knowledge of fractions is built. The smaller cylinders represent the four other components of elementary mathematics, shown according to the order in which they appear in instruction. These are: measurement (M); elementary geometry, simple equations (E); and simple statistics (S). (The last is similar to the U.S. "measurement and data" and includes tables, pie charts, line graphs, and bar graphs.) The dotted outlines and interiors of these components indicate that they are not self-contained subjects. The sizes of the five cylinders reflect their relative proportions within elementary mathematics, and their positions reflect their relationship with arithmetic: arithmetic is the main body of elementary mathematics, and the other components depend on it. Each nonarithmetic component occurs at a stage in the development of school arithmetic that allows the five components to interlock to form a unified whole.



A. China: Before 2001 *Standards* B. U.S.: 2000 NCTM *Standards*

Figure 1. Two organizations of elementary school mathematics.

Example B has a "strands structure". Its components are juxtaposed but not connected. Each of the ten cylinders represents one standard in *Principles and Standards for School Mathematics*. The content standards appear in the front, and the process standards appear in the back. No self-contained subject is shown. This type of structure has existed in the U.S. for almost fifty years, since the beginning of the 1960s. Over the decades, the strands have been given different names (e.g., "strands", "content areas", or "standards") and their number, form, and content have varied many times.

In these two structural types, the main difference is that the core subject structure has a self-contained subject that continues from beginning to end. In contrast, the strands structure does not, and all its components continue from beginning

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to end of elementary mathematics instruction. School arithmetic, the core subject in Figure 1A, does not appear as a category in Figure 1B.

U.S. elementary mathematics used to have a structural type like that of Example A. However, in the 1960s it began to change radically, eventually acquiring the structural type illustrated by Example B. The next two sections describe the features, origins, and evolution of these two structural types.

Core-Subject Structure: Features, Origin, and Evolution

Notable Features of Example A

Because I was not able to obtain the pre–2001 Chinese mathematics education framework, the details shown in Figure 2 are drawn from a set of Chinese elementary textbooks published in 1988.[1] The main part of Figure 2 is school arithmetic, the content of the gray cylinder in Figure 1A. The large rectangle shows arithmetic instruction beginning at the bottom in grade 1 and continuing upward to grade 6. Light gray indicates whole number content, and dark gray indicates fraction content (including decimals, ratio, and proportion).

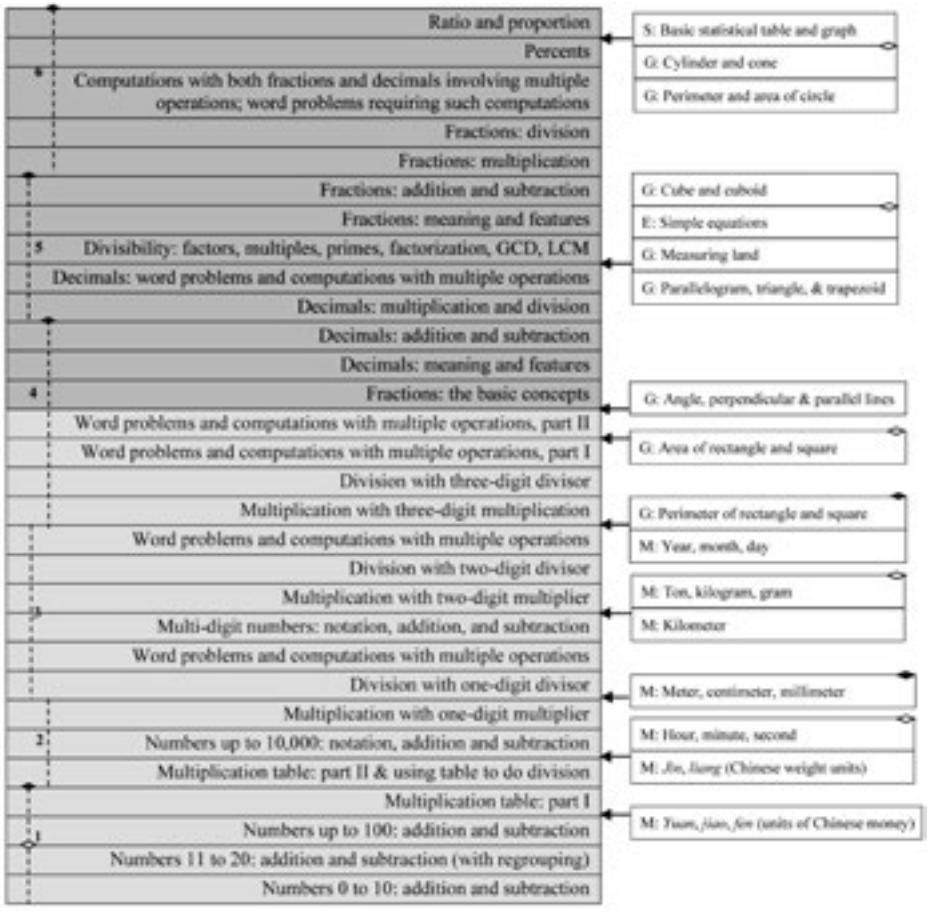

Figure 2. A pre-2001 organization of school mathematics in China.

The small boxes at the right represent the remaining four components: measurement (M), elementary geometry (G), simple equations (E), and simple statistics (S). Their placement indicates their order in instruction. The arrows indicate when each nonarithmetic section occurs relative to arithmetic instruction.

The dotted vertical lines at the left and numbers beside them indicate the grades in which the topics occur. The white rhombus indicates the end of the first semester; the black rhombus indicates the end of the school year.[2]

Next we will discuss the features of Example A that are visible in Figure 2.

The first feature is the large portion of the figure occupied by arithmetic. Together the twelve textbooks used for grades 1 to 6 have 1,352 pages.[3] Arithmetic occupies 1,103 pages, which is 81.6 percent of the total. As for other components, measurement occupies 36 pages, elementary geometry 135 pages, simple equations 23 pages, simple statistics 18 pages, and 37 pages are for abacus.[4] All the nonarithmetic content (including abacus) is only 18.4 percent.

The second feature visible in Figure 2 is the relationship between arithmetic and nonarithmetic content. Please note the insertion points for

[1] *In 1988 China had several series of elementary mathematics textbooks. This series was one of the most widely used and was produced by writing groups from Beijing, Tianjin, Shanghai, and Zhejiang. The organizing structure discussed in this section was common to all the textbook series used in China.*

[2] *The school year in China has two semesters, each about twenty weeks long.*

[3] *Please notice the differences between Chinese and U.S. elementary mathematics textbooks. The series of textbooks for six years has twelve small books, one book for each semester. All their content is considered essential rather than optional. On average, each book in the series has 113 pages, with page dimensions of 8 inches by 6 inches. Of all these books, only the first uses color and that occurs on only two pages. Each student gets his or her own set of textbooks. In contrast, in the U.S. an elementary mathematics textbook for one year often has about six hundred pages, frequently uses color, and has pages approximately twice the size of the Chinese textbook pages. In general, the textbooks are the property of the school district rather than the student, and students are not able to bring the textbooks home.*

[4] *There are two sections devoted to abacus instruction. The first, on addition and subtraction, occurs during the last unit of the first semester of grade 4. The second, on multiplication and division, occurs during the last unit of the first semester of grade 4. In order to simplify Figure 2, these are not shown.*

nonarithmetic content indicated by arrows. We can perceive the thirty sections of arithmetic in Figure 2 as several larger chunks, each with its own mathematical unity. That unity is supported by instructional continuity; that is, within a chunk, consecutive sections of arithmetic content occur in instruction without interruption from nonarithmetic content. For example, the first thirty weeks of instruction consist only of arithmetic—numbers 0 to 10 and their addition and subtraction, followed by numbers from 11 to 20 and their addition and subtraction (including regrouping), followed by numbers to 100 and their addition and subtraction. These three sections are tightly connected, supporting students' learning of numbers less than 100 and their addition and subtraction, thus laying a solid cornerstone for later learning. Another unified chunk is formed by the section on divisibility to the section on percents, allowing students to learn the four operations with fractions (which is difficult) without interruption. Moreover, in the twelve semesters of the six years, ten semesters start with arithmetic, and nonarithmetic content occurs at the end of the semester. In this organization, arithmetic is noticeably emphasized.

The third feature visible in Figure 2 is the ordering of the instructional sections. This order attends to both mathematical relationships among calculation techniques and considerations of learning. For example, the first three sections of grade 1 are ordered by calculation technique. If technique were the sole consideration, these would be immediately followed by addition and subtraction of numbers less than 1000. However, in the textbook the fourth and fifth sections are on multiplication tables and using multiplication tables to do division. Learning multiplication tables and doing division with them allows students to continue their study of numbers up to 100 with a new approach. That is very beneficial for creating a solid foundation for elementary mathematics learning. Another example: after the section "Fractions: the basic concepts", the textbook does not immediately continue with "Fractions and operations". Instead it has a section on decimals. Calculation techniques for operations with decimals are very similar to those of whole numbers, but the concept of decimals is a special case of the concept of fractions. This arrangement affords understanding of the concept of decimals, review of the four operations with whole numbers, and preparation for future learning of fractions, their properties, and operations with fractions. (Note that this organization affords but does not guarantee this understanding. Curriculum design and instruction also need to be consistent with this goal.)

There are also three features worth noting about the nonarithmetic sections shown in Figure 2. First, in the whole process of elementary mathematics learning, the nonarithmetic content is supported by the arithmetic content that precedes it but, at the same time, reinforces that arithmetic content. In general, each section of nonarithmetic content occurs when arithmetic learning has arrived at a stage that prepares students to learn that content. For example, the section on units of Chinese money occurs immediately after "Numbers up to 100: addition and subtraction". At that point, students have acquired significant knowledge of numbers within 100 and are able to add and subtract these numbers. That forms the foundation for students to learn the units of Chinese money. (Chinese money has three units: *fen, yuan, jiao*: 1 *yuan* is 10 *jiao*, 1 *jiao* is 10 *fen*; thus 1 *yuan* is 100 *fen*.) At the same time, learning the units of Chinese money provides students a new perspective on the arithmetic that they have just learned, allowing them to review and consolidate their prior learning. Similarly, because reading an analogue clock relies on multiples of 5, the section on units of time allows students the opportunity to apply the multiplication that they have just learned and reinforce this knowledge.

The four nonarithmetic components appear consecutively except for one short overlap. The first component is measurement, which consists of seven instructional sections, all of which occur before third grade. Next is elementary geometry, which is formed by eight sections, distributed from third grade to sixth grade. At the end of the first semester of fifth grade, the component simple equations occurs. This component has only one section and occurs between two sections of elementary geometry. After geometry, almost at the end of sixth grade, simple statistics occurs. This kind of arrangement ensures that one type of nonarithmetic content is finished before a new type begins.

The third notable feature is that the sizes of the nonarithmetic components are different. If we consider the total nonarithmetic content as 100 percent, their sizes are, from greatest to smallest: elementary geometry (64 percent), measurement (17 percent), simple equations (11 percent), simple statistics (8 percent). That means that the core-subject structure doesn't treat nonarithmetic components equally but emphasizes some more than others. The one receiving most emphasis is elementary geometry. In fact, if the measurement of length in the measurement component is counted as part of elementary geometry, then elementary geometry occupies even more than 64 percent. This noticeable emphasis on elementary geometry is associated with the mathematical content of middle school. In elementary school, arithmetic prepares the foundation for learning algebra, and elementary geometry prepares the foundation for learning geometry.

In summary, if considered individually, the sections shown in Figure 2 may not seem remarkable

or interesting. However, when their interrelationships are considered, these sections are revealed as a tightly connected, carefully designed six-year-long path for learning mathematics.

Essential Feature of Core-Subject Structure: An Underlying Theory

If Chinese elementary mathematics had only the features visible in Figure 2, it would not deserve the label "core-subject structure". These features do not indicate whether the school arithmetic shown is a collection of skills or a self-contained subject with principles similar to those of the discipline of mathematics. The latter is true: there is a theory of school arithmetic that underlies the topics in the gray column of Figure 2.

The precursor of school arithmetic was "commercial mathematics", which existed in Europe for several hundred years after Arabic numbers were introduced. Its content was computational algorithms without explanations.[5] In the mid-nineteenth century, with the movement toward public education in the U.S. and Europe, mathematical scholars participated in producing elementary school arithmetic textbooks.[6] Their exemplar was Euclid's *Elements*, the most influential mathematics textbook in history. These scholars followed the approach of the *Elements*, striving to establish a system of definitions for operations with whole numbers and fractions. Near the end of the nineteenth century this system was almost complete. Interestingly, although this system is fairly exhaustive, China did not contribute to its construction. On the contrary, in the U.S. elementary mathematics textbooks of the late nineteenth century, we see the efforts and contributions of U.S. scholars.

Rather than starting from self-evident geometrical concepts such as line and point as Euclid did, these scholars began with the self-evident concept of unit to create a definition system for all of school arithmetic. For example, relying on the definition of unit 1, two basic quantitive relationships—the sum of two numbers and the product of two numbers—are defined. The operations of addition and subtraction are defined in terms of the former, and multiplication and division in terms of the latter.[7] With this definition system, school arithmetic is self-contained in the sense that each of its concepts is defined in terms of previous concepts, tracing back to the starting point, the unit 1. The concepts in the system are sufficient to explain the algorithms for the four operations on whole numbers and fractions that elementary students learn. With this definition system, we cannot only make coherent explanations for operations with whole numbers and fractions but can also analyze fairly complicated quantitative relationships using the definitions of the system. For example, the problem given on the tomb of the famous mathematician Diophantus can be solved using such an analysis.[8] The elementary students who learn operations with whole numbers and fractions with this definition system master the algorithms for computation while learning abstract thinking. The definition system of school arithmetic is the main part of the theory of school arithmetic. In China and some other countries, this system of definitions still underlies instruction for operations with whole numbers and fractions.[9]

Judging Whether a Country's School Arithmetic Has an Underlying System of Definitions

How can one judge whether a country has a definition system unifying its school arithmetic? The following problem can provide an efficient test. Moreover, by showing the complexity of the quantitative relationships that can be analyzed, it illustrates the intellectual power of school arithmetic with an underlying definition system.

A few years ago the field of U.S. mathematics education experienced a small shock from a word problem in a fifth-grade Singapore textbook.

> Mrs. Chen made some tarts. She sold 3/5 of them in the morning and 1/4 of the remainder in the afternoon. If she sold 200 more tarts in the morning than in the afternoon, how many tarts did she make?[10]

[5] *As Keith Devlin points out in Chapter 4 of his book* The Man of Numbers, *although Fibonacci provided explanations based on the* Elements *in his* Liber Abaci, *"how-to" books for commercial arithmetic focused on worked examples.*

[6] *The term "mathematical scholars" is intended to suggest the difference between present-day mathematicians and some of those nineteenth-century contributors. The latter included professors of mathematics such as Charles Davies, whose mathematical activity was not centered on research.*

[7] *See the supplementary online material at* `http://lipingma.net/math/math.html` *for more details.*

[8] *This problem is: "God vouchsafed that he should be a boy for the sixth part of his life; when a twelfth was added, his cheeks acquired a beard; He kindled for him the light of marriage after a seventh, and in the fifth year after his marriage He granted him a son. Alas! late-begotten and miserable child, when he had reached the measure of half his father's life, the chill grave took him. After consoling his grief by this science of numbers for four years, he reached the end of his life". Using the definition system, a solution is obtained from (5 + 4) ÷ (1/2 − 1/6 − 1/12 − 1/7) = 84.*

[9] *There is no evidence that the definition system in Chinese elementary mathematics was adopted directly from the U.S.*

[10] Primary Mathematics 5A Workbook *(3rd ed.), 1999, Curriculum Planning & Development Division, Ministry of Education, Singapore, p. 70.*

Although people educated in the U.S. could solve this problem with nonarithmetic approaches, no one knew how to solve it using an arithmetic equation, such as

$$\begin{aligned} & 200 \div [3/5 - 1/4 \times (1 - 3/5)] \\ = \; & 200 \div 1/2 \\ = \; & 400 \quad \text{Answer: 400 tarts} \end{aligned}$$

Because concepts other than "unit" in the definition system are defined in terms of earlier concepts, the later a concept is defined, the more previously defined concepts it may rely on. The concept needed to solve the tarts problem occurs in the last section of the definition system. People whose elementary mathematics instruction included all the concepts of the definition system are prepared to solve this problem. Otherwise they are not prepared to solve this problem using an arithmetic equation. Thus, testing elementary students after they learn fractions by asking them to solve this word problem provides evidence of whether or not their country still uses a fairly complete definition system.[11] This definition system underlies elementary mathematics in Singapore; thus, at the end of elementary school, Singapore students are prepared to solve this problem using arithmetic. In the U.S., not only elementary students but their teachers and the educators of those teachers are not able to solve the problem with arithmetic. This suggests that the definition system has, at least, decayed in the U.S.

The Construction of School Arithmetic

Examination of U.S. elementary textbooks suggests that, after the end of the nineteenth century, when most of the definition system was established, the development of school arithmetic as a subject came to a halt.[12] However, in some other countries, the development of school arithmetic continued. From the content of Chinese elementary mathematics we can see three kinds of later evolution.

First, introduction of the basic laws: commutative, associative, distributive, and compensation laws.[13] These do not appear in nineteenth-century U.S. arithmetic textbooks. With these laws, explanations for computational algorithms become more concise, and applications of the algorithms become more flexible. Knowledge of these laws also forms a good foundation for learning algebra in middle school. This group of basic laws together with the definition system forms a theory of school arithmetic.

Second, types of word problems were introduced that described quantitative relationships in contexts, such as the relationship of distance, time, and velocity. These problem types came from ancient civilizations such as Rome and China and reflected an approach to mathematics different from that of Euclid.[14] The theory of school arithmetic established by following the approach of the *Elements* emphasizes rigorous reasoning, but these word problems provide prototypical examples of quantitative relationships. Solving variants of these problems promotes flexible use of these relationships. These types of word problems rarely appeared in late nineteenth-century U.S. elementary textbooks, but elementary textbooks in China, Russia, and perhaps other countries introduce them systematically. To solve these word problems by analyzing the quantitative relationships on the reasoning within the theory is a supplement and a contrast. The supplement comes from seeing a different approach to mathematics. The contrast comes from the differences in the two approaches and underlying mathematical traditions. Moreover, it broadens students' thinking and enriches the mathematical content.

Third, the pedagogy of school arithmetic developed further. The definition system of school arithmetic that we see in late nineteenth-century U.S. textbooks was presented with rigorous wording and in logical order. Although it was rigorous according to the discipline of mathematics, as presented it was too abstract for elementary school students. That might be a reason why the construction of the theory of school arithmetic stopped in early twentieth-century America. However, with many years of effort, China and some other countries have found instructional approaches for teaching school arithmetic that has this underlying theory. These approaches vary in at least three ways: in the order of the content, how it is represented, and the design of

[11] *The time at which students are asked this question, just after learning division by fractions, is very important. Prior to that, students have not learned the entire definition system. Later, students will learn to solve such problems using algebra.*

[12] *In some early twentieth-century writings in U.S. mathematics education, such as Buckingham's* Elementary Arithmetic: Its Meaning and Practice, *we see evidence of further exploration of the definition system. However, I have found no evidence that such explorations affected elementary mathematics textbooks.*

[13] *Like the definition system, the basic laws are presented with words, numbers, and the signs introduced in the definition system, with no symbols beyond arithmetic (letters are not used). For example, the commutative law for addition may be presented as "If two addends interchange their place, the sum does not change," with an example such as 3 + 2 = 5, 2 + 3 = 5. The compensation law for addition may be presented as "If one addend increases by an amount and the other addend decreases by the same amount, the sum does not change," with an example such as 5 + 4 = 9, (5 + 2) + (4 – 2) = 9. This feature of not using language beyond arithmetic is significant in terms of ensuring that the students' learning task does not go beyond their intellectual readiness.*

[14] *See the supplementary online material at* `http://lipingma.net/math/math.html` *for more details.*

exercises. "Three approaches to one-place addition and subtraction" [Ma, n. d.] gives examples of how these three aspects can work together to introduce concepts defined within a system and basic laws to first-grade students.

After these changes—introduction of basic laws, introduction of prototypical problems, and pedagogical advances—the construction of school arithmetic as a subject was basically complete. It consisted of four components:

- Arabic numerals and notation for whole numbers, fractions, and operations on them, inherited from commercial arithmetic.
- Definition system augmented by basic laws.
- Prototypical word problems with variants.
- Instructional approaches.

This school arithmetic was self-contained: it had an underlying theory following the approach of the *Elements*. It was open: although based on the Euclidean tradition of Greek mathematics, it included mathematical traditions of other civilizations. It was teachable: developments in pedagogical approaches created a school arithmetic that was learnable by following the character of students' thinking and leading students step by step to progressively more abstract thinking.

In the U.S., although much of the definition system had been established by the end of the nineteenth century, during several decades of the progressive education movement the three types of developments discussed above did not occur in significant ways. Thus in the U.S. the construction of school arithmetic as a subject was never really completed. In other words, a well-developed school arithmetic never really existed as a subject to be taught to U.S. children.

U.S. Strands Structure: Origin, Features, and Development

Although it never had a well-developed school arithmetic, after the beginning of elementary education, arithmetic was the core of elementary mathematics in the U.S. for almost one hundred years. However, today's U.S. elementary mathematics has a different type of structure. When did this change happen? How did it evolve into the structure shown in Figure 1B? What did this change in structure mean to U.S. elementary mathematics? We begin with the creation of this structure in the first California mathematics framework.

During the past few decades, the relationship between mathematics education in California and the rest of the nation has been intriguing. In some sense, we can say that California has been the forerunner of the rest of the United States. In her book *California Dreaming: Reforming Mathematics Education* Suzanne Wilson mentions several times how mathematics reform in California has influenced that of the entire nation. She points out

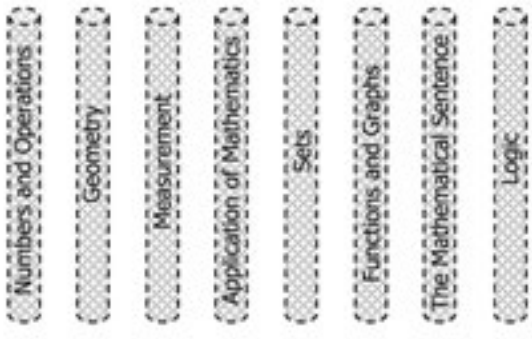

Figure 3. The structure suggested by the First Strands Report.

that the 1989 NCTM *Curriculum and Evaluation Standards for School Mathematics* and the 1985 *California Mathematics Framework* "drew on the same research, commitments, and ideas" (2003, p. 26). What we will discuss here, however, is an even earlier, more profound, California influence on national mathematics education. This is the fundamental change in the structure of elementary mathematics content initiated by the first California mathematics framework known as "The Strands Report".

The First California Mathematics Framework: Creation of Strands Structure

In October of 1957 the Soviet Union launched Sputnik. This unusual event caused the U.S. to reflect on its science and mathematics education. In 1958 the National Science Foundation funded the School Mathematics Study Group (SMSG), led by the mathematician Edward Begle, to promote the reform of U.S. mathematics curriculum, later known as the "new math".

In 1960 California formed the State Advisory Committee on Mathematics, with Begle as its chief consultant to launch the statewide reform of mathematics education. The committee was composed of three subcommittees. The first subcommittee on "Strands of Mathematical Ideas" consisted mainly of mathematics professors. Its charge was to decide the new mathematical structure of the new curriculum. The charge of the other two subcommittees was to implement the new curriculum: one to decide how to prepare teachers for the new curriculum and the other to investigate "the more recent 'new' mathematics programs that have attracted national attention" and study "commercially produced materials that could be used profitably to supplement the state adopted materials" (p. v).

In 1963 the reports from the three committees were published as *Summary of the Report of the Advisory Committee on Mathematics to the California State Curriculum Commission*. Because its main section was "The Strands of Mathematics" the whole report was known as "The Strands

Report". Later, its official name became the *First California Mathematics Framework*. In this report, the arithmetic-centered structure of elementary mathematics was replaced by a different type of structure consisting of juxtaposed components, creating the strands structure.

"The Strands Report" began:

> The curriculum which we recommend departs but little from the topics normally studied in kindergarten and grades one through eight, topics which long ago proved their enduring usefulness. But it is essential that this curriculum be presented as one indivisible whole in which the many skills and techniques which compose the present curriculum are tied together by *a few basic strands of fundamental concepts* which run through the entire curriculum. (pp. 1–2, emphasis added)

According to the report, these "basic strands" are:[15]

1. Numbers and operations
2. Geometry
3. Measurement
4. Application of mathematics
5. Sets
6. Functions and graphs
7. The mathematical sentence
8. Logic

The idea of tying together elementary mathematics content with these eight strands meant a twofold revolution in the elementary mathematics curriculum. One was the revolution in the components of content. Arithmetic was no longer considered to be the main content. Instead, concepts from advanced mathematics such as sets, functions, and logic were introduced into elementary mathematics. Second was a revolution in the structural type, establishing a new strands structure for elementary mathematics.

Each of the eight strands was represented as a few concepts from a branch of mathematics but not as a self-contained subject. Although the report discussed a few important concepts for each strand, there was no evidence that these important concepts sufficed to form a system that provided explanations for the operations of elementary mathematics. For example, the strand "Numbers and operations", which might be considered closest to arithmetic, included fifteen concepts, such as one-to-one correspondence, place value, number and numeral, and Cartesian product (CSED, pp. 4–13).[16] The report claimed that these fifteen concepts were important but did not explain how they were related. The other seven strands were discussed in a similar way.

From the earlier quotation, we can see that the authors of "The Strands Report" intended to express all of elementary mathematics in terms of a few basic concepts and thus unify its content. However, realization of this idea was not widespread in U.S. elementary education. In this way, the newly introduced concepts from advanced mathematics did not unify elementary mathematics, although the earlier definition system of school arithmetic was officially abandoned. Since then, the concepts in U.S. elementary mathematics education have never had an underlying definition system that played the same role as the earlier one.

Today, when we read "The Strands Report", we should admit that it has some interesting and inspiring ideas and discussions. We can also understand that its authors, facing concerns about national security at that time, wished to introduce concepts from advanced mathematics. However, maybe because of insufficient time or other reasons that we don't know, they didn't even make an argument for the new approach. Why change the previous elementary mathematics curriculum with arithmetic at its center to this curriculum with eight strands?[17] What is the advantage of doing so? Why these eight strands and not others? Why were these eight strands the most appropriate for making elementary mathematics into "one indivisible whole"?

"The Strands Report" presented the wish of unifying elementary mathematics curriculum into an indivisible whole; however, its structure militated against this aim. It did not present evidence that the eight strands would form an indivisible whole. Moreover, because its structure consisted of juxtaposed categories without evidence to show that

[15] *The report may have drawn on two intellectual resources: Bruner's* Process of Education *(1960) and Nicolas Bourbaki's* Elements of Mathematics. *Discussion of their possible influence on the first Strands Report is beyond the scope of this article.*

[16] *The fifteen concepts in the Numbers and operations strand are: One-to-one correspondence (p. 4), Place value (p. 5), Number and numeral (p. 6), Order: The number line (p. 6), Operations: Cartesian-product (pp. 7–8), Array (p. 7), Closure (p. 8), Commutativity (p. 9), Associativity (p. 9), Identity elements—zero and one (p. 10), Distributivity (p. 10), Base (p. 11), The decimal system (p. 12), Square root (p. 13).*

[17] *The report says: "The arithmetic…must* not *appear to the pupil as a sequence of disconnected fragments or computational tricks. Some of the important unifying ideas are discussed briefly in the following section of this report" (p. 4). The report did not mention that there was a self-contained definition system underlying late nineteenth-century U.S. elementary mathematics. From this, I infer that the authors of the report were not aware of the definition system.*

First Strands Report, 1963	Second Strands Report, 1972	"Basics Framework", 1975
1. Numbers and operations	1. Numbers and operations	1. Arithmetic, numbers and operations
2. Geometry	2. Geometry	2. Geometry
3. Measurement	3. Measurement	3. Measurement
4. Application of mathematics	4. Applications of mathematics	4. Geometric intuition
5. Functions and graphs	5. Statistics and probability	5. Problem solving and applications
6. Sets	6. Sets	6. Probability and statistics
7. The mathematical sentence	7. Functions and graphs	7. Relations and functions
8. Logic	8. Logical thinking	8. Dosposition to model
	9. Problem solving	9. Logical thinking

Figure 4. Changes in the strands.

these categories were the only appropriate choice, changes in the strands were unavoidable. In fact, such changes occurred only a few years later and have continued to occur.

The direct result of representing elementary mathematics as a strands structure is that arithmetic stopped being its core. "The Strands Report" put some "arithmetic topics" into the Numbers and operations strand and some into other strands. From that point on, school arithmetic, which had stopped its development in the early twentieth century, officially disintegrated.

The Second California Mathematics Framework: First Change in the Strands

Four years later, in 1967, the California State Mathematics Advisory Committee submitted its second Strands Report. This was formally published in 1972 as *The Second Strands Report: Mathematics Framework for California Public Schools*. In this second report, the number and names of the strands changed.

The "Mathematical sentence" strand was removed. Two new strands, "Statistics and probability" and "Problem solving", were added, changing the number of strands from eight to nine. At the same time, the "Logic" strand was changed to "Logical thinking". No explanation of these changes was given in the document.

As we have seen, the strands structure allowed an unlimited number of possibilities for changing the names, number, content, and features of the strands. After this, U.S. elementary mathematics lost its stability and coherence. After only four years, the same mathematics professors who wrote the first Strands Report changed the strands without explanation. In a strands structure, no strand was self-contained; moreover, the relationship among the strands was such that individual strands could be readily changed. Anyone writing a framework could easily change the content of mathematics education by changing a strand. Later, when the main authors of the mathematics framework were not mathematicians but teachers and cognitive scientists, they retained its structure, but changed its strands to fit their views of mathematics education.

The "Back to Basics" Framework: Same Structure, Different Vision

Three years after the publication of the second Strands Report, the direction of mathematics education in California changed dramatically. The education department decided to give up the "new math" promoted in the two earlier frameworks and emphasize "the acquisition of basic mathematics skills" (CSDE, 1975, Preface). An ad hoc Mathematics Framework Committee was formed, led by a high school teacher. In 1975 the third California mathematics framework was published.[18] The Superintendent of Public Instruction wrote in the foreword that although this new framework could be called a "post-new math framework", he himself preferred to call it the "basics framework". He emphasized that "the contents reflect the concerns of teachers rather than those of mathematicians." It is obvious that the vision of this framework is fundamentally different from that of the earlier two. The vision of the mathematicians who wrote the first two Strands Reports was abandoned. Mathematicians were no longer the leaders in writing frameworks.

As a sign of the end of "new math", the "Sets" strand was removed. The new framework combined "Problem solving", the last strand of the previous framework, with its fourth strand "Application of mathematics". Two strands had their names changed: "Numbers and operations" changed to "Arithmetic, numbers and operations", and "Functions and graphs" changed to "Relations and functions" (see Figure 4).

Another type of change in the "basics framework" was the way in which objectives were presented. The first framework had abandoned the traditional presentation of content by grade, instead

[18] *From this version on, California frameworks addressed grades K through 12. In this article I discuss only the aspects of the frameworks that pertain to elementary mathematics.*

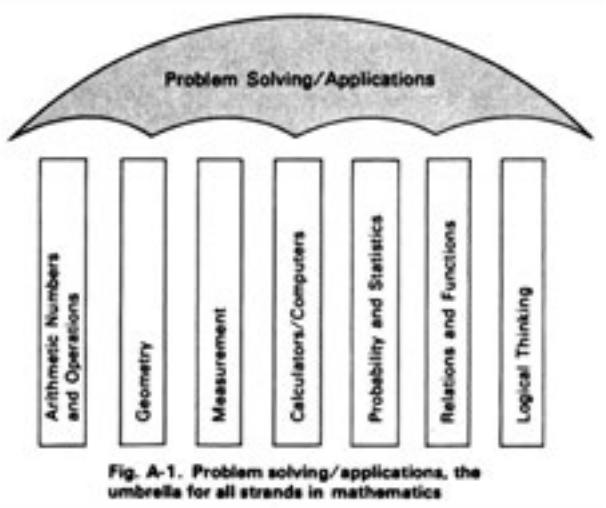

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Figure 5. The 1980 Addendum emphasized problem solving (CSDE, 1982, p. 60).

combining the content of grades K–8.[19] The basics framework used a different arrangement and presented the K–8 objectives for each strand by grade bands: K–3, 4–6, 7–8 (see its Appendix A). A third type of change was the creation of two kinds of strand categories: "strands" and "content areas" (1975, CSDE, p. 11).

Between the "new math" and "back to basics" eras, the vision of mathematics education changed fundamentally. However, the structure created by the mathematicians who wrote the first framework remained. This structure allows fundamental changes in vision to be presented simply by changing the strand categories.

1980 Addendum to the Framework: Problem Solving above All

A few years after the "basics framework" was published, the California State Department of Education published *Mathematics Framework and the 1980 Addendum for California Public Schools, Kindergarten through Grade Twelve*, consisting of the "basics framework" together with an addendum. The number of pages in the addendum was four-fifths the number of pages in the framework, in order to revise the vision of the "basics framework":

> As the result of the back-to-basics movement, there is a tendency by some educators to allocate too much time in mathematics classes to working with drill and factual recall. With the advent of low cost, high performance microprocessors and calculators, it becomes possible for computations to be done more accurately and in less time than in the past. This allows more time for problem solving, the major focus of the mathematics curriculum. (CSDE, 1982, p. 75)

To emphasize the importance of problem solving, the addendum took one strand from the previous framework and made it an umbrella for the other strands, which were called "skill and concept areas" to emphasize their subordinate role (CSDE, 1982, p. 59). This idea was emphasized by a figure (see Figure 5).

The approach of the *1980 Addendum* differentiated the strands, making some more important than others. This approach was continued in the next framework and influenced the 1989 NCTM *Curriculum and Evaluation Standards*.

1985 *California Framework* and 1989 NCTM *Curriculum and Evaluation Standards*: Creation of Subitems

The 1985 California framework and the 1989 NCTM standards shared a similar new vision of mathematics education. The new, exciting vision presented in these two documents was to let every student, not only academic elites, acquire "mathematical power" (CSDE, 1985) and become "mathematically literate" (NCTM, 1989).

As mentioned earlier, during the new math movement mathematicians intended to use fundamental mathematical concepts such as "set" and "function" to explain the content of elementary mathematics. However, the 1980s round of reform seems to have been influenced by cognitive science. Terms related to cognition, such as "ability", "cognition", "number sense", "spatial sense", "to communicate", "to understand", appear frequently in these documents.

The 1985 California framework stated:

> Mathematical power, which involves the ability to discern mathematical relationships, reason logically, and use mathematical techniques effectively, must be the central concern of mathematics education and must be the context in which skills are developed…. The goal of this framework is to structure mathematics education so that students experience the enjoyment and fascination of mathematics as they gain mathematical power. (pp. 1–2)

The 1989 NCTM standards suggested that to become mathematically literate involved five goals for students:

1. to value mathematics

[19] *The first Strands Report said: "Definite grade placement is not crucial. We must recognize that concepts are not mastered immediately but are built up over a period of time. It is therefore important that these notions be introduced as early as possible and be linked with the pupils' mode of thinking. Above all we seek, to the limit of each pupil's capability, his understanding of that unified mathematical structure which is the content of K–8 mathematical study." (CSDE, 1963, p. 2)*

2. to become confident in their ability to do mathematics
3. to become mathematical problem solvers
4. to learn to communicate mathematically
5. to learn to reason mathematically

The authors were convinced that if students are "exposed to the kinds of experience outlined in the *Standards*, they will gain *mathematical power*" (p. 5).

The structural type of the NCTM standards was visibly influenced by the earlier California frameworks. Although the frameworks referred to "strands" or "areas" and the standards referred to "standards", these items were organized in very similar ways. Via the NCTM standards, the strands structure that originated in the first California framework had a national impact. Wilson wrote:

> The boundaries between the national and California discussions of mathematics education and its reform were porous and permeable. It was hard—as observers—to separate those discussions and to determine where ideas originated…. Many California schoolteachers were part of the writing of and the reaction to the development of the NCTM *1989 Standards*. (2003, p. 127)

Although it was based on the *1980 Addendum*, the 1985 framework had a new kind of item: "major areas of emphasis that are reflected throughout the framework" (CSDE, 1985, p. 2), which occurred before the discussion of the strands. There were five of these areas:

1. problem solving
2. calculator technology
3. computational skills
4. estimation and mental arithmetic
5. computers in mathematics education

The 1985 framework changed some of the strands. "Problem solving/application" changed from a strand to a major area of emphasis and a new strand called "Algebra" was added. Some strands had their names changed: "Arithmetic, number and operation" to "Number"; "Relations and functions" to "Patterns and functions"; "Logical thinking" changed back to "Logic"; "Probability and statistics" to "Statistics and probability". In this way, five major "areas of emphasis" plus seven "strands" or "areas" became the twelve parts of the strands structure in the new framework.

This framework created a new kind of strands structure that had items and subitems. Under each strand a list of student understandings and actions was given. Although they were stated as objectives, their content suggested a partition of each strand. For example, under "Number" there are seven objectives. Under "Measurement" there are nine objectives. The 1985 framework had seven strands with forty-one objectives.

The NCTM 1989 standards used a similar structure. It set up thirteen standards:

> Each standard starts with a statement of what mathematics the curriculum should include. This is followed by a description of the student activities associated with that mathematics and a discussion that includes instructional examples. (NCTM, 1989, p. 7)

Like the 1985 framework, the 1989 NCTM standards separated the thirteen standards into two groups. The first four standards formed one group shared by all the grades: "Mathematics as problem solving", "Mathematics as communication", "Mathematics as reasoning", and "Mathematics as connections". The remaining nine standards formed a group related to content, and their names differed by grade band. For example, the names of the K–4 standards were "Estimation", "Number sense and numeration", "Concepts of whole number operations", "Geometry and spatial sense", "Measurement", "Statistics and probability", "Fractions and decimals", and "Patterns and relationships".

Similar to the 1985 framework, the 1989 NCTM standards had several objectives listed for each standard. Thus, both the 1985 framework and the 1989 standards had two layers: items (strands or standards), each of which was followed by a bulleted list of more detailed subitems. In general, a teacher concerned about addressing the standards seems more likely to have attended to the bullets rather than to the more general strands or standards. For example, when a K–4 teacher sees the first standard, "Mathematics as problem solving", he or she might think of one standard. When seeing the five bullets listed for this standard, the teacher's attention may be attracted to these, because they are supposed to be implemented in teaching. Thus, the content and number of subitems may have a direct impact on classroom teaching.

Table 1 lists the thirteen standards and fifty-six bullets of the K–4 standards (NCTM, 1989, pp. 23–61).

If one has the patience to read all fifty-six bullets in Table 1, one will find that many descriptions are vague and the relationships of the bullets are not visible. Several items are hard to understand without further explanation,[20] which the document does not give.

[20] *Some examples occur in Standard 8: Whole number computation which has as the last three of its four goals: relate the mathematical language and symbolism of operations to problem situations and informal language. Recognize that a wide variety of problem structures can be represented by a single operation. Develop operations sense.*

Table 1. 1989 NCTM K–4 Standards and Bullets

Standard 1: Mathematics as problem solving

1. Use problem-solving approaches to investigate and understand mathematical content;
2. Formulate problems from everyday and mathematical situations;
3. Develop and apply strategies to solve a wide variety of problems;
4. Verify and interpret results with respect to the original problem;
5. Acquire confidence in using mathematics meaningfully.

Standard 2: Mathematics as communication

6. Relate physical materials, pictures, and diagrams to mathematical ideas;
7. Reflect on and clarify their thinking about mathematical ideas and situations;
8. Relate their everyday language to mathematical language and symbols;
9. Realize that representing, discussing, reading, writing, and listening to mathematics are a vital part of learning and using mathematics.

Standard 3: Mathematics as reasoning

10. Draw logical conclusions about mathematics;
11. Use models, known facts, properties, and relationships to explain their thinking;
12. Justify their answers and solution processes;
13. Use patterns and relationships to analyze mathematical situations;
14. Believe that mathematics makes sense.

Standard 4: Mathematical connections

15. Link conceptual and procedural knowledge;
16. Relate various representations of concepts or procedures to one answer;
17. Recognize relationships among different topics in mathematics;
18. Use mathematics in other curriculum areas;
19. Use mathematics in their daily lives.

Standard 5: Estimation

20. Explore estimation strategies;
21. Recognize when an estimate is appropriate;
22. Determine the reasonableness of results;
23. Apply estimation in working with quantities, measurement, computation, and problem solving.

Standard 6: Number sense and numeration

24. Construct number meanings through real-world experiences and the use of physical materials;
25. Understand our numeration system by relating counting, grouping, and place-value concepts
26. Develop number sense;
27. Interpret the multiple uses of numbers encountered in their real world.

Standard 7: Concepts of whole number operations

28. Develop meaning for the operations by modeling and discussing a rich variety of problem situations;
29. Relate the mathematical language and symbolism of operations to problem situations and informal language;
30. Recognize that a wide variety of problem structures can be represented by a single operation;
31. Develop operations sense.

Standard 8: Whole number computation

32. Model, explain, and develop reasonable proficiency with basic facts and algorithms;
33. Use a variety of mental computation and estimation techniques;
34. Use calculators in appropriate computational situations;
35. Select and use computation techniques appropriate to specific problems and determine whether the results are reasonable.

Standard 9: Geometry and spatial sense

36. Describe, model, draw, and classify shapes;
37. Investigate and predict the results of combining, subdividing, and changing shapes;
38. Develop spatial sense;
39. Relate geometric ideas to number and measurement ideas.

Standard 10: Measurement

41. Understand the attributes of length, capacity, weight, mass, area, volume, time, temperature, and angle;
42. Develop the process of measuring and concepts related to units of measurement;
43. Make and use estimates of measurement;
44. Make and use measurements in problem and everyday situation.

Standard 11: Statistics and probability

45. Collect, organize, and describe data;
46. Construct, read, and interpret displays of data;
47. Formulate and solve problems that involve collecting and analyzing data;
48. Explore concepts of chance.

Standard 12: Fractions and decimals

49. Develop concepts of fraction, mixed numbers, and decimals;
50. Develop number sense for fractions and decimals;
51. Use models to relate fractions to decimals and to find equivalent fractions;
52. Use models to explore operations on fractions and decimals;
53. Apply fractions and decimals to problem situations.

Standard 13: Patterns and relationships

54. Recognize, describe, extend, and create a wide variety of patterns;
55. Represent and describe mathematical relationships;
56. Explore the use of variables and open sentences to express relationships.

The 1989 NCTM standards were intended to guide teachers' mathematics teaching by providing standards for curriculum and assessment. But, in my opinion, whether the reader is a curriculum designer, assessment creator, or teacher, these fifty-six bullets will be overwhelming and eventually ignored. Here I must point out that the strands structure opened the door for the existence of this disconnected list.

In 1992 California published a new mathematics framework in order to make the content taught in California closer to that described in the NCTM standards. These, in turn, had been inspired by the previous California framework.

A major disadvantage of representing the goals of elementary mathematics instruction in terms of cognitive actions or behaviors related to mathematics is that implementation of such descriptions is difficult. Of course mathematics learning is a cognitive activity. However, the descriptors of those cognitive activities are often vague and have multiple meanings, even for cognitive scientists. For example, "developing number sense" (bullet 26) is an important goal of the 1989 NCTM standards. However, what is number sense? There are so many interpretations it is hard to choose. In his article "Making sense of number sense", Daniel Berch noted, "Gersten et al. pointed out that no two researchers define number sense in exactly the same way. What makes this situation even more problematic, however, is that cognitive scientists and math educators define the concept of number sense in very different ways" (2005, p. 333). Then "after perusing the relevant literature in the domains of mathematical cognition, cognitive development, and mathematics education," Berch "compiled a list of presumed features of number sense" with thirty items, some of them quite different (2005, p. 334). To require teachers to work towards teaching goals which are so vaguely defined is not practical.

1999 California Framework, 2000 NCTM Standards: Establishment of Sub-subitems

In 1999 California published its sixth mathematics framework. In 2000 NCTM published its *Principles and Standards for School Mathematics*. The vision of these two documents differed from that of their three immediate predecessors. The computational skills deemphasized in the previous round of reform received more emphasis. The 1999 framework arranged mathematical content by grades and changed "strands" to "standards". The 2000 NCTM standards reduced the previous thirteen standards to ten. The last five of these standards, which were similar to the first four standards of 1989, were called "process standards". The first five were called "content standards". Thus, for example, in 1989, "Mathematics as problem solving" was first in the list of thirteen standards. In 2000 "Problem solving" was sixth in the list of ten standards, suggesting a change in status.

In these two documents, items and subitems appeared as in previous documents, together with a new structural feature, sub-subitems. The 1999 framework had five standards. Each standard had subitems, and each subitem had sub-subitems. The 2000 NCTM standards retained the structure of the 1989 standards, with each standard partitioned into several goals. A new structural feature, however, was that under each content standard goal were listed several expectations. For example, in the pre K–2 grade band, the first standard, "Number and operation", is partitioned into three goals. Together the three goals consist of twelve expectations. For pre K–2, the total number of goals for process standards and expectations for content standards is sixty-three. Thus, compared with the 1989 standards, although the number of standards was reduced, there was an increase in the number of the most specific items. The continued increases in the number of specific items in the strands structure may be an important reason why the U.S. elementary mathematics curriculum became broader and shallower.

In 2006, in order to change the "mile wide and inch deep" U.S. curriculum,[21] NCTM made a significant move, publishing *Curriculum Focal Points for Prekindergarten through Grade 8 Mathematics* (known as "Focal Points"), which provided "descriptions of the most significant mathematical concepts and skills at each grade level" (NCTM, 2006, p. 1). "Focal Points" adopted the approach of California's 1999 framework of arranging content by grade rather than by grade band.

"Focal Points" gives three focal points for each year with detailed descriptions of each. This approach helps to emphasize a few ideas; however, given that the strands structure was retained, there is no single self-contained subject which serves as the core of the curriculum. The wide and shallow curriculum could become narrower because the number of items had been reduced, but narrowing does not automatically produce depth.

Conclusion

Notable Aspects of the Strands Structure: Not Stable, Not Continuous, Not Coherent

The big influence of the first California framework, "The Strands Report", published during the new math movement, was to fundamentally change the structure of U.S. mathematics content from a core-subject structure to a strands structure. During the past few decades, although the names of items changed from "strands" to "areas" to "standards", the strands structure has remained. The damage this structure has caused to U.S. elementary mathematics education is the instability of content,

[21] *See NCTM, 2006, p. 3, and Schmidt et al., 1997.*

discontinuity in instruction, and incoherence in concepts.

The title, the content, and the number of items forming elementary mathematics content created by some people (for example, a committee) can easily be changed by a group of other people (for example, another committee). For instance, the ten framework and standards documents discussed earlier almost always had different names for items. There were ninety-four different names for items on the first layer. Of these, twenty-eight names were used only once, and fourteen names were used only twice. The most stable were "Geometry" and "Measurement". These appeared in six documents.

Instability. The instability caused by the strands structure is certainly a cause of complications for practitioners such as teachers, textbook authors, and test developers. Each change in number, name, and content of items, even changes in their order, requires a response, sometimes a response significantly different from previous responses. Such changes every few years are difficult, even for experts in mathematics education, not to mention elementary teachers who teach several subjects. Such frequent changes even affect parents, making it difficult for them to tutor their children in elementary mathematics.

Another damage caused by instability is that experience cannot accumulate. For the development of any field, accumulation over time is very important. This requires the content of the field to be basically stable. If it is always changing, abandoning or creating content, it is hard for us to keep meaningful things. The content and pedagogy of core-subject elementary mathematics were developed and formed over a long period. The terms in the definition system of school arithmetic have been used for several hundred years. Following the approach of the *Elements*, which is two thousand years old, mathematical scholars revised the definitions of these terms and established a definition system. Then, based on this definition system, they established a theory of school arithmetic. After several more decades, textbook authors and teachers developed a way to teach school arithmetic based on this theory to elementary students. Part of this approach is in the textbooks, part is in journal articles, and part is in the mouths and ears of elementary teachers. This accumulation of knowledge and experience is not easily noticed, but can only occur in a relatively stable situation.

Discontinuity. As mentioned before, in the core-subject structure the continuity of instruction was protected and ensured. In the strands structure, the content of instruction needs to jump from item to item. Because of these jumps and because so many items are to be addressed at the same time, it is impossible for U.S. elementary school students' learning to have continuity. This is an invisible but severe injury to students' learning.

Incoherence among concepts. The many concepts of the present-day U.S. elementary curriculum do not cohere. Some come from current standards, and some remain from earlier standards. For example, although the new math movement has been dormant for a long time, some of its concepts remain in elementary education. For the meanings of the four operations on whole numbers and the concepts of addition and subtraction on whole numbers, the eleven models described by researchers who study children's cognitive activity are popular. Concepts of multiplication on whole numbers include "repeated addition", "equal-sized groups", and various interpretations of "Cartesian product". But concepts of the four operations on fractions are not described in ways that are connected to these operations on whole numbers.

The field of mathematics education has noticed this incoherence. Almost all of the ten frameworks and standards documents created since the 1960s mention the idea of unification. However, this unification was never widespread in school mathematics during these decades. In my opinion, the largest obstacle to unification is the strands structure. In order to get their textbooks adopted, publishers need to demonstrate adherence to state frameworks or standards. This is often done by using their categories and organization.[22] If curriculum materials adhere to the strands structure without further unification of the concepts, then unification becomes the responsibility of teachers. Teachers who are able to do this must (1) have a unified and deep knowledge of the discipline of mathematics and (2) be very familiar with features of student learning. It is not impossible to produce people who meet these requirements, but it has a very high social cost. The quantity of elementary school mathematics teachers is so large that producing sufficient numbers of such people is an extremely difficult problem.

I think that readers will agree that these features—instability, discontinuity of teaching and learning, and incoherence among concepts—have damaged U.S. elementary student learning. These are inherent in the strands structure.

To Reconsider School Arithmetic and Its Potential: One Suggestion for U.S. Mathematics Education

Is there any subject that can unify the main content of elementary mathematics: the four operations on whole numbers and fractions, their algorithms, and quantitative relations? Yes, this is school arithmetic. U.S. scholars contributed to this arithmetic as it was being constructed, but it

[22] *For an example, see Ginsburg, Klein, & Starkey, 1998, pp. 437–438.*

was left to other countries to complete this process and make it teachable.

Since the early 1960s, from the new math until today, in U.S. elementary mathematics I see a trend of pursuing advanced concepts such as set theory, number theory, functions, and advanced cognitive abilities such as problem solving, mathematical thinking, and "thinking like a mathematician." During recent decades, efforts have been made to put algebra content into early grades. It seems that only by pursuing those advanced concepts and abilities can the quality of school mathematics be raised. However, together with the intent to pursue advanced concepts and cognitive abilities, we see "math phobia" among teachers and students.

2001 Chinese Standards	2011 Chinese Standards
1. Number sense	1. Number sense
2. Symbol sense	2. Disposition to attend to symbols
3. Spatial concepts	3. Spatial concepts
4. Concept of statistics	4. Geometric intuition
5. Disposition to apply mathematics	5. Data analysis concepts
6. Reasoning ability	6. Computational ability
	7. Reasoning ability
	8. Disposition to model
	9. Disposition to apply mathematics
	10. Disposition for innovation

Figure 6. Changes in Chinese Standards.

One reason that U.S. elementary mathematics pursues advanced ideas is that the potential of school arithmetic to unify elementary mathematics is not sufficiently known. This is a blind spot for current U.S. elementary mathematics. One popular, but oversimplified, version of this trend is to consider arithmetic to be solely "basic computational skills" and consider these basic computational skills as equivalent to an inferior cognitive activity such as rote learning. Thus for many people arithmetic has become an ugly duckling, although in the eyes of mathematicians it is often a swan.

I would like to mention two things: (1) Some countries considered to have good mathematics education, such as Singapore, have elementary mathematics with arithmetic as its core subject; (2) The Russian elementary mathematics textbooks with algebraic content that have attracted attention from those concerned about U.S. elementary mathematics have an underlying theory of school arithmetic from grade 1 onward. The algebra content in the Russian elementary textbooks available in the U.S. is founded on this underlying theory.

The precursor of school arithmetic was "commercial mathematics", a collection of algorithms without explanations for computing operations on whole numbers and fractions. This may not qualify as mathematics; however, after scholars built a theory in the manner of the *Elements*, commercial mathematics was reborn as a subject that embodied mathematical principles. The profound understanding of fundamental mathematics that I discuss in my book [Ma, 1999] is an understanding of this reborn arithmetic from a teacher's perspective. The Chinese elementary teachers that I interviewed for my book *Knowing and Teaching Elementary Mathematics* had not studied any advanced mathematics. However, most had a sound understanding of elementary mathematics. A subgroup of very experienced teachers (about 10 percent of my sample) had what I called a "profound understanding of fundamental mathematics." Their profound understanding was acquired by studying and teaching school mathematics with this arithmetic as its core.[23] What I called "fundamental mathematics" is more accurately described as the foundation for learning mathematics. School arithmetic is the cornerstone of this foundation. Therefore, I suggest that U.S. elementary mathematics education reconsider school arithmetic, its content, and its potential in mathematics education.

Chinese Standards: A Cautionary Tale

In 2001 and 2012 China published mathematics curriculum standards (called, respectively, "experimental version" and "2011 version"). Reading these curriculum standards, we can see the authors' intent to have a Chinese character; however, it is obvious that they have borrowed significant ideas, wording, and writing style from the 1989 NCTM standards.

One of my main concerns is that Chinese curriculum standards, like the first California framework of 1963, may radically change the structure of Chinese elementary mathematics. The 2001 Chinese standards have four categories of general goals. These four categories and four areas are very similar to the two groups of standards in the 1989 *Curriculum and Evaluation Standards*. In this way, the previous Chinese core-subject elementary mathematics has been changed to a strands structure.

The eight items have the same noticeable features as the U.S. strands items: (1) there is no item that is a self-contained subject and (2) the relationships among the items are not described. Therefore, although there are phrases such as "connect", "tightly connected", and "interwoven", these phrases are used in a way that is similar to

[23] *See Chapter 6 of* [*Ma, 1999*].

the "unify" and "consistent" discussed before; that is, they have no concrete referent. In this way Chinese elementary mathematics may follow U.S. elementary mathematics and step by step become unstable, inconsistent, and incoherent. In fact, the problems of the strands structure have already appeared in China.

We must note that the influence of structural change will be deep and long. Visions of education can be adjusted. Teaching methods can be revised. But if the structure of the subject to be taught decays, it is hard to restore it. No matter what direction mathematics education reform takes, we should not ignore questions about changes in the structure of the subject as it is organized and presented to teachers, curriculum designers, assessment developers, and others concerned with mathematics education.

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What Do Secondary Preservice Mathematics Teachers Need to Know? Content Courses Connecting Secondary and Tertiary Mathematics

Eileen Murray and Jon R. Star

The recently released report *The Mathematical Education of Teachers* II (MET-II) [Conference Board of the Mathematical Sciences (CBMS), 2012] notes that, while most secondary mathematics teachers major in mathematics, many of the courses taken focus on mathematics needed for graduate study or careers in business. Prospective mathematics teachers could be better served by courses that "provide opportunities for future teachers to learn the mathematics they need to know to be well-prepared beginning teachers who will continue to learn new mathematical content and deepen their understanding of familiar topics" [CBMS, 2012, p. 5]. At present we appear to be in an exciting period of innovation and experimentation in the development of such courses, as mathematicians with interest in secondary education have created a wide array of new courses designed specifically for mathematics majors studying to become teachers.

Teacher education programs include a variety of courses designed to improve teachers' knowledge. These courses fall largely into two categories: mathematics courses offered by mathematics departments and teaching methods courses offered by education departments. Many teaching methods courses have begun to incorporate content knowledge, especially as it relates to the mathematics prospective teachers will teach and the specialized mathematical knowledge needed for the specific tasks of teaching [Ball, Thames, and Phelps, 2008]. Yet there does not appear to have been substantial change in the types of mathematics content courses that prospective teachers (as mathematics majors) take, with one exception. There are a growing number of courses offered by mathematics departments where prospective teachers learn new mathematics while simultaneously building connections between tertiary and secondary mathematics. These *connections courses* are presumed to help prospective secondary mathematics teachers (PSMT) situate and motivate the mathematics that they will teach.

The impetus for the increasing number of connections courses has come about for at least two reasons. First, research over the past twenty-plus years has articulated the need for such knowledge, expanded our thinking about what mathematics teachers need to know, and pushed us to think about how this knowledge develops. Second, we see an increasing number of productive and sustained collaborations between mathematicians and mathematics educators, such that many in the

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mathematics community are now engaged in efforts to improve K–12 mathematics education.

To better understand the landscape of connections courses, we conducted an informal survey of institutions to uncover some of the innovative courses that are currently offered to PSMT. We looked at department websites, spoke with colleagues in mathematics and mathematics education, collected syllabi, and interviewed course instructors. We concluded that the landscape of connections courses appears to be composed of two distinct types of courses: (a) *secondary mathematics from an advanced standpoint* and (b) *tertiary mathematics with connections*.

In *secondary mathematics from an advanced standpoint* courses, secondary mathematics topics are covered at a level of depth and rigor suitable for undergraduate mathematics students, but the connections to the mathematics content PSMT will be teaching are explicitly investigated. Such focus allows teachers to see the importance of the mathematics they are required to take as undergraduates and contemplate pedagogical strategies that might support students' thinking in ways that can make advanced mathematics more accessible.

For example, mathematicians and mathematics educators at Michigan State University (MSU) have developed a capstone course for mathematics majors planning on becoming secondary teachers. The course aims to deepen PSMT understanding of secondary mathematics by focusing specifically on analysis and algebra, as well as to help PSMT describe the connections *among* secondary topics and connections *between* secondary and tertiary mathematics. Since the course is an upper-level mathematics course, it is not simply a high school mathematics class, but one that (according to the course syllabus) provides students "insight and understanding of high school mathematics from the viewpoint of junior/senior-level college mathematics." Objectives include analyses of alternative approaches to mathematical ideas, extensions and generalizations of familiar theorems, and discussions of relations between topics studied in this course and contemporary high school curricula.

To achieve these objectives, the MSU course uses two textbooks: *Mathematics for High School Teachers—An Advanced Perspective* [Usiskin et al., 2002] and *Field Theory and Its Classical Problems* [Hadlock, 1979]. The first textbook approaches secondary topics using tertiary mathematics, such as by considering algebraic structures and solving equations by considering seemingly simple questions such as, When do the equations $a + x = b$ and $ax = b$ have solutions? When are those solutions unique? When are there no solutions? These questions extend high school algebra to abstract algebra through the generalization of the operations of addition and subtraction to any binary operation. Such explorations can deepen teachers' knowledge about solving equations and the nature of solutions.

The second textbook delves into interesting problems in Galois theory but requires nothing more than knowledge of calculus and linear algebra. Hadlock illustrates connections between tertiary and secondary mathematics by discussing classical Greek problems that are presented in high school but never proved (e.g., trisecting an angle) and by devoting significant attention to polynomials, a secondary topic, using fields and field extensions. When approaching classical problems, the course prompts MSU students to create a bridge between the mathematics they will teach and solutions that may require more complex mathematics.

The second type of connections course, *tertiary mathematics with connections*, aims to provide PSMT with the knowledge necessary to teach mathematics effectively by beginning with tertiary content and subsequently focusing on the importance of these topics within secondary mathematics. These courses generally focus on one content area, such as algebra, real analysis, or geometry, which appears to be most relevant to high school teaching. The courses largely use advanced textbooks, and connections are drawn from class discussion or supplementary materials usually written by the instructor.

For example, the University of Illinois-Chicago offers a tertiary-mathematics-with-connections course in real analysis for PSMT, Mathematical Analysis for Teachers. The goals are to provide a rigorous first course in real analysis and insight into connections between what PSMT learn in college and the secondary mathematics they will be teaching. Students embark on a rigorous, axiomatic development of the real number system where they are required to prove most theorems. Students then prove the major theorems of calculus and find and explain examples and counterexamples to definitions and theorems encountered. Connections naturally arise throughout the course through common errors in teaching and doing secondary mathematics that are unavoidable because of the nature of mathematics. For example, students have the opportunity to discuss solutions to quadratic (and higher polynomial) equations when they work to prove that there are no zero divisors for the real numbers. Many PSMT may be comfortable saying that if $(x - 1)(x - 3) = 0$, then $x = 1$ and $x = 3$ are the solutions. However, without the above theorem they cannot explain why these are the only two solutions. Examples such as this one aim to provide PSMT with the opportunity to see how concepts and methods of proof in real analysis are directly applicable to the mathematics they will be teaching.

Secondary mathematics teachers need deep knowledge of mathematics to be effective. Recent policy documents, including the MET-II report,

make clear that secondary mathematics teachers not only need high-quality content courses but also a set of different kinds of learning experiences that help make connections between tertiary and secondary mathematics.

We have focused on two types of courses: *secondary mathematics from an advanced standpoint* and *tertiary mathematics with connections*. While we feel confident in the legitimacy of these two categories of connections courses, we acknowledge that there may be courses and categories we were unable to detect in our inquiry. However, our goal was to try to capture the range of what might exist at present, showcase some of the courses that are working to build specific content knowledge for PSMT, and stimulate dialogue. We hope that our work can become a springboard for more systematic analyses of the spectrum of content courses now being offered and developed across the U.S. We believe that these courses can help prepare our future mathematics teachers by building a strong foundation of mathematical content knowledge.

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Principles for Implementing a Potential Solution to the Middle East Conflict

Thomas L. Saaty and H. J. Zoffer

Introduction

The purpose of this paper is to show how the Analytic Hierarchy Process (AHP) applies mathematics to deal with the most complex problems of the world in a comprehensive and holistic way—in this case the Israeli-Palestinian conflict. This process has been helpful in finding solutions to some of the world's most complex struggles, including those in South Africa and Northern Ireland. But it has not been used extensively to address the Middle East conflict because of the unique aspects of that struggle.

Five years ago, we began preliminary work to organize the excruciatingly difficult issues associated with that six-decades-old confrontation. We began by testing how this *retributive conflict* (one in which both sides profess to desiring a solution but are equally committed to inflicting pain on the other party) could be profitably addressed by the AHP. This paper should serve as an illustration of how mathematics can help quantify the value of tradeoffs through relative scales (priorities derived from pairwise comparison judgments). The reader can find the mathematical foundations of the theory in an article recently published by the first author in these *Notices* in February 2013 [3]; see also [4]. Figure 1 shows a map of Israel and Palestine as the borders currently exist, as well as the countries which share borders with them. The other figures are self-explanatory.

Figure 1. Israel and Palestine.

Figure 2. The ancient Wailing Wall.

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Figure 3. Palestinian refugee camps in Lebanon.

Figure 4. Israeli settlements in Palestinian lands.

Figure 5. The wall built to prevent Palestinians from entering Israel.

The advantages of the AHP in dealing with conflicts were detailed in our earlier papers [1, 2], but for those unfamiliar with the AHP, suffice it to say that the process creatively decomposes complex issues into smaller and more manageable segments. It also minimizes the impact of unrestrained emotions by imposing a mathematical construct, pairwise comparisons, and prioritization with a numerical ordering of the issues and concessions. Ultimately, the process yields tradeoffs that are quantitatively developed to equate costs and benefits for each side that ensure a fair solution. No other approach can produce similar outcomes and measure a category of factors, including both tangible and intangible items. All of this can occur without the bloody confrontations that are reflective of the face-to-face negotiations previously used to address this situation.

The intuitive idea behind the AHP is as follows. The AHP uses what is known as a fundamental scale of absolute numbers derived from stimulus-response theory to quantify judgments in making reciprocal pairwise comparisons of elements in a matrix as to dominance with respect to a given property. Using this scale of numbers, priorities of the relative dominance of each element over all the others are then derived using the normalized sum of all the numbers in each row. These numbers indicate how much each element dominates every other element. But all the elements are not equally important. If we knew how important they are, we would use that priority of importance to weight each judgment and then add the weighted numbers in each row and get these priorities back. Not knowing the priorities, we start by assuming that all the elements are equally important and use the same constant number to weight the judgments in each row and add over that row. Doing that, we get a first estimate of the priorities. This estimate comprises the exact priorities when we have measurements. But, when we don't have measurements, we have an estimate of the priorities again used to weight the judgments in each row and sum the weighted numbers in each row to get a new estimate of the priorities of the elements. We stop if the first set of priorities is identical to the second set. Otherwise, we again use this second set of priorities to weight the judgments in each row and add the weighted numbers to get a third estimate. We continue the process until the last estimate of the priorities is close enough for our need for accuracy to the one before it. Now we have the priorities we are looking for. Computing the principal eigenvector does exactly what we just described above.

From individual judgments one derives a representative group judgment by using the geometric mean and also, when necessary, by using the priorities of the wisdom of the judges to raise their quantitative judgments to the power of their priority. This contradicts Arrow's theory which proves the impossibility of combining individual judgments if one uses only "A is preferred to B" or "B is preferred to A".

A referee observed that *Notices* is about mathematics and the AHP has a very sophisticated mathematics at its core, but space limitations make it hard to dwell both on the details of the AHP and those of the application involved.

Making Peace without Peacemakers

Why has the Middle East conflict proved impervious to all blandishments in every negotiation and to the pressures from internal and external policymakers for so many decades?

It is not because no one has identified a potential solution that would achieve an end to the most complex conflict of our time. Indeed, more presidents, prime ministers, special envoys, journalists, and academics have devoted their time and effort to pursuing success in resolving this problem than perhaps any other modern-day controversy. The truth of the matter is that some of those most closely and intimately involved with the process believe that the outline for the settlement is generally well known and cries out for implementation.

One could say that the closer one comes to a reasonable solution, the less likelihood there seems to be of a commonly accepted willingness to achieve the potential of the work that has been done. The war of words continues to suggest that each side in the Middle East controversy is willing and able to achieve a solution, but when the feet hit the ground, there is always an impediment, a prerequisite, a new complaint, or an aggravating opinion expressed by the other side.

Let us now examine in depth the potential disposition of the parties involved. It seems logical that in any controversy where resources, fiscal and human, are at risk that the parties would inevitably seek peace to benefit their communities and the people they represent. The fact that these parties have been willing to fail to conclude what is fast approaching another hundred-years war must mean that there are factors in place that are not generally spoken about. It is impossible to know exactly whether these factors are or are not at work, but in the interest of transparency, our offering a set of suppositions at least exposes some possible reasons why progress has been so impeded.

The first factor that needs identifying is the difference in power between the parties. While many may deny the impact of the power differential, what seems clear is that most of the power function resides in the Israeli community. The second factor is the supposition that delaying settlement of the controversy has some advantages for both sides. A third factor may be that the Israeli government is so committed to the problem posed for them by Iran that they see this as a higher-priority issue than making immediate peace with the Palestinians. A fourth factor may be a feeling on one or both sides that, in spite of protestations to the contrary, the current American administration is not totally supportive of either the Israeli or Palestinian position. A fifth factor may apply only to the Palestinian side and relates to the question of a one-state or a two-state solution. While most analysts of the situation believe that only a two-state solution has any chance of a long-lasting peace, there are some who believe that a single state has many advantages, particularly for the Palestinians. Israelis feel that it is totally unacceptable, because birthrate factors will eventually yield a Palestinian majority.

The foregoing factors are purely speculative and may or may not account for the lack of progress in achieving a peaceful solution. For whatever reason, which may include or not include factors noted above, there has been a noticeable reluctance on the part of both sides to extend themselves to achieve peace.

Why Use the Analytic Hierarchy Process

In other applications of the AHP where the problem addressed was the resolution of a conflict, it was not always necessary to go into a second stage of detail to develop an implementation plan. That is, when the final analysis was completed, it was clear what the optimal solution would be based on the judgments of the participants. However, in the case of the Israeli-Palestinian conflict, it seems clear that an agreement as to the optimal solution represents the first stage in a two-stage process.

The question of dissemination of results is a tricky matter. In spite of the willingness of participants to present an agreed-upon outcome to their governments, those currently in charge may resist the process because of a variety of political reasons. It will be a challenge to engage United States or European Union diplomats to apply pressure on the parties to allow the process to be officially condoned using representatives that the leaders appoint. Obviously, there is a long shot that the implementable solution devised by the current participants will be accepted by the respective parties. But, even if it is not, the leaders will be under some pressure to allow the AHP to be used with official blessings. All of this depends on the current Pittsburgh Principles being successfully implemented to yield an acceptable solution, even if it is only one of the possible solutions.

Admittedly, we have been focusing on the process itself rather than on the solution, since the participants were not official representatives of their governments. But their willingness to take the principles and the subsequent implementation agreement to their respective governments to show them that a feasible potential solution exists gives us hope that what we thought would be a virtual solution might actually yield a proposal that can be considered by both governments.

One might ask why it is that so many distinguished politicians and negotiators have failed to

reach consensus after sixty years of trying. Here are some possible reasons:

1. They had no way to measure the importance and value of intangible factors which can dominate the process.
2. They had no overall unifying structure to organize and prioritize issues and concessions.
3. They had no mechanism to trade off concessions by measuring their worth.
4. They had no way to capture each party's perception of the other side's benefits and costs.
5. They had no way to provide confidence to the other party that the opposing party is not gaining more than they are.
6. They had no way to avoid the effect of intense emotions and innuendoes which negatively affect the negotiation process.
7. They had no way to test the sensitivity and stability of the solution to changes in their judgments with respect to the importance of the factors that determined the best outcome.

It is not a coincidence that the Analytic Hierarchy Process addresses each of these reasons in a comprehensive and deliberate way, thus eliminating many of the obstructions for moving forward to identify an equitable solution.

We report here on a meeting of the two sides that was held in Pittsburgh, Pennsylvania, in August 2011. Much to the participants' surprise, the process itself had created an environment in which finding common ground was far more possible than at the beginning of the seminar. The participants began very tentatively to explore the wording of some general principles that would summarize their work together. It should be noted that they were very skeptical that such an outcome could be achieved. After significant discussion they found ten major issues on which they could reach agreement and wording acceptable to each side. Each group worked separately in articulating these principles, and the coordinators of each group went back and forth between the groups to modify the wording of each principle so it was acceptable to the other side. At the end of the seminar they had total agreement on ten principles, which they proudly dubbed the "Pittsburgh Principles".

It seems clear that while we have achieved important milestones in addressing the structure of the conflict and identification of the issues and possible concessions, there remains a complex implementation process that needs to be addressed. In general, the current status of the planning literature has not paid sufficient attention to the crucial task of implementing carefully drawn plans. It is equally apparent that the "devil" is indeed "in the details". We are optimistic that these participants have developed trust and camaraderie as a result of their week in Pittsburgh wrestling with the AHP. The likelihood of success in coming to agreement on implementation strategies is substantially enhanced as a result of their prior interactions.

In planning for the implementation seminar that we report on here, we intend to take advantage of the expertise of those in both communities who have specialized knowledge of the matters noted in the Principles. These experts will provide written papers, probably often in disagreement, for the participants to review prior to their arriving in Pittsburgh. It will be necessary to engage in a number of AHP analyses before arriving at an agreed-upon implementation plan. This will be a complex and comprehensive initiative but one that will yield a suggested solution to the controversy if these participants had been officially designated by their respective governments.

The Retributive Function and Tradeoffs

Given the entrenchment of both sides, a negotiator has an opportunity in an appropriate setting to call attention to the gap between the perceived benefits and costs of the concessions made by both sides and to help each party to reach a conclusion through the introduction of "bargaining chips". In the negotiation setting, if A and B are participants, then A considers a particular concession not only with respect to the incremental benefit (cost) to A but also the cost (benefit) to B in providing (receiving) the concession. The greater the perceived cost of each concession to B, the greater the value of that concession to A.

Hence A's gain from a given concession from B may be described as the product of A's benefits and B's costs (as perceived by A). We have the following ratios for the two parties A and B:

(According to A's perceptions)

A's ratio:

$$\frac{\text{Gain to } A \text{ from } B\text{'s Concession}}{A\text{'s Perception of } B\text{'s Gain from } A\text{'s Concession}} = \frac{\sum A\text{'s Benefits} \times B\text{'s Costs from } B\text{'s Concession}}{\sum B\text{'s Perceived Benefits} \times A\text{'s Costs from } A\text{'s Concession}} = \frac{\text{Gain to } A}{\text{Loss to } A},$$

where $\sum$ is the sum over all the benefits obtained by A in the numerator and by B in the denominator. Hence, given A's ratio, A's gain is a product of both the utility benefit received and the cost to B in providing that benefit as described in the numerator of the equation. The total gain to A is diminished by the product of the cost to A in concessions given to B and the perception of the benefit received by B for A's concessions in the

denominator. A's benefits and costs are readily measured by A; however, the costs and gains to B are not readily available to A and are therefore estimated as perceived by A. A expects to have a gain ratio greater than one, which suggests that the gains to A are greater than the perceived benefits to B. Likewise, B expects to have a gain ratio greater than one. For equality in "trade" to be achieved, the two parties should be nearly equal in value, which suggests that the two gain as much as the perceived benefits to and costs of concessions to the other. B's utility is given by the function:

(According to B's perceptions)

B's ratio:

$$\frac{\text{Gain to } B \text{ from } A\text{'s Concession}}{A\text{'s Perception of } A\text{'s Gain from } B\text{'s Concession}} = \frac{\sum B\text{'s Benefits} \times A\text{'s Costs from } A\text{'s Concession}}{\sum A\text{'s Perceived Benefits} \times B\text{'s Costs from } B\text{'s Concession}} = \frac{\text{Gain to } B}{\text{Loss to } B}.$$

The measure of equality between the parties in the trade of concessions may be calculated as the ratio of the two ratios.

The retributive gain is the amount that A benefits from making B "pay", while a loss is accounted for by the amount that A "lost" in the negotiation process. Under no circumstance would we expect A to agree to concessions when there is a perceived loss when A has dominance over B. In the case where A has dominance over B, the best that B can do is minimize the disparity in gains.

How to Select Concessions from One Party to Match Concessions from Another Party

To decide how to match the concessions of one party with the concessions from another party we need to first create all possible concession bundles for both parties. A concession bundle is a set of individual concessions. The parties can then trade concession bundles. The problem is that there are many possible concession bundles even when the parties in conflict have a moderately small number of possible concessions. For example, if one party had 13 concessions and another had 14 concessions, there are 8,191 and 16,383 possible concession bundles, respectively. Since we need to match a bundle of one party with all possible bundles of the other party to determine which concession bundle is more advantageous, we need to solve 7,563 matching problems for one party and 14,787 problems for the other party. Were we to do it all at once, the problem would be even more difficult to solve, because the problem would involve $8191 \times 16383 = 134,193,153$ variables. A possible solution is to divide the concessions into groups, such as short, medium, and long-term sets, and then form the bundles.

Let C_A and C_B be the set of concession bundles of two parties A and B in a conflict. Let $c_i(k)$ be the ith concession bundle of party k. Let $p(i, A|j, B)$ be the ratio gain from the ith concession bundle of party A when party B offers the jth concession. Let $q(j, B|i, A)$ be the ratio gain from the jth concession bundle of party B when party A offers the ith concession. Let x_{ij} be a binary variable where $x_{ij} = 1$ if the ith concession bundle of A is matched with the jth concession bundle of B.

Concession bundles from one party can be paired with concession bundles of the other party. Thus, the total gain of party A is given by $\sum_{i\in C_A}\sum_{j\in C_B} p(i, A|j, B)x_{ij}$, and the total gain of party B is given by $\sum_{i\in C_A}\sum_{j\in C_B} q(j, B|i, A)x_{ij}$. To balance both gains and provide both parties with the maximum gain, we solve a MaxMin problem, i.e., a maximization model whose objective function is an arbitrary variable such that $\sum_{i\in C_A}\sum_{j\in C_B} p(i, A|j, B)x_{ij} \geq x_0$ and $\sum_{i\in C_A}\sum_{j\in C_B} q(j, B|i, A)x_{ij} \geq x_0$. If all the concessions are matched, then $\sum_{i\in C_A} x_{ij} = 1$ and $\sum_{j\in C_B} x_{ij} = 1$. If only a subset of $S_A \in C_A$ is matched with C_B, then $\sum_{j\in C_B} x_{ij} = 1$, for $i \in S_A$ and $\sum_{i\in C_A} x_{ij} = 1$. If only a subset $S_A \in C_A$ is matched with a subset $S_B \in C_B$, then $\sum_{j\in C_B} x_{ij} = 1$ for $i \in S_A$ and $\sum_{i\in C_A} x_{ij} = 1$ for $j \in S_B$. Thus, the more general problem is given by:

$$\begin{aligned}
&Max\ x_0\\
&\text{s.t.,}\\
&\sum_{i\in C_A}\sum_{j\in C_B} p(i, A|j, B)x_{ij} \geq x_0\\
&\sum_{i\in C_A}\sum_{j\in C_B} q(j, B|i, A)x_{ij} \geq x_0\\
&\left|\sum_{i\in C_A}\sum_{j\in C_B} p(i, A|j, B)x_{ij} - \sum_{i\in C_A}\sum_{j\in C_B} q(j, B|i, A)x_{ij}\right|'' \\
&\sum_{j\in C_B} x''_{ij} = 1, i \in S_A\\
&\sum_{j\in C_B} x_{ij} = 0, i \in S_A\\
&\sum_{i\in C_A} x''_{ij} = 1, j \in S_B\\
&\sum_{i\in C_A} x_{ij} = 0, j \in S_B\\
&x_{ij} = 0, 1,\ i \in C_A \text{ and } j \in C_B
\end{aligned}$$

Outcomes of the August 2011 Meeting

The details of applying the AHP process to the conflict in South Africa and its implementation, to that in Northern Ireland, and to the Israeli-Palestinian conflict have been outlined in several

articles published over the past several years. For this reason they will not be repeated here. The major difference between the earlier experiments and the August 2011 meeting in Pittsburgh is that the participants in the latest meeting were all residents of either Israel or Palestine and were well known in their communities for their involvement in and knowledge of the multitude of negotiations between the parties. They represented a level of involvement not previously possible in earlier meetings. In addition, the process was carried to a conclusion that yielded principles for an ultimate solution to the problem.

One of the first tasks the participants faced was identifying all possible issues that were required to be addressed, if peace was to be a reality. In earlier experiments with this approach we identified more than a hundred such issues. They were then categorized into a number of groupings. The participants in this meeting reviewed these groupings and added and deleted issues according to their relevance. The final list of issues is shown in Table 1.

We then considered all of the possible concessions that each side might make to address these issues in seeking an acceptable solution. No possible concession was to be ignored, no matter how unlikely it was that one side or the other would agree to such a concession. Participants were free to suggest concessions they could make or the other side could make. This is one of the basic components of the AHP process: namely, that neither side can deny the other side the opportunity to present concessions they feel are relevant to the discussion.

The August 2011 participants were furnished with a list of concessions that earlier meetings had identified, and they were asked to add any other concessions that they could conceive of. When this process was completed, the list of possible concessions for consideration was as in Table 1a.

The listing of issues and possible concessions is only the first step in beginning the AHP process. Eventually the Israeli participants will determine the gains to the Israelis from the Palestinian concessions, the Israeli costs from the Israeli concessions, the Israeli perception of Palestinian costs from Palestinian concessions, and the Israeli perception of Palestinian gains from Israeli concessions. Similarly, the Palestinian participants will determine the Palestinian gains from Israeli concessions, the Palestinian costs from Palestinian concessions, Palestinian perception of Israeli gains from Palestinian concessions, and the Palestinian perception of Israeli costs from Israeli concessions.

The process continues with the participants on each side identifying a set of criteria for their side for each of the four concerns mentioned above. Each participant makes pairwise comparisons of the criteria as to their importance in serving the goal of that party in deciding on benefits and costs. Then they rate the importance of each concession, one at a time, with respect to each criterion in terms of how strongly it contributes to that criterion.

Table 2 shows how this process works. Participants evaluate each criterion against all the others in terms of the dominance of a criterion on the left with respect to a criterion at the top, here only identified by the number of each criterion on the left. There are five elements in each cell which represent the judgments of the five participants in the same order on the one-to-nine fundamental scale of the AHP. The number "one" in the cell where the criterion is compared with itself automatically represents the judgments of all the participants and could have been shown as five separate "ones". Reciprocals are automatically entered in the position where the first element of a comparison was the second one in an earlier comparison and the second element was the first in the earlier comparison. Thus if A dominates B five times, then B dominates A with the reciprocal value $1/5$ times. The diagonal itself consists of "ones". This explains why the bottom part below the main diagonal in the table is left blank, because it is understood to be made of reciprocal values to those above the main diagonal.

The next problem is how to combine the five judgments in each cell into a single judgment that represents the group as a whole. The arithmetic mean does not work to combine numbers into a single number whose reciprocal value is equal to one obtained by applying the arithmetic mean to the reciprocal values of those numbers. However, the geometric mean turns out to be the only way to make the reciprocal of a synthesized value of a set of judgments equal to the synthesized value of the reciprocal judgments. Table 3 gives those synthesized values with their reciprocals below the main diagonal. The column on the right gives the priorities of the elements in these comparisons.

The foregoing two tables were developed to obtain priorities for Israeli gains from Palestinian concessions. There are seven other sets of tables, not shown here, from which priorities, as in the last column of the second table mentioned above, are similarly obtained. These priorities are each listed immediately below their criteria on top of each of the following eight tables for the evaluation of concessions. For example, the priority for Integrity and Unity of Israeli Society Post Agreement, is .0753, as shown in Table 3. This same value appears underneath that criterion in Table 4a. Thus the eight tables (Tables 4a–4d, 5a–5d) represent the criteria listed at the top with their priorities listed immediately below them. The priorities of the

criteria in each table sum to 1. The concessions are listed at the left of each table. Under the word "Score" in each of the tables is the column of synthesized priorities of each concession, obtained by weighting the score of the concession in each row by the corresponding priority of that criterion and adding. For example, the score of concession 1 is

$$0.8905 = 0.95 \times .0753 + 0.78 \times .1636 + 0.49 \times .0477 + 0.782 \times 0.397 + 0.96 \times .2216 + 0.98 \times 0.654 + 0.96 \times .0529 + 0.78 \times .0959 + 1.0 \times .1899 + 0.93 \times .0479.$$

We have included the full complement of tables so that the reader can trace the origins of the numbers.

Tables 6a and 6b summarize the gains and losses of each side. In each of the columns of scores in the previous tables we divided by the largest entry in that column to obtain the two tables below. Columns four and seven in each table are the product of the two columns to their left multiplied by one thousand to make them more manageable without changing their relative values.

For the Israelis, for example, for a given concession, to trade it with a concession from the Palestinians, we compute the gain-to-loss ratio by multiplying the numbers in the fourth and seventh columns for the Palestinian concession and dividing it by the corresponding product of the fourth and seventh columns of the first table for the Israeli concession. If the ratio is less than one, there is no trade and a zero is assigned to the ratio. If the ratio is more than one, then the trade could take place, provided that the gain-to-loss ratio of the Palestinians is also greater than one and within a reasonably defined percentage from the Israeli ratio. Note that one can do the same for several concessions for one party, but this requires the use of an optimization model to find out how the concessions map against each other.

In the table where the Israeli and Palestinian concessions are matched, the numbers to the right of the concessions correspond to the Israeli and Palestinian ratios, respectively, obtained from Tables 7a and 7b. For example, the Israeli concession "Comply with all UN applicable resolutions" when matched with the Palestinian concession yields a ratio equal to 1.062 located in the (12, 6) position of the Israeli's ratios table. Similarly, the corresponding Palestinian ratio for this concession in the Palestinian's ratios table position (12, 6) yields a value equal to 1.052. These concessions were coupled for tradeoff because their ratios satisfy the closeness criterion of being within no more than 1% of each other. The model [6] produces this result.

Israeli Ratio for (I-12, P-6)):

$$\frac{\text{Gain to } I\text{'s from } P\text{'s Concession \#6}}{I\text{'s perception of } P\text{'s gain from } I\text{'s Concession \#12}} = \frac{I\text{'s benefits (0.8741)} \times I\text{'s perception of } P\text{'s costs (1)}}{I\text{'s costs (0.8596)} \times I\text{'s perception of } P\text{'s benefits (0.9571)}} = \frac{0.8741}{0.8228} = 1.062.$$

Palestinian Ratio for (P-6, I-12):

$$\frac{\text{Gain to } P\text{'s from } I\text{'s Concession \#12}}{P\text{'s perception of } I\text{'s gain from } P\text{'s Concession \#6}} = \frac{P\text{'s benefits (0.9787)} \times P\text{'s perception of } I\text{'s costs (0.9075)}}{P\text{'s costs (0.90353)} \times P\text{'s perception of } I\text{'s benefits (0.9343)}} = \frac{0.8882}{0.8443} = 1.052.$$

Similarly, ratios for the tradeoff of all single concessions were computed and matched for their values. Only those that were within 1% of each other were selected. This process yielded a few tradeoffs. The percentage limitation was then extended to 5% and then to 10% and corresponding concessions were selected. The total trading value for each side using these three percentage values yielded virtually equivalent totals, shown at the bottom of Table 8a, indicating that the process performed well.

Once this information was available to the participants, they were then asked to identify the six most important concessions that the other side could make. The Israelis chose the six concessions, they would most like to see the Palestinians make, and the Palestinians chose the six concessions they would most like to see the Israelis make. These are listed in Table 10 according to the numbered order in the list of concessions shown earlier in the paper. This listing is not related to any sort of tradeoff nor with regard to the importance of the concessions. However, the inclusion of any concessions on either side in this listing is indicative of the fact that both sides considered them to be significant concessions. If only one side felt a concession was significant, it was not included in the listing.

The participants in the seminar saw only table 8a. When we finished trading off one concession against another concession, there still remained a number of concessions that had not been traded off. However, it was possible to conclude the analysis by using the one-on-one tradeoffs.

The principal investigators wondered whether bundling two or three concessions together might provide an even more precise outcome to the process. Following the seminar we developed Tables 8b and 8c in a similar way for trading off two and three concessions at a time, respectively. It is significant to note that it can happen in the one-on-one tradeoff procedure that some concessions are not addressed because one or both parties do not consider them important. However, when trading off two against two or

three against three, these concessions add some positive value to the tradeoff. Our analysis suggests that, by including the two-against-two and three-against-three analyses, the process does not yield significantly incremental improvement over the one-on-one process, though it does make use of more concessions and extends the process to its ultimate conclusion. While it is speculative as to whether the final outcome might have changed, it is not the final outcome that we were emphasizing. It was whether or not the AHP process could yield a fair solution to the controversy.

Frequently in conflicts there are controversial issues that one side feels have more significance than the other side does and thus lead to frustration and prolonged disagreement. The AHP provides an opportunity to include many of these issues through bundling to avoid the criticism that these issues are ignored.

Development of the Pittsburgh Principles

The participants carefully considered the information on tradeoffs, which was presented in Table 8a. The majority of concessions were traded off within the limitations of the process. Some were traded off within 1% limitations, and others with 5% and 10% limitations. If this had been an exercise where the participants had been chosen by the principals on each side, the next step would have been to examine the tradeoffs and begin to produce a solution to the controversy. But the participants knew that there remained the major task of addressing implementation issues, which had impeded the success of other peace programs. They felt that, in the absence of an implementation structure, the best they could do was to see if there was any agreement on basic principles.

This discussion began with the participants identifying, in their judgment, the six most crucial concessions that the other side could make. This led to slight changes in wording that did not change the essential meaning of the concessions. The Palestinians identified six concessions which represented particularly important actions on the part of the Israelis. Similarly, the Israelis identified what they thought to be the most important concessions which the Palestinians could make to further the cause of peace. Both Palestinian and Israeli concessions are shown in Table 10.

The participants recognized that, if their work was to be completed, they would need to spend at least another week using the AHP process to create an implementation plan for the Pittsburgh Principles. They indicated that they would like to return to Pittsburgh to complete this work, even though the principal investigators offered them several options closer to their home territory.

Conclusions

It seems clear that, while we have achieved important milestones in addressing the structure of the conflict and identification of the issues and possible concessions, there remains a complex implementation process that needs to be addressed. In general, the current status of the planning literature has not paid sufficient attention to the crucial task of implementing carefully drawn plans. It is equally apparent that the "devil" is indeed "in the details". We are optimistic that these participants have developed trust and camaraderie as a result of their week wrestling with the AHP. The likelihood of success in coming to agreement on implementation strategies is substantially enhanced as a result of their prior interactions.

In planning for the implementation seminar, we intend to take advantage of the expertise of those in both communities who have specialized knowledge of the matters noted in the Principles. These experts will provide written papers, probably often in disagreement, for the participants to review prior to their arriving in Pittsburgh. It will be necessary to engage in a number of AHP analyses before arriving at an agreed-upon implementation plan. This will be a complex and comprehensive initiative but one that will yield a suggested solution to the controversy if these participants have been officially designated by their respective governments.

The Pittsburgh Principles, which were the ultimate outcome of this experiment, may seem to be a modest statement, but in the eyes of the participants they were a daunting achievement. As one of the participants wrote in assessing his involvement in the seminar:

> I participated in quite a few meetings with Palestinians in Palestine, and almost every country in Europe, including Belfast, Northern Ireland. They usually had a similar format: travel for the weekend, meet in a nice place and start talking. Very quickly, the polite conversation includes cynical and insulting comments, and eventually deteriorates to shouting at each other. The discussion ends with the rift as large as it was before the meeting and waiting for the next round of talks to narrow it. We have become "peace talkers". We keep on talking without anything actually happening. Because of that, when I received the invitation, I was curious but also skeptical. After all, with so many failed attempts, it is difficult to remain optimistic. I told myself that the experiment might be challenging and interesting intellectually. So I accepted the invitation and everything since then is history.

Another participant who could not leave Pittsburgh without expressing his surprise and enthusiasm for the experiences he had undergone wrote to the principal investigators as follows:

> I must admit that, before we started, I was skeptical about our chance to develop something serious, but it proved that I was wrong and we did develop a very impressive paper of principles which reflects what both sides accept at a moment of truth and will not accept if it is only to satisfy their political ambitions in front of the street demagogy. I must congratulate you that your theory worked well. I had been in hundreds of meetings between Israelis and Palestinians where we tried to reach a joint statement but failed because in most of the cases each side was trying to score points and court his own public opinion rather than being objective and try to be real and responsible.

Yet a third participant, after processing what he had been through in the prior week, admitted that he feared that the process would be somewhat academic and removed from the urgency of the moment. He wrote:

> After a week with the senior figures you have impressively collected for this program, nothing seems more relevant and influential. This is the most serious engagement Israelis and Palestinian have had (considering the seniority of the political/professional level of participants). It has proven that a structured and fair process, handled by honest mediators, can and should work. The system offers, for the first time in the history of resolving this conflict, a smart way to quantify the emotional intangibles that have hindered past processes and help offset the regular positional bargaining dynamics.

With the kinds of responses noted above, the principal investigators feel emboldened to push forward to complete the final phase of this initiative. The participants represented experienced, significant, informed, and committed representatives of their communities. Their enthusiasm for the process outlined above gives us hope that there are yet new bandages to be applied to old wounds.

Some have said and argued quite convincingly that the time for a two-state solution has either passed or is very close to that position. While there may be several reasons for this argument, some of them seemingly valid, we believe that reducing the options available to the parties is counterproductive to producing a fair solution acceptable to both sides. The basis of the work done so far has rested on the conclusion of a previous AHP study made by Israelis and Palestinians that a two-state solution has the highest priority. The main danger in suggesting that a two-state solution is no longer an option, no matter how appealing that may be to some people, is that lack of a second viable option poses a serious impediment to the process yielding an equitable outcome to both sides.

Acknowledgment

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Table 1. List of Outstanding Issues Organized by Category.

GEOGRAPHIC and DEMOGRAPHIC ISSUES	POLITICAL ISSUES	POLITICAL ISSUES Behavioral
Access of Palestinians to Available Natural Resources	Accountability and Reasonability of Hamas in the Gaza Strip	Bad Faith Negotiations
Archeological Issues	Agreement on One-State Solution	Compromise
Golan Heights	Agreement on Two-State Solution	Confidence-Building Measures
How to Address the Palestinian Diaspora	AIPAC (American Israel Political Action Committee)	Corruption
How to Resettle Palestinian Refugees	American Politicians	Deception and Manufacturing of History
Immigration	Citizenship Rights of Palestinian Community in Israel	Equal Treatment of All Parties
Palestinian Access to the Mediterranean Sea	Colonialism	Ethnic Cleansing
Palestinian Problem of Split Land Mass between Gaza and the West Bank	Condemnation of Violence as a Tool of Negotiation	Harassment
Population	Control	Human Rights
Problems for Israel in Living in an Ocean of Arab Countries	Denunciation of Irrelevant United Nations Resolutions	Human Shields
Right of Palestinians to Return to Their Homes in Israel	European Acceptance of Responsibility for the Holocaust and Settlement of Israelis in Israel	Intermarriage
Rights of Palestinians to Israeli-Controlled Land	Funding of Terrorism	Learning to Forgive without Forgetting
Status of Israeli Settlements	Historical Legitimacy of Ownership of Land in the Area	Love
Water	How to Deal with Charges of Apartheid	Mutual Recognition of Rights of Each Party
ECONOMIC and BUSINESS ISSUES	International Relationships	Nonviolence
Compensation for Victims of Terrorism	Islamic State	Psychological Barriers
Compensation to Palestinians for Loss of Land	Jewish Refugee Issues	Psychological Damage
Dealing with Property Confiscation Issues	Mutual Compensation	Racism
Economic Choices	Problems Associated with Hamas	Recognition of the Holocaust
How to Resettle Palestinian Refugees	Residency Rights	Recognition of the Nakba Condition
Restitution	Role of the Druze in Negotiations	Religious Fundamentalism
EDUCATION ISSUES	Sovereignty	Representation of Women in the Negotiations
Education	Status of Israel	Respect
Incitement in the Educational School System	Status of Jerusalem	Subjugation and Humiliation
Indoctrination	Status of Palestinian Authority	Suicide Bombers
Industrial Parks	Status of Ramallah	Trust
Lack of Creativity and Problem Solving	Syrian Accommodation for Settlement of Palestinian Refugees	**MILITARY ISSUES**
Language Training	**SOCIAL ISSUES**	Arms Smuggling
Stolen Culture	Basic Human Needs	Disarmament
SECURITY ISSUES	**RELIGIOUS and IDEOLOGICAL ISSUES**	House Demolition
Bombing of Israeli Children	Armageddon	Invasion
Gilad Shalit (Release of Prisoners)	Christian Zionism (Evangelists)	Missile Building
Safe Passage	Holy Places	Nuclear Responsibility
Safety and Security	Jewish Zionism	War Crimes
Terrorism	Palestinian Christians	**LEGAL ISSUES**
The Wall	Religious Prophecy	International Law
		Prisoners

Table 1a

Israelis' Concessions	Description
1	Abandon the idea of a Jewish state
2	Accept Palestinian full control of the borders of the Palestinian state and its outlets
3	Accept the historical responsibility for the Palestinian refugee problem
4	Accept the Palestinian refugees' right to return
5	Accept to abide by the status quo in the holy places in Jerusalem
6	Accept to abolish the law of return
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas
8	Accept East Jerusalem as the capital of the Palestinian state
9	Accept a two-state solution on the borders of June 4, 1967
10	Allow all parties to have equal access to and control of religious sites and holy places
11	Allow the sharing of all natural resources between Palestinians and Israelis
12	Comply with all applicable UN resolutions
13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation
14	Release all political prisoners, including those who are Israeli citizens
15	Share Jerusalem as two capitals of two states
16	Solve the Palestinian refugee problem in a just and agreed-upon manner
17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs and guarantee the rights of Israeli minorities

Palestinians' Concessions	Description
1	Accept mutually agreed-upon land swap
2	Accept settlers under Palestinian sovereignty as residents
3	Accept the temporary presence of a multinational military monitoring system in the Jordan Valley
4	Accept a two-state solution
5	Accept a two-state solution which includes a noncontiguous state
6	Acknowledge Israel's existence as a Jewish state
7	Acknowledge Israel's existence as an independent state
8	Agree to compromise on the demand of the right of return
9	Agree with Palestinian demilitarized state
10	Preserve the status quo in the holy places of Jerusalem
11	Allow Israel to use Palestinian airspace
12	Declare against Iranian nuclear development
13	Denounce and rein in violence
14	Denounce Iranian pursuit of nuclear arms and support Israeli effort to remove the threat
15	Lobby Arab states to allow both Israelis and Palestinians to have the right to return to their land of origin
16	Compromise on the status of Jerusalem
17	Guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people, both in Gaza and the West Bank
18	Refrain from and work against any anti-Israel sentiments in Palestinian schools
19	Seek assistance for a legitimate settlement of refugees
20	Share natural resources
21	Work cooperatively and in active engagement with Israel

Table 2. Values Assigned by Five Israeli Participants.

		1	2	3	4	5	6	7	8	9	10
1	Integrity and Unity of Israeli Society Post Agreement	1	1/8,1/3,1/4,1/5,3	3,5,5,1,1	3,5,4,1/2,3	1/8,1,1,1/7,1/3	1,5,1,1/3,1	2,5,5,1/4,1/5	2,1,2,1/5,1	1/6,1/7,1/3,1/7,3	1/3,5,3,1/5,5
2	Security		1	2,3,5,2,5	2,7,7,4,2	1/4,1,1/2,1/3,1/2	7,9,1,5,1	7,7,7,4,1	1,2,1/3,1,3	1/3,1,1,2,2	1,9,4,4,5
3	Strengthening the Alliance with the United States			1	2,1,1,1,4	1/8,1/3,1/8,1/9,5	1,3,1/5,2,1/5	3,3,3,1,1/5	2,1/3,1/4,1/5,1/3	1/5,1/7,1/3,1/4,1/5	1/2,1,1,1/5,1
4	Make Israel more Attractive to Jewish Diaspora and Israeli Citizens				1	1/5,1/7,1/8,1/8,1/3	2,3,1/8,1/2,1	2,3,2,1/2,1/5	1/4,1/5,1/3,1/6,1	1/5,1/6,1/3,1/5,1	1/4,5,1/5,1/4,3
5	End of Claims					1	4,9,1,5,1	3,9,7,5,3	3,2,2,3,5	1/4,1/3,1/2,3,1	5,9,6,9,3
6	Legitimization of the State of Israel						1	1,1,1,1/3,1	1,1/7,1,1,3	1/3,1/3,1/2,1/3,3	1,1/2,5,1,1/3
7	Stop being Occupiers							1	1/2,1,1/4,1,5	1,1/7,1/7,1/4,1	1/4,1,1/5,2,5
8	Peace, Prosperity and Stability in Region								1	1/3,1,1/4,1/2,1	2,5,2,4,1
9	Maintain the Jewish Majority of Israel Alongside the Arab Minority									1	7,7,3,5,5
10	Weakening the Radical Forces in the Middle East Headed by Iran										1

Table 3. The Geometric Means and Derived Priorities in the Last Column.

		1	2	3	4	5	6	7	8	9	10	Priorities
1	Integrity and Unity of Israeli Society Post Agreement	1	1/2.759	2.371	2.46	1/2.787	1.108	1.201	1/1.046	1/3.117	1.38	0.0753
2	Security		1	3.129	3.792	1/2.169	3.16	4.241	1/1.149	1.059	3.728	0.1636
3	Strengthening the Alliance with the United States			1	1.516	1/3.219	1/1.33	1/1.401	1/2.46	1/4.618	1/1.585	0.0477
4	Make Israel more Attractive to Jewish Diaspora and Israeli Citizens				1	1/5.827	1/1.217	1/1.037	1/3.245	1/3.393	1/1.398	0.0397
5	End of Claims					1	2.825	4.904	2.825	1/1.516	5.923	0.2216
6	Legitimization of the State of Israel						1	1.246	1/1.185	1/1.783	1/1.496	0.0654
7	Stop being Occupiers							1	1/1.099	1/2.874	1/1.149	0.0529
8	Peace, Prosperity and Stability in Region								1	1/1.888	2.402	0.0959
9	Maintain the Jewish Majority of Israel Alongside the Arab Minority									1	5.165	0.1899
10	Weakening the Radical Forces in the Middle East Headed by Iran										1	0.0479
										Inconsistency	0.027	

Table 4a. Israeli Benefits from Palestinian Concessions.

			Integrity and Unity of Israeli Society Post Agreement	Security	Strengthening the Alliance with the United States	Make Israel more Attractive to Jewish Diaspora and Israelis Citizens	End of Claims	Legitimization of the State of Israel	Stop being Occupiers	Peace, Prosperity and Stability in Region	Maintain the Jewish Majority of Israel Alongside with the Arab Minority	Weakening the Radical Forces in the Middle East Headed by Iran
		Score	.0753	.1636	.0477	.0397	.2216	.0654	.0529	.0959	.1899	.0479
1	Accept mutually agreed upon land swap	0.8905	0.95	0.78	0.49	0.782	0.96	0.98	0.96	0.78	1	0.93
2	Accept settlements under Palestinian sovereignty as residents	0.225	0.54	0.028	0.42	0.252	0.064	0.242	0.274	0.144	0.42	0.242
3	Accept the temporary presence of multinational military monitoring system in Jordan Valley	0.6783	0.372	0.92	0.9	0.84	0.78	0.78	0.88	0.94	0.094	0.94
4	Accept Two-State Solution	0.9591	0.91	0.84	0.94	0.96	1	1	0.98	1	1	0.95
5	Acceptance of a Two-State solution which includes a Non-Contiguous State	0.7275	0.292	0.68	0.91	0.76	0.62	0.78	0.91	0.83	0.88	0.78
6	Acknowledge Israel's Existence as a Jewish State	0.8431	0.98	0.272	0.86	1	1	0.96	0.78	0.95	1	0.78
7	Acknowledge Israel's Existence as an Independent State	0.7769	0.236	0.224	0.78	0.82	1	1	0.73	0.93	1	1
8	Agree to Compromise to the Demand of the Right of Return	0.9645	1	0.91	0.93	0.88	1	0.98	0.93	0.93	1	0.98
9	Agreeing with Palestinian demilitarized state for a limited time period	0.5756	0.26	0.65	0.92	0.78	0.65	0.652	0.71	0.88	0.106	0.96
10	Preserve the Status Quo in the Holy places of Jerusalem	0.6781	0.502	0.172	0.94	0.94	0.94	0.98	0.89	0.98	0.384	0.91
11	Allow Israel to use Palestinian airspace	0.6358	0.7	0.98	0.91	0.76	0.78	0.63	0.45	0.6	0.046	0.94
12	Declare Against Iranian Nuclear Development	0.3827	0.422	0.322	0.94	0.5	0.222	0.83	0.028	0.76	0.046	0.98
13	Denounce & Reign in Violence	0.5935	0.79	0.81	0.94	0.76	0.47	0.89	0.176	0.89	0.126	0.95
14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	0.4791	0.722	0.53	0.94	0.5	0.39	0.84	0.046	0.76	0.046	1
15	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	0.1938	0.076	0.046	0.462	0.334	0.192	0.304	0.124	0.254	0.224	0.194
16	Make Compromise on the Status of Jerusalem	0.8923	0.96	0.5	0.96	0.91	0.96	0.96	0.96	1	0.98	1
17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	0.8238	0.93	0.71	0.89	0.95	0.98	0.98	0.69	0.96	0.53	0.98
18	Refrain and work against any anti-Israel sentiments in Palestinian schools	0.7314	0.65	0.75	0.84	0.79	0.83	0.95	0.68	0.94	0.402	0.83
19	Seek Assistance for a Legitimate Settlement of Refugees Anywhere Except Israel	0.9232	0.94	0.76	0.96	0.98	1	0.95	0.95	0.88	0.98	0.81
20	Sharing of Natural Resources	0.3925	0.028	0.384	0.62	0.29	0.52	0.58	0.57	0.73	0.106	0.272
21	Work Cooperatively and in active engagement w/ Israel	0.7343	0.434	0.84	0.94	0.68	0.86	0.89	0.92	0.94	0.304	0.98

Table 4b. Israeli Costs from Israeli Concessions.

			Integrity and Unity of Israeli Society Post Agreement	Security	Strengthening the Alliance with the United States	Make Israel more Attractive to Jewish Diaspora and Israelis Citizens	End of Claims and End of Conflict	Legitimization of the State of Israel	Stop being Occupiers	Peace, Economy and Stability in Region	Maintain the Jewish Majority of Israel Alongside with the Arab Minority	Weakening the Radical Forces in the Middle East Headed by Iran
		Score	.0659	.1831	.0457	.0322	.2093	.0778	.0477	.0860	.2249	.0274
1	Abandon the Idea of Jewish State	0.9204	1	1	0.94	1	1	1	0	0.98	1	0
2	Accept Palestinian full control of the boarders of the Palestinian State and its outlets	0.5932	0.84	0.98	0.452	0.66	0.272	0.76	0	0.37	0.75	0
3	Accept the historical responsibility for the Palestinian refugee problem	0.8331	0.98	0.85	0.98	0.96	0.85	0.96	0	0.93	0.91	0
4	Accept the Palestinian refugee rights to return	0.8716	0.98	0.95	0.284	1	0.98	0.98	0	0.95	1	0
5	Accept to abide by the status quo in the holy places in Jerusalem	0.1805	0.172	0.352	0.174	0.29	0.046	0.094	0	0.192	0.24	0
6	Accept to abolish law of return	0.8122	1	0.452	0.73	1	1	1	0	1	1	0
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	0.1826	0.39	0.47	0.076	0.154	0.046	0.082	0	0.082	0.175	0
8	Accept East Jerusalem as the capital of the Palestinian State	0.7638	1	0.7	0.076	0.76	0.96	0.94	0	0.89	0.85	0
9	Accept Two-State Solution on the borders of the 4th of June 1967	0.0502	0.252	0.094	0.01	0.094	0.028	0.01	0	0.046	0.01	0
10	Allow all parties to have equal access to and control of religious sites and holy places	0.0926	0.3	0.142	0.046	0.262	0.046	0.028	0	0.082	0.078	0
11	Allow the sharing of all natural resources between Palestinians and Israelis	0.1031	0.172	0.162	0.028	0.26	0.076	0.046	0	0.082	0.115	0
12	Comply with all applicable UN Resolutions	0.7912	0.92	0.91	0.692	0.722	0.68	0.89	0	0.91	0.975	0
13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	0.3307	0.72	0.39	0.028	0.37	0.452	0.452	0	0.5	0.115	0
14	Release all political prisoners including those who are Israeli citizens	0.4766	0.7	0.94	0.064	0.63	0.47	0.75	0	0.67	0.093	0
15	Share Jerusalem as two capitals of two states	0.1503	0.55	0.174	0.064	0.45	0.028	0.046	0	0.094	0.21	0
16	Solve the Palestinian refugee problem in a just and agreed upon manner	0.1662	0.58	0.254	0.076	0.046	0.094	0.112	0	0.22	0.13	0
17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	0.0682	0.162	0.156	0.046	0.112	0.028	0.028	0	0.01	0.064	0

Table 4c. Israeli Perception of Palestinian Costs from Palestinian Concessions.

			Giving up on the Idea of a Greater Palestine	Remainder of part of the Settlement Community	Loss of 'Victim' Status	Loss of Land (67 Boarder) / Swap	Loss of International Financial Support	Partial Control of East Jerusalem as the Capital of Palestine	Partial Solution Refuge Problem	Partial Control of the Muslim Holy Places
		Score	.0880	.0964	.0288	.1500	.0252	.1735	.3101	.1280
1	Accept mutually agreed upon land swap	0.3888	0	0	0	0.7	0	0.354	0.632	0.206
2	Accept settlements under Palestinian sovereignty as residents	0.2903	0	0	0	0.94	0	0.404	0.224	0.076
3	Accept the temporary presence of multinational military monitoring system in Jordan Valley	0.0677	0	0	0	0.322	0	0.028	0.028	0.046
4	Accept Two-State Solution	0.1016	0	0	0	0.174	0	0.124	0.028	0.354
5	Acceptance of a Two-State solution which includes a Non-Contiguous State	0.1843	0	0	0	0.254	0	0.302	0.144	0.384
6	Acknowledge Israel's Existence as a Jewish State	0.612	0	0	0	0.482	0	0.91	0.93	0.73
7	Acknowledge Israel's Existence as an Independent State	0.3792	0	0	0	0.562	0	0.7	0.414	0.352
8	Agree to Compromise to the Demand of the Right of Return	0.5237	0	0	0	0.79	0	0.094	0.96	0.712
9	Agreeing with Palestinian demilitarized state for a limited time period	0.0828	0	0	0	0.322	0	0.064	0.064	0.028
10	Preserve the Status Quo in the Holy places of Jerusalem	0.2053	0	0	0	0.076	0	0.502	0.064	0.68
11	Allow Israel to use Palestinian airspace	0.0671	0	0	0	0.354	0	0.01	0.028	0.028
12	Declare Against Iranian Nuclear Development	0.0213	0	0	0	0.028	0	0.028	0.028	0.028
13	Denounce & Reign in Violence	0.0685	0	0	0	0.094	0	0.194	0.028	0.094
14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	0.0271	0	0	0	0.046	0	0.046	0.028	0.028
15	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	0.2242	0	0	0	0.176	0	0.094	0.554	0.076
16	Make Compromise on the Status of Jerusalem	0.3807	0	0	0	0.514	0	0.94	0.094	0.87
17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	0.3215	0	0	0	0.352	0	0.602	0.302	0.552
18	Refrain and work against any anti-Israel sentiments in Palestinian schools	0.1145	0	0	0	0.094	0	0.058	0.24	0.124
19	Seek Assistance for a Legitimate Settlement of Refugees Anywhere Except Israel	0.5339	0	0	0	0.762	0	0.224	0.98	0.6
20	Sharing of Natural Resources	0.0333	0	0	0	0.108	0	0.028	0.028	0.028
21	Work Cooperatively and in active engagement w/ Israel	0.1137	0	0	0	0.126	0	0.176	0.156	0.124

Table 4d. Israeli Perception of Palestinian Benefits from Israeli Concessions.

			Freedom, Dignity and Feeling of Equality	Independent State	Evacuation of the Settlers in the Settlements	International Recognition & Permanent Boarders	Maximization of the Area (Land)	Economic Stability and Prosperity	East Jerusalem as the Capital of Palestine	Solve the Refuges Problem	Control of the Muslim Holy Places
		Score	.1449	.2145	.0661	.0368	.0816	.0219	.1361	.2128	.0853
1	Abandon the Idea of Jewish State	0.7252	0.96	0.84	0	0	0	0	0.88	0.98	0.91
2	Accept Palestinian full control of the boarders of the Palestinian State and its outlets	0.5538	0.96	1	0	0	0	0	0.39	0.56	0.32
3	Accept the historical responsibility for the Palestinian refugee problem	0.1962	0.37	0.24	0	0	0	0	0.11	0.36	0.03
4	Accept the Palestinian refugee rights to return	0.5985	0.96	0.83	0	0	0	0	0.35	1	0.24
5	Accept to abide by the status quo in the holy places in Jerusalem	0.392	0.74	0.30	0	0	0	0	0.94	0.09	0.85
6	Accept to abolish law of return	0.3104	0.71	0.14	0	0	0	0	0.09	0.72	0.13
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	0.3734	0.90	0.84	0	0	0	0	0.30	0.08	0.06
8	Accept East Jerusalem as the capital of the Palestinian State	0.5851	0.93	0.94	0	0	0	0	1	0.14	0.96
9	Accept Two-State Solution on the borders of the 4th of June 1967	0.595	0.91	0.70	0	0	0	0	0.93	0.78	0.24
10	Allow all parties to have equal access to and control of religious sites and holy places	0.386	0.89	0.32	0	0	0	0	0.66	0.08	0.95
11	Allow the sharing of all natural resources between Palestinians and Israelis	0.2069	0.58	0.40	0	0	0	0	0.08	0.08	0.09
12	Comply with all applicable UN Resolutions	0.6941	0.86	0.91	0	0	0	0	0.81	0.96	0.70
13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	0.6465	0.95	0.98	0	0	0	0	0.96	0.63	0.39
14	Release all political prisoners including those who are Israeli citizens	0.3467	0.94	0.87	0	0	0	0	0.05	0.06	0.05
15	Share Jerusalem as two capitals of two states	0.4371	0.68	0.53	0	0	0	0	0.75	0.22	0.88
16	Solve the Palestinian refugee problem in a just and agreed upon manner	0.5315	0.80	0.81	0	0	0	0	0.11	1.00	0.16
17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	0.0805	0.34	0.06	0	0	0	0	0.03	0.05	0.05

Table 5a. Palestinian Benefits from Israeli Concessions.

			Permanent Borders	Sovereign Palestinian State	Share of Water and Other resources	Resolution of the refugee problem	Shared Control of Jerusalem and Holy Places	International guarantees and assurances to protect Palestine State security and integrity	Evacuation of the Israeli settlements	Having full control over air space, maritime, borders and outlets	Release of political prisoners including those who are Israeli citizens	Respect the integrity of West Bank and Gaza	Stop incitment and raging hatred	East Jerusalem as the capital of the State of Palestine
		Score	.2095	.2054	.0181	.0654	.0613	.0403	.0415	.1086	.0186	.0571	.0087	.1654
1	Abandon the Idea of Jewish State	0.8333	0.83	0.91	0.09	0.79	0.66	0.84	0.94	0.87	0.65	0.93	0.45	0.86
2	Accept Palestinian full control of the borders of the Palestinian State and its outlets	0.9288	0.93	0.98	0.81	0.68	0.94	0.89	0.96	0.96	0.71	0.98	0.53	0.98
3	Accept the historical responsibility for the Palestinian refugee problem	0.8981	0.94	0.87	0.9	0.92	0.89	0.92	0.98	0.81	0.82	0.95	0.84	0.9
4	Accept the Palestinian refugee rights to return	0.8341	0.71	0.96	0.32	0.87	0.84	0.63	0.93	0.84	0.76	0.87	0.5	0.91
5	Accept to abide by the status quo in the holy places in Jerusalem	0.7519	0.76	0.69	0.25	0.84	0.78	0.89	0.76	0.63	0.76	0.78	0.6	0.87
6	Accept to abolish law of return	0.5122	0.53	0.32	0.4	0.58	0.35	0.4	0.55	0.5	0.4	0.7	0.47	0.75
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	0.9237	0.93	0.92	0.8	0.81	0.92	0.9	0.9	0.96	0.89	0.98	0.78	0.96
8	Accept to withdraw from East Jerusalem	0.9389	1	0.98	0.71	0.83	0.9	0.87	0.96	0.86	0.8	0.96	0.65	0.98
9	Accept Two-State Solution on the borders of the 4th of June 1967	0.9228	0.98	0.98	0.55	0.84	0.63	0.87	0.98	0.94	0.89	0.98	0.78	0.94
10	Allow all parties to have equal access to and control of religious sites and holy places	0.7561	0.76	0.78	0.73	0.65	0.84	0.73	0.84	0.76	0.45	0.6	0.68	0.81
11	Allow the sharing of all natural resources between Palestinians and Israelis	0.6282	0.53	0.6	0.86	0.6	0.63	0.78	0.6	0.73	0.68	0.78	0.39	0.63
12	Comply with all applicable UN Resolutions	0.9245	0.91	0.89	0.92	0.94	0.87	0.89	0.96	0.95	0.9	1	0.92	0.96
13	Evacuate settlement of Jewish settlers on land claimed by the Palestinians with or without compensation	0.8741	0.89	0.79	0.81	0.92	0.92	0.81	0.98	0.89	0.79	0.92	0.73	0.91
14	Release all political prisoners including those who are Israeli citizens	0.7068	0.84	0.65	0.71	0.78	0.55	0.78	0.81	0.55	0.98	0.79	0.84	0.63
15	Shared Jerusalem as a religious and political center with all parties	0.7954	0.8	0.71	0.73	0.7	0.87	0.74	0.87	0.78	0.89	0.89	0.5	0.89
16	Solve the Palestinian refugee problem in a just and agreed upon manner	0.8341	0.79	0.82	0.74	0.96	0.9	0.87	0.93	0.84	0.88	0.92	0.5	0.79
17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	0.3881	0.29	0.42	0.55	0.4	0.44	0.45	0.27	0.35	0.37	0.4	0.93	0.44

Table 5b. Palestinian Costs from Palestinian Concessions.

			Conflict between Palestinian diaspora and the internal leadership	Giving up the claim over historic Palestine occupied in 1948 and known later as the State of Israel	Partial loss/depletion of natural resources by sharing them with Israel	Loss of military capability to defend the State of Palestine	Territorial loss as a result of unfair land swap	Accomodation and rehabilitation of Palestinian refugees not allowed to return to Israel	Restrictions on national sovereignty by accepting demilitarization and multinational monitoring	Loss of property rights	Dislocation and fragmentation of Palestinian social fabric
		Score	.0948	.2055	.1257	.0575	.2173	.1192	.1013	.0395	.0392
1	Accept mutually agreed upon land swap	0.6178	0	0.86	0.87	0	1	0.96	0	0	0
2	Accept settlers under Palestinian sovereignty as residents	0.5866	0	0.91	0.73	0	0.89	0.96	0	0	0
3	Accept the temporary presence of multinational military monitoring system in Jordan Valley	0.5353	0	0.81	0.45	0	0.96	0.87	0	0	0
4	Accept Two-State Solution	0.5629	0	0.86	0.71	0	0.84	0.96	0	0	0
5	Acceptance of a Two-State solution which includes a Non-Contiguous State	0.5576	0	0.92	0.88	0	0.71	0.87	0	0	0
6	Acknowledge Israel's Existence as a Jewish State	0.597	0	0.92	0.66	0	0.98	0.94	0	0	0
7	Acknowledge Israel's Existence as an Independent State	0.5706	0	0.92	0.6	0	0.86	1	0	0	0
8	Agree to Compromise on the Right of Return	0.6144	0	0.92	0.94	0	0.92	0.9	0	0	0
9	Agreeing with Palestinian demilitarized state for a limited time period	0.5761	0	0.98	0.79	0	0.79	0.87	0	0	0
10	Preserve the Status Quo in the Holy places of Jerusalem	0.5082	0	0.87	0.5	0	0.87	0.65	0	0	0
11	Allow Israel to use Palestinian airspace	0.5919	0	0.93	0.86	0	0.93	0.76	0	0	0
12	Declare Against Iranian Nuclear Development	0.3649	0	0.81	0.42	0	0.27	0.73	0	0	0
13	Denounce & Reign in Violence	0.4545	0	0.81	0.76	0	0.48	0.74	0	0	0
14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	0.3369	0	0.71	0.65	0	0.13	0.68	0	0	0
15	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	0.5365	0	0.86	0.83	0	0.66	0.94	0	0	0
16	Make Compromise on the Status of Jerusalem	0.6608	0	1	0.98	0	0.98	1	0	0	0
17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	0.383	0	0.84	0.5	0	0.35	0.6	0	0	0
18	Refrain and work against any anti-Israel sentiments in Palestinian schools	0.4858	0	0.85	0.76	0	0.63	0.66	0	0	0
19	Seek Assistance for a Legitimate Settlement of Refugees except Israel	0.5697	0	1	0.74	0	0.76	0.89	0	0	0
20	Sharing of Natural Resources	0.5391	0	0.76	0.74	0	0.89	0.81	0	0	0
21	Work Cooperatively and in active engagement w/ Israel	0	0	0	0	0	0	0	0	0	0

Table 5c. Palestinian Perception of Israeli Benefits from Palestinian Concessions.

			Gaining ligitimacy of the Palestinian and Arab and Muslim World	Integration in the Middle East with normal relations with its neighbors and Arab World	End of claims by the Palestinians	Obtaining security by acceptance and recognition of the Palestinians and Arab and Muslim World	Sharing the Palestinians with their own natural resources	Obtaining territorial gains	Economic relations and new markets including tourism with neighboring Arab and Islamic countries	Reduction of military expenditures enabling national development	Regional cooperation against external threats	Acknowledgement of Israeli control over the Wailing Wall and the Jewish Quarter in the Old City of Jerusalem
		Score	0.1111	0.0658	0.2556	0.108	0.0215	0.1184	0.0999	0.0239	0.0333	0.1626
1	Accept mutually agreed upon land swap	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
2	Accept settlements under Palestinian sovereignty as residents	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
3	Accept the temporary presence of multinational military monitoring system in Jordan Valley	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
4	Accept Two-State Solution	0.5617	0.82	0.00	0.92	0.84	0.00	0.00	0.00	0.00	0.00	0.89
5	Acceptance a Two-State solution which includes a Non-Contiguous State	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
6	Acknowledge Israel's Existence as a Jewish State	0.5867	0.94	0.00	0.90	0.86	0.00	0.00	0.00	0.00	0.00	0.98
7	Acknowledge Israel's Existence as an Independent State	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
8	Agree to Compromise to the Demand of the Right of No Return	0.6009	0.94	0.00	0.96	0.91	0.00	0.00	0.00	0.00	0.00	0.94
9	Agreeing with Palestinian demilitarized state for a limited time period	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
10	Preserve the Status Quo in the Holy places of Jerusalem	0.1463	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90
11	Allow Israel to use Palestinian airspace	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
12	Declare Against Iranian Nuclear Development	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
13	Denounce & Reign in Violence	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
15	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
16	Make Compromise on the Status of Jerusalem	0.6278	0.98	0.00	0.98	0.98	0.00	0.00	0.00	0.00	0.00	1.00
17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
18	Refrain and work against any anti-Israel sentiments in Palestinian schools	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
19	Seek Assistance for a Legitimate Settlement of Refugees	0.2454	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	Sharing of Natural Resources	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20
21	Work Cooperatively and in active engagement w/ Israel	0.1255	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.20

Table 5d. Palestinian Perception of Israeli Costs from Israeli Concessions.

			Changing of Zionist narrative	Property restitution and compensation	Settlements evacuation	Rehabilitating evacuated settlers from the Palestinian territories
		Score	.4541	.0689	.2723	.2047
1	Abandon the Idea of Jewish State	0.8198	0.98	0	0.79	0.78
2	Accept Palestinian full control of the boarders of the Palestinian State and its outlets	0.8226	0.92	0	0.81	0.9
3	Accept the historical responsibility for the Palestinian refugee problem	0.6633	0.76	0	0.71	0.61
4	Accept the Palestinian refugee rights to return	0.8055	0.92	0	0.86	0.75
5	Accept to abide by the status quo in the holy places in Jerusalem	0.642	0.65	0	0.68	0.79
6	Accept to abolish law of return	0.6273	0.73	0	0.5	0.78
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	0.7665	0.84	0	0.76	0.87
8	Accept East Jerusalem as the capital of the Palestinian State	0.8205	0.92	0	0.87	0.81
9	Accept Two-State Solution on the borders of the 4th of June 1967	0.7687	0.83	0	0.89	0.73
10	Allow all parties to have equal access to and control of religious sites and holy places	0.4622	0.4	0	0.79	0.32
11	Allow the sharing of all natural resources between Palestinians and Israelis	0.4453	0.37	0	0.68	0.45
12	Comply with all applicable UN Resolutions	0.7683	0.76	0	0.9	0.87
13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	0.8466	0.91	0	0.96	0.84
14	Release all political prisoners including those who are Israeli citizens	0.551	0.55	0	0.55	0.74
15	Share Jerusalem as two capitals of two states	0.6209	0.76	0	0.81	0.27
16	Solve the Palestinian refugee problem in a just and agreed upon manner	0.7767	0.84	0	0.82	0.84
17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	0.4225	0.42	0	0.34	0.68

Table 6a. Summary for Israelis.

	See Table 1b	See Table 1d		See Table 2a	See Table 2d	
Concessions	Israelis' Costs	Israelis' Perception of Palestinians' Benefits	Israelis' Total Loss	Palestinians' Benefits	Palestinians' Perception of Israelis Costs	Palestinians' Total Gain
	(1)	(2)	(1)*(2)*1000	(3)	(4)	(3)*(4)*1000
1	**1**	**1**	1000.00	**0.8830**	**0.9683**	855.03
2	**0.6445**	**0.7637**	492.18	**0.9894**	**0.9717**	961.31
3	**0.9051**	**0.2705**	244.88	**0.9574**	**0.7835**	750.15
4	**0.9470**	**0.8253**	781.53	**0.8830**	**0.9515**	840.11
5	**0.1961**	**0.5405**	106.01	**0.7979**	**0.7583**	605.05
6	**0.8824**	**0.4280**	377.70	**0.5426**	**0.7410**	402.01
7	**0.1984**	**0.5149**	102.15	**0.9787**	**0.9054**	886.12
8	**0.8299**	**0.8068**	669.54	**1**	**0.9692**	969.17
9	**0.0545**	**0.8205**	44.75	**0.9787**	**0.9080**	888.67
10	**0.1006**	**0.5323**	53.55	**0.8085**	**0.5459**	441.41
11	**0.1120**	**0.2853**	31.96	**0.6702**	**0.5260**	352.52
12	**0.8596**	**0.9571**	822.76	**0.9787**	**0.9075**	888.20
13	**0.3593**	**0.8915**	320.31	**0.9255**	**1**	925.53
14	**0.5178**	**0.4781**	247.56	**0.7553**	**0.6508**	491.59
15	**0.1633**	**0.6027**	98.42	**0.8511**	**0.7334**	624.17
16	**0.1806**	**0.7329**	132.34	**0.8830**	**0.9174**	810.08
17	**0.0741**	**0.1110**	8.23	**0.4149**	**0.4991**	207.05

Table 6b. Summary for Palestinians.

	See Table 1b	See Table 1d		See Table 2a	See Table 2d	
Concessions	Israelis' Costs	Israelis' Perception of Palestinians' Benefits	Israelis' Total Loss	Palestinians' Benefits	Palestinians' Perception of Israelis Costs	Palestinians' Total Gain
	(1)	(2)	(1)*(2)*1000	(3)	(4)	(3)*(4)*1000
1	**1**	**1**	1000.00	**0.8830**	**0.9683**	855.03
2	**0.6445**	**0.7637**	492.18	**0.9894**	**0.9717**	961.31
3	**0.9051**	**0.2705**	244.88	**0.9574**	**0.7835**	750.15
4	**0.9470**	**0.8253**	781.53	**0.8830**	**0.9515**	840.11
5	**0.1961**	**0.5405**	106.01	**0.7979**	**0.7583**	605.05
6	**0.8824**	**0.4280**	377.70	**0.5426**	**0.7410**	402.01
7	**0.1984**	**0.5149**	102.15	**0.9787**	**0.9054**	886.12
8	**0.8299**	**0.8068**	669.54	**1**	**0.9692**	969.17
9	**0.0545**	**0.8205**	44.75	**0.9787**	**0.9080**	888.67
10	**0.1006**	**0.5323**	53.55	**0.8085**	**0.5459**	441.41
11	**0.1120**	**0.2853**	31.96	**0.6702**	**0.5260**	352.52
12	**0.8596**	**0.9571**	822.76	**0.9787**	**0.9075**	888.20
13	**0.3593**	**0.8915**	320.31	**0.9255**	**1**	925.53
14	**0.5178**	**0.4781**	247.56	**0.7553**	**0.6508**	491.59
15	**0.1633**	**0.6027**	98.42	**0.8511**	**0.7334**	624.17
16	**0.1806**	**0.7329**	132.34	**0.8830**	**0.9174**	810.08
17	**0.0741**	**0.1110**	8.23	**0.4149**	**0.4991**	207.05

Table 7a. Israeli Ratios.

Israelis' Ratios	Accept mutually agreed upon land swap	Accept settlers under Palestinian sovereignty as residents	Accept the temporary presence of multinational military monitoring system in Jordan Valley	Accept Two-State Solution	Acceptance a Two-State solution which includes a Non-Contiguous State	Acknowledge Israel's Existence as a Jewish State	Acknowledge Israel's Existence as an Independent State	Agree to Compromise to the Demand of the Right of Return	Agreeing with Palestinian demilitarized state	Preserve the Status Quo in the Holy places of Jerusalem	Allow Israel to use Palestinian airspace	Declare Against Iranian Nuclear Development	Denounce & Reign in Violence	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	Make Compromise on the Status of Jerusalem	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	Refrain and work against any anti-Israel sentiments in Palestinian schools	Seek Assistance for a Legitimate Settlement of Refugees	Sharing of Natural Resources	Work Cooperatively and in active engagement w/ Israel
Abandon the Idea of Jewish State	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Accept Palestinian full control of the borders of the Palestinian State and its outlets	1.192	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.169	0.000	0.000	1.697	0.000	0.000
Accept the historical responsibility for the Palestinian refugee problem	2.395	0.000	0.000	0.000	0.000	3.570	2.038	3.494	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.350	1.832	0.000	3.410	0.000	0.000
Accept the Palestinian refugee rights to return	0.000	0.000	0.000	0.000	0.000	1.118	0.000	1.095	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.068	0.000	0.000
Accept to abide by the status quo in the holy places in Jerusalem	5.533	1.044	0.000	1.557	2.143	8.246	4.708	8.072	0.000	2.225	0.000	0.000	0.000	0.000	0.000	5.429	4.233	1.338	7.877	0.000	1.334
Accept to abolish law of return	1.553	0.000	0.000	0.000	0.000	2.314	1.321	2.266	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.524	1.188	0.000	2.211	0.000	0.000
Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	5.742	1.083	0.000	1.616	2.224	8.557	4.886	8.377	0.000	2.309	0.000	0.000	0.000	0.000	0.000	5.634	4.392	1.389	8.175	0.000	1.385
Accept East Jerusalem as the capital of the Palestinian State	0.000	0.000	0.000	0.000	0.000	1.306	0.000	1.278	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.247	0.000	0.000
Accept Two-State Solution on the borders of the 4th of June 1967	13.108	2.473	1.738	3.689	5.076	19.534	11.153	19.123	1.804	5.270	1.615	0.000	1.539	0.000	1.645	12.860	10.027	3.170	18.660	0.000	3.161
Allow all parties to have equal access to and control of religious sites and holy places	10.953	2.066	1.453	3.083	4.242	16.323	9.320	15.980	1.508	4.404	1.350	0.000	1.286	0.000	1.375	10.747	8.379	2.649	15.593	0.000	2.641
Allow the sharing of all natural resources between Palestinians and Israelis	18.354	3.463	2.434	5.166	7.108	27.352	15.617	26.776	2.526	7.380	2.262	0.000	2.155	0.000	2.303	18.008	14.040	4.439	26.129	0.000	4.426
Comply with all applicable UN Resolutions	0.000	0.000	0.000	0.000	0.000	1.062	0.000	1.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.015	0.000	0.000
Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	1.831	0.000	0.000	0.000	0.000	2.729	1.558	2.672	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.797	1.401	0.000	2.607	0.000	0.000
Release all political prisoners including those who are Israeli citizens	2.369	0.000	0.000	0.000	0.000	3.531	2.016	3.457	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.325	1.812	0.000	3.373	0.000	0.000
Share Jerusalem as two capitals of two states	5.959	1.124	0.000	1.677	2.308	8.881	5.071	8.694	0.000	2.396	0.000	0.000	0.000	0.000	0.000	5.847	4.559	1.441	8.484	0.000	1.437
Solve the Palestinian refugee problem in a just and agreed upon manner	4.432	0.000	0.000	1.247	1.716	6.605	3.771	6.466	0.000	1.782	0.000	0.000	0.000	0.000	0.000	4.349	3.390	1.072	6.310	0.000	1.069
Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	71.312	13.453	9.458	20.070	27.616	106.275	60.678	104.036	9.816	28.674	8.787	1.679	8.374	2.674	8.949	69.967	54.551	17.249	101.521	2.692	17.196

Table 7b. Palestinian Ratios.

Palestinians' Ratios	Accept mutually agreed upon land swap	Accept settlers under Palestinian sovereignty as residents	Accept the temporary presence of multinational military monitoring system in Jordan Valley	Accept Two-State Solution	Acceptance a Two-State solution which includes a Non-Contiguous State	Acknowledge Israel's Existence as a Jewish State	Acknowledge Israel's Existence as an Independent State	Agree to Compromise to the Demand of the Right of Return	Agreeing with Palestinian demilitarized state	Preserve the Status Quo in the Holy places of Jerusalem	Allow Israel to use Palestinian airspace	Declare Against Iranian Nuclear Development	Denounce & Reign in Violence	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land o origin	Make Compromise on the Status of Jerusalem	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	Refrain and work against any anti-Israel sentiments in Palestinian schools	Seek Assistance for a Legitimate Settlement of Refugees	Sharing of Natural Resources	Work Cooperatively and in active engagement w/ Israel
Abandon the Idea of Jewish State	4.573	4.816	5.277	1.122	5.066	1.013	4.951	0.000	4.904	4.770	4.773	7.742	6.216	8.385	5.266	0.000	7.376	5.815	2.537	5.240	21.376
Accept Palestinian full control of the borders of the Palestinian State and its outlets	5.141	5.415	5.933	1.261	5.696	1.139	5.566	1.080	5.513	5.363	5.366	8.704	6.988	9.428	5.920	0.000	8.293	6.538	2.852	5.892	24.033
Accept the historical responsibility for the Palestinian refugee problem	4.012	4.225	4.630	0.000	4.445	0.000	4.344	0.000	4.302	4.185	4.187	6.792	5.453	7.357	4.620	0.000	6.471	5.102	2.226	4.597	18.754
Accept the Palestinian refugee rights to return	4.493	4.732	5.185	1.102	4.978	0.000	4.865	0.000	4.818	4.687	4.690	7.607	6.107	8.239	5.174	0.000	7.247	5.714	2.493	5.149	21.003
Accept to abide by the status quo in the holy places in Jerusalem	3.236	3.408	3.735	0.000	3.585	0.000	3.503	0.000	3.470	3.375	3.377	5.478	4.398	5.934	3.726	0.000	5.220	4.115	1.795	3.708	15.126
Accept to abolish law of return	2.150	2.264	2.481	0.000	2.382	0.000	2.328	0.000	2.306	2.243	2.244	3.640	2.922	3.943	2.476	0.000	3.468	2.734	1.193	2.464	10.050
Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	4.739	4.991	5.469	1.163	5.251	1.050	5.131	0.000	5.082	4.944	4.946	8.023	6.442	8.690	5.457	0.000	7.644	6.027	2.629	5.431	22.153
Accept East Jerusalem as the capital of the Palestinian State	5.183	5.459	5.982	1.272	5.743	1.148	5.612	1.089	5.558	5.407	5.410	8.775	7.045	9.505	5.969	0.000	8.361	6.591	2.875	5.940	24.229
Accept Two-State Solution on the borders of the 4th of June 1967	4.753	5.005	5.485	1.166	5.266	1.053	5.146	0.000	5.097	4.958	4.961	8.046	6.460	8.715	5.473	0.000	7.666	6.044	2.637	5.446	22.217
Allow all parties to have equal access to and control of religious sites and holy places	2.361	2.486	2.724	0.000	2.615	0.000	2.556	0.000	2.532	2.463	2.464	3.997	3.209	4.329	2.718	0.000	3.808	3.002	1.310	2.705	11.035
Allow the sharing of all natural resources between Palestinians and Israelis	1.885	1.986	2.176	0.000	2.089	0.000	2.041	0.000	2.022	1.967	1.968	3.192	2.563	3.457	2.171	0.000	3.041	2.398	1.046	2.161	8.813
Comply with all applicable UN Resolutions	4.750	5.003	5.482	1.165	5.263	1.052	5.143	0.000	5.094	4.955	4.958	8.042	6.457	8.711	5.470	0.000	7.662	6.041	2.635	5.444	22.205
Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	4.950	5.213	5.713	1.214	5.484	1.096	5.359	1.040	5.308	5.163	5.166	8.380	6.728	9.077	5.700	0.000	7.984	6.295	2.746	5.672	23.138
Release all political prisoners including those who are Israeli citizens	2.629	2.769	3.034	0.000	2.913	0.000	2.847	0.000	2.819	2.743	2.744	4.451	3.574	4.821	3.027	0.000	4.241	3.343	1.458	3.013	12.290
Share Jerusalem as two capitals of two states	3.338	3.516	3.853	0.000	3.698	0.000	3.614	0.000	3.580	3.482	3.484	5.652	4.537	6.121	3.844	0.000	5.385	4.245	1.852	3.825	15.604
Solve the Palestinian refugee problem in a just and agreed upon manner	4.332	4.563	5.000	1.063	4.800	0.000	4.691	0.000	4.646	4.519	4.522	7.335	5.889	7.944	4.989	0.000	6.988	5.509	2.403	4.965	20.252
Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	1.107	1.166	1.278	0.000	1.227	0.000	1.199	0.000	1.187	1.155	1.156	1.875	1.505	2.031	1.275	0.000	1.786	1.408	0.000	1.269	5.176

Table 8a. One-to-one concessions.

#	Israeli Concessions	Trade Value		#	Palestinian Concessions	Trade Value
12	Comply with all applicable UN Resolutions	1.06	1%	6	Acknowledge Israel's Existence as a Jewish State	1.05
9	Accept Two-State Solution on the borders of the 4th of June 1967	5.08	5%	5	Acceptance a Two-State solution which includes a Non-Contiguous State	5.26
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	4.88	5%	7	Acknowledge Israel's Existence as an Independent State	5.13
16	Solve the Palestinian refugee problem in a just and agreed upon manner	4.43	5%	1	Accept mutually agreed upon land swap	4.33
13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	4.61	5%	19	Seek Assistance for a Legitimate Settlement of Refugees	2.75
11	Allow the sharing of all natural resources between Palestinians and Israelis	2.3	10%	15	Lobby Arab States to Allow both Israelis and Palestinians to Have the Right to Return to their land of origin	2.17
15	Share Jerusalem as two capitals of two states	4.56	10%	17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	5.38
10	Allow all parties to have equal access to and control of religious sites and holy places	2.64	10%	18	Refrain and work against any anti-Israel sentiments in Palestinian schools	3
17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs	1.68	10%	12	Declare Against Iranian Nuclear Development	1.87
8	Accept East Jerusalem as the capital of the Palestinian State	1.28	10%	8	Agree to Compromise to the Demand of the Right of Return	1.09
2	Accept Palestinian full control of the borders of the Palestinian State and its outlets	5.43	1%	2	Accept settlers under Palestinian sovereignty as residents	5.41
5	Accept to abide by the status quo in the holy places in Jerusalem			16	Make Compromise on the Status of Jerusalem	
		37.95				37.44

Table 8b. Two-to-two concessions.

#	Israeli Concessions	Trade Value		#	Palestinian Concessions	Trade Value
9	Accept Two-State Solution on the borders of the 4th of June 1967	20.19		6	Acknowledge Israel's Existence as a Jewish State	20.25
16	Solve the Palestinian refugee problem in a just and agreed upon manner			21	Work Cooperatively and in active engagement w/ Israel	
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	10.95		1	Accept mutually agreed upon land swap	11.05
10	Allow all parties to have equal access to and control of religious sites and holy places			14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	
13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation	9.88		17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	9.83
15	Share Jerusalem as two capitals of two states			19	Seek Assistance for a Legitimate Settlement of Refugees	
2	Accept Palestinian full control of the borders of the Palestinian State and its outlets	9.82		9	Agreeing with Palestinian demilitarized state	9.89
17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs			12	Declare Against Iranian Nuclear Development	
11	Allow the sharing of all natural resources between Palestinians and Israelis	7.37		3	Accept the temporary presence of multinational military monitoring system in Jordan Valley	7.45
12	Comply with all applicable UN Resolutions			10	Preserve the Status Quo in the Holy places of Jerusalem	
5	Accept to abide by the status quo in the holy places in Jerusalem	5.43		2	Accept settlers under Palestinian sovereignty as residents	5.46
8	Accept East Jerusalem as the capital of the Palestinian State			16	Make Compromise on the Status of Jerusalem	
3	Accept the historical responsibility for the Palestinian refugee problem	4.3		7	Acknowledge Israel's Existence as an Independent State	4.34
6	Accept to abolish law of return			8	Agree to Compromise to the Demand of the Right of Return	
		67.94				68.27

Table 8c. Three-to-three concessions.

#	Israeli Concessions	Trade Value		#	Palestinian Concessions	Trade Value
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas.	33.07		10	Preserve the Status Quo in the Holy places of Jerusalem	33.07
8	Accept East Jerusalem as the capital of the Palestinian State			17	Palestinians must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank	
17	Stop incitement by the religious and national education and religious leaders in Israel against Muslims and Arabs			21	Work Cooperatively and in active engagement w/ Israel	
2	Accept Palestinian full control of the borders of the Palestinian State and its outlets	18.66		13	Denounce & Reign in Violence	18.73
9	Accept Two-State Solution on the borders of the 4th of June 1967			14	Denounce Iranian pursuit of nuclear arms and support Israelis effort to remove the threat	
13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians with or without compensation			19	Seek Assistance for a Legitimate Settlement of Refugees	
4	Accept the Palestinian refugee rights to return	15.62		7	Acknowledge Israel's Existence as an Independent State	15.69
11	Allow the sharing of all natural resources between Palestinians and Israelis			12	Declare Against Iranian Nuclear Development	
12	Comply with all applicable UN Resolutions			18	Refrain and work against any anti-Israel sentiments in Palestinian schools	
1	Abandon the Idea of Jewish State	10.35		1	Accept mutually agreed upon land swap	11.02
5	Accept to abide by the status quo in the holy places in Jerusalem			3	Accept the temporary presence of multinational military monitoring system in Jordan Valley	
10	Allow all parties to have equal access to and control of religious sites and holy places			11	Allow Israel to use Palestinian airspace	
3	Accept the historical responsibility for the Palestinian refugee problem	8.88		2	Accept settlers under Palestinian sovereignty as residents	8.86
15	Share Jerusalem as two capitals of two states			6	Acknowledge Israel's Existence as a Jewish State	
16	Solve the Palestinian refugee problem in a just and agreed upon manner			9	Agreeing with Palestinian demilitarized state	
6	Accept to abolish law of return	2.32		5	Acceptance a Two-State solution which includes a Non-Contiguous State	2.38
14	Release all political prisoners including those who are Israeli citizens			16	Make Compromise on the Status of Jerusalem	
		88.9				89.75

Table 9. The Pittsburgh Principles.

	Israeli-Palestinian Pittsburgh Declaration of Principles August 2011
1	A Two-Sate Solution on the boarders of the 4th of June 1967, with mutually agreed upon land swaps
2	Israel must respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas, and the Palestinian State must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank.
3	East Jerusalem will be the capital of the Palestinian State. The parties will maintain the Status Quo of the Holy places in Jerusalem
4	Acknowledge Israel's Existence as a Jewish Sate without jeopardizing the rights of its minority Israeli citizens
5	Evacuation of Israeli settlers from the Palestinian territories that are not included in the landswaps
6	Palestinian full control of the borders of the Palestinian State and it outlets, and deployment of a temporary agreed upon multinational military monitoring system in the Jordan Valley.
7	Solve the Palestinian refugee problem in a just and agreed upon manner
8	A demilitarized Palestinian state
9	Agreed upon international monitoring mechanism and agreed upon binding international arbitration mechanisms
10	The full implementation of these principles concludes the end of the conflict and the claims of the two parties

Table 10. The Set of Six Most Important Concessions.

#	Israeli Concessions
2	Accept Palestinian full control of the borders of the Palestinian State and its outlets
7	Accept to respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas
8	Accept East Jerusalem as the capital of the Palestinian State
9	Accept a Two-State Solution on the borders of the 4th of June, 1967
13	Evacuate settlers of Jewish settlements on land claimed by the Palestinians, with or without compensation
16	Solve the Palestinian refugee problem in a just and agreed upon manner

#	Palestinian Concessions
1	Accept mutually agreed-upon land swap
3	Accept the temporary presence of a multinational military monitoring system in Jordan Valley
6	Acknowledge Israel's existence as a Jewish state
9	Agree with a Palestinian demilitarized state
10	Preserve the status quo in the holy places of Jerusalem
17	Guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people both in Gaza and the West Bank

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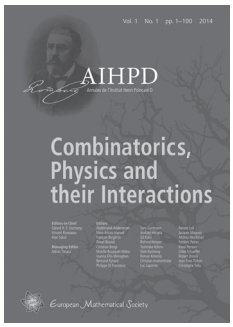

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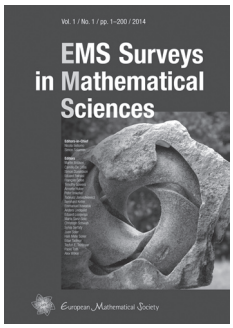

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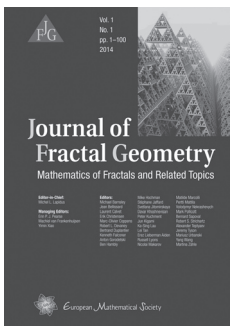

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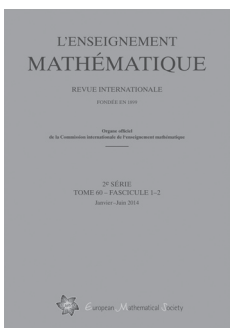

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WHAT IS...

a Flag Algebra?

Alexander A. Razborov

Before attempting to answer the question from the title, it would be useful to say a few words about another question: what kind of problems have flag algebras been invented for?

Let us consider three similar combinatorial puzzles. Assume that we have a (simple, undirected) graph with n vertices. What is the minimal number of edges m (as a function in n) that guarantees the existence of a triangle? Also, assuming that m is above this threshold, *how many* triangles are guaranteed to exist? Let us now offset everything by one, and instead of graphs consider (simple) 3-graphs, i.e., sets of unordered triples (called 3-*edges*) on n vertices. We again ask, what is the minimal number m of 3-edges that guarantees the existence of four vertices such that all four possible triples spanned by these vertices are in the set of 3-edges?

The subarea of discrete mathematics that deals with questions of this sort is called *extremal combinatorics*, and it is very strategically located at a crossroads between "pure" mathematics and its applications. One good way to describe flag algebras is as an attempt to expose and emphasize some common mathematical structure underlying many standard techniques in extremal combinatorics, and a survey of *concrete* results obtained in this way can be found in [1]. Before going into more detail, however, let me encourage the reader to put this article aside and try to predict the current status of the three problems from the previous paragraph.

Ready? The first problem (on the threshold value $m(n)$) was solved in a classic paper by Mantel published in 1907. The second problem (on the minimal number of triangles beyond the threshold) had been open for some forty years. It was asymptotically solved only recently using flag algebras. The generalization to 3-graphs was suggested by Turán in another classic paper written in 1941; he conjectured that $m \le (\frac{5}{9}+o(1))\binom{n}{3}$ and gave the first construction attaining this bound. This conjecture remains unsolved despite repeated attempts by many strong researchers, and it has greatly stimulated the development of the whole field. Some partial results toward Turán's $(3,4)$-conjecture (by the way, its analogues are open for any values of the parameters 4 and 3 as long as $4 > 3 > 2$), though, were obtained with the help of flag algebras. As Sidorenko, one of the leading experts in the area, put it in his survey dated 1995, "The general problem of Turán having an *extremely* simple formulation but being extremely hard to solve, has become one of the most fascinating *extremal problems* in combinatorics."

Now, let us do one of the many proofs of Mantel's result: it will serve as a motivating running example for our definitions. Let $d_1,\dots,d_n$ be vertex degrees in our graph, and let $e(v) \approx d_v/n$ be the *relative* degree of the vertex $v \in \{1,2,\dots,n\}$. (Strictly speaking, $e(v) = d_v/(n-1)$, but systematically ignoring low-order terms is one of the most basic principles of the theory we are discussing.) We

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have

(1)
$$0 \le \frac{1}{n}\sum_{v=1}^{n}(e(v)-\frac{1}{2})^2 \approx \frac{1}{n^3}\sum_v d(v)^2 - \frac{1}{n^2}\sum_v d(v) + \frac{1}{4}.$$

The term $(1/n^2)\sum_v d(v)$ is easy to interpret: it is simply (remember that we are ignoring low-order terms!) the edge density ρ $(= m/\binom{n}{2})$. To calculate $(1/n^3)\sum_v d(v)^2$, we use double counting and we look at configurations in our graph spanned by three vertices. We can see there are 0, 1, 2, or 3 edges, and let us denote by $I_3, \bar{P}_3, P_3, K_3$ the respective densities or probabilities with which these configurations occur ("I" stands for "independent", "P" stands for "path", "$\bar{P}$" stands for "complement of a path", and "K" stands for a misspelled "clique"). Then a moment's reflection reveals that $(1/n^3)\sum_v d(v)^2 \approx (1/3)P_3 + K_3$: only these two cases contribute to the sum, and K_3 contributes thrice as much since we have three different choices of v in it. But ρ can also be expressed in these terms as $\rho = \frac{1}{3}\bar{P}_3 + \frac{2}{3}P_3 + K_3$: we generate a random pair of vertices in two steps, first by picking a random *triple* and then by selecting a random pair within this triple. Plugging all this into (1), after simple calculations we conclude that $\rho \le (1/2) - \bar{P}_3 + K_3$. Thus, $\rho > 1/2$ implies the existence of triangles, and, moreover, their density K_3 satisfies $K_3 \ge \rho - 1/2$. If we are slightly more careful and instead of $(1/n)\cdot\sum_{v=1}^{n}(e(v)-1/2)^2$ compute $(1/n)\cdot\sum_{v=1}^{n}(e(v)-\rho)^2$ (that is, the *actual* variance of the degree sequence), we will get a better bound $K_3 \ge \rho(2\rho-1)$ proved by Goodman in 1959. This latter bound had remained the best known for the second problem on our list until it was superseded in a beautiful paper by Bollobás (1975).

Let us now see which kind of structure we can extract from this template (all this material can be found in [2]). Our target graph G is large and unknown. Thus, for every fixed graph H we introduce a formal real-valued variable with the same name and the intuitive meaning "the density of induced copies of H in G" (in the argument above, H was one of $\rho, I_3, \bar{P}_3, P_3$, or K_3). As we often need to sum these quantities with real coefficients, we form the linear space of formal (finite) linear combinations of these variables. The identity $\rho = \frac{1}{3}\bar{P}_3 + \frac{2}{3}P_3 + K_3$ that we used above can be widely generalized: the density of any fixed graph H can be expressed in terms of densities of graphs with a fixed but larger number of vertices. We factor our space out by these relations. Multiplication is also available: for example, ρ^2 can be expressed as a linear combination of [the densities of] graphs on four vertices; this is done by double counting similar to our calculation of $(1/n^3)\sum_v d(v)^2$. All these developments give us a commutative associative algebra $\mathcal{A}^0$.

Furthermore, when the size of the target graph G tends to infinity, the densities of induced copies of H converge to an algebra homomorphism ϕ from $\mathcal{A}^0$ to $\mathbb{R}$. These algebra homomorphisms possess an extra property that $\phi(H)$, being a density, is nonnegative for any graph H. Then it turns out that we also have an important "completeness result": every *abstract* algebra homomorphism from $\mathcal{A}^0$ to $\mathbb{R}$ with this nonnegativity property (let us call their set $\mathrm{Hom}^+(\mathcal{A}^0, \mathbb{R})$) can be obtained from a convergent sequence $\{G_n\}$. In other words, the object $\mathrm{Hom}^+(\mathcal{A}^0, \mathbb{R})$ defined in the best mathematical traditions quite abstractly nonetheless corresponds *exactly* to the class of extremal problems we intend to study. For example, the second problem on our list can be reformulated like this: given $x \in [0,1]$, compute the minimal possible value of $\phi(K_3)$, where $\phi \in \mathrm{Hom}^+(\mathcal{A}^0, \mathbb{R})$ satisfies $\phi(\rho) = x$, and, yes, we do mean min here, not inf, since $\mathrm{Hom}^+(\mathcal{A}^0, \mathbb{R})$ is compact. The computation *does* begin with the words "let us fix once and for all an extremal ϕ."

Having thus reformulated the questions of study in the appropriate language, the rest of the theory is basically devoted to developing useful syntactic tools for *proving* theorems about the behavior of the limit densities $\phi(H)$. Most of these tools have evolved from analogous methods employed in finite arguments, but, again, the mathematical structure allows us to search for the desired proofs either completely automatically or in an interactive computer-human mode. This allows us to expand the search space by an order of (literally!) hundreds or thousands. We once more refer to [1] for a survey of concrete results that have been obtained with this method, and now we review some of these tools.

Our account above was tailored to the case of ordinary graphs, but this was done only for simplicity of exposition. The theory of flag algebras was deliberately set up in such a way that it applies in a uniform way to *arbitrary* combinatorial structures: hypergraphs, directed graphs, mixtures of these, colored versions of these, you name it. In logical terms, the set-up can be described as a "universal theory in a language containing only predicate symbols," but the only property that is actually needed is that a subset of vertices of a model spans an (induced) submodel. This is paramount since structures other than simple graphs are where the most important *open* problems in the area reside, Turán's $(3,4)$-problem being just the tip of the iceberg.

Next, our definitions can be readily generalized to the case when all our models are required to contain k distinguished "base" vertices (for an

analogy, the reader should think of base points in algebraic topology) that must be preserved by all mapping involved. This clearly makes sense only when we also specify what we see on $c_1, \dots, c_k$ itself; for example, if $k = 2$, then in the graph theory we should specify whether (c_1, c_2) is an edge or not. Thus, we say that a *type* σ is simply a model with the ground set $\{1, 2, \dots, k\}$, a *flag*[1] of type σ is a model with k base vertices respecting the structure of σ, and then (finally!) the *flag algebra* $\mathcal{A}^\sigma$ and $\mathrm{Hom}^+(\mathcal{A}^\sigma, \mathbb{R})$ are defined just as before. As an example, let 1 be the (only) type of size 1, and let $e \in \mathcal{A}^1$ be an edge with one distinguished vertex in it. Then, instead of computing the sum $(1/n^3)\sum_{v=1}^n d(v)^2$ in (1), we could alternatively express first $e^2 = K_3^1 + P_3^{1,c}$, where K_3^1 and $P_3^{1,c}$ are 1-flags that are obtained from K_3, P_3, respectively, by adding one base vertex which is the center of the path in the case of P_3.

Every flag algebra $\mathcal{A}^\sigma$ has a good supply of elements that are guaranteed to be evaluated to a nonnegative value by any $\phi \in \mathrm{Hom}^+(\mathcal{A}^\sigma, \mathbb{R})$: these are the squares f^2 and their positive linear combinations. We can also define a linear *averaging operator* $[\![\cdot]\!]_\sigma$ that generalizes the summation in (1). For example, $[\![K_3^1]\!]_1 = K_3$, $[\![P_3^{1,c}]\!]_1 = (1/3)P_3$, which gives us another proof of what we did above differently, $[\![e^2]\!]_1 = (1/3)P_3 + K_3$. Now we have a healthy supply of nonnegative elements in $\mathcal{A}^0$, too: these are $[\![f^2]\!]_\sigma$, where $f \in \mathcal{A}^\sigma$ for some type σ, and their positive linear combinations, possibly mixing up relations coming from different types.

It already turns out that these simple ideas (called in [1] "plain methods") can solve many open problems if you look deep enough, i.e., for $f^2 \in \mathcal{A}^\sigma$ that involve flags on sufficiently many vertices (from four to six in a typical application). It is obvious from the look of most of these results that they could hardly be obtained by hand and that they do require computer assistance. Fortunately, the question of "how to represent a specific f in the form $\sum_i \alpha_i [\![f_i^2]\!]_{\sigma_i}$ $(\alpha_i \ge 0)$" is completely answered by semidefinite programming (SDP), and, equally fortunately for flag algebras, for the latter we have not only theoretical results (polynomial time algorithms) but also good noncommercial packages that really do the job. In my own work I most often use CSDP, a package developed by Brian Borchers (`https://projects.coin-or.org/Csdp`); it is also used in the publicly available *flagmatic software* (`http://www.maths.qmul.ac.uk/~ev/flagmatic/`) by Emil R. Vaughan. One thing that greatly hinders these developments is the absence (to the best of my knowledge) of generic SDP-solvers that also provide certificates of feasibility/unfeasibility: many actual calculations in flag algebras are performed so close to the border between them that numerical results often cannot be trusted.

Besides purely computational convenience, flag algebras lead to more sophisticated structures and objects that also have found applications in concrete proofs; due to lack of space we can only name some of them here (see [2] for all missing details).

There are many useful constructions that allow us to convert combinatorial objects of one sort into objects of another sort. For example, given a directed graph, we can view it as an ordinary graph by erasing its orientation, or, given a 3-graph and a vertex in it, we can look at its link, which is again an ordinary graph. Constructions of this kind are captured by the logical notion of an interpretation, and in the language of flag algebras they lead to algebra homomorphisms between $\mathcal{A}^\sigma$ for different theories. This allows us to conveniently move around theorems (i.e., statements of the form $f \ge 0$) from one context to another.

The space $\mathrm{Hom}^+(\mathcal{A}^0, \mathbb{R})$ is compact, which implies that, for every extremal problem, there exists an *individual* optimal solution to it. Extremality can be exploited in a variety of ways: for example, one can write (an analogue of) a functional derivative according to some intuitive changes and use its equality to zero as a new useful relation not necessarily possessed by an arbitrary $\phi \in \mathrm{Hom}^+(\mathcal{A}^0, \mathbb{R})$.

Tuples of densities $\phi \in \mathrm{Hom}^+(\mathcal{A}^0, \mathbb{R})$ encode a surprising amount of information about the intended object. For example, if we "pick" a base vertex (or, more generally, a copy of a more complicated type σ) at random, then it "should" give rise to a probability distribution over $\phi \in \mathrm{Hom}^+(\mathcal{A}^\sigma, \mathbb{R})$. It turns out that this information can already be uniquely retrieved from ϕ even when we do not really have a good idea which space we are sampling from. For example, we can straightforwardly (say, avoiding Szemeredi's Regularity Lemma) determine the fraction of vertices in a graph that have relative degree at least 1/3 using ϕ only.

It is tempting to employ a similar axiomatic approach in other areas where the Cauchy-Schwarz inequality is used. The difficulties arising here are of a more technical and practical nature: since the group of symmetries is not as rich in those

[1] *The choice of the term "flag" to stand for "a partially labeled combinatorial structure in which labeled vertices span a prescribed model σ" is admittedly somewhat arbitrary. It is largely suggested by a visual association: a few vertices are fixed rigidly while many more are "free" and "waving" through the model we are studying. It has very little to do with other usages of this term in mathematics…incidentally, I have never seen a good explanation of what increasing sequences of linear spaces have to do with corporeal flags, either.*

situations, it is more difficult to come up with a calculus that is good not only theoretically but also allows us to get new concrete results. Some work in this direction, however, has already been done; see [1, Section 4.2].

Last, but definitely not least, we are often interested not only in the properties of the limit densities ϕ itself, but also in what is the *actual* limit object these densities correspond to (or, in more logical terms, in the associated *model theory*). This leads to the deep and beautiful theory of *graph limits* with many connections to other disciplines, and we highly recommend Lovász's recent book [3] for an introduction to the subject. We strongly feel that emphasizing more connections between the syntactical (flag algebras) and semantical (graph limits) approaches to the same class of objects should be very beneficial for both.

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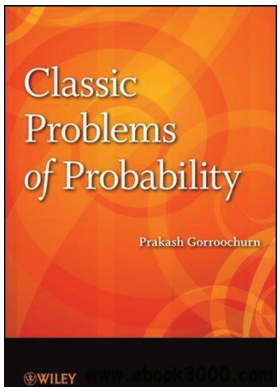

Classic Problems of Probability

Reviewed by Andrew I. Dale

Classic Problems of Probability
Prakash Gorroochurn
John Wiley and Sons, 2012
US$16.55, 320 pp.
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In one of his "Monday Chats" in 1850, Charles-Augustin Sainte-Beuve wrote, "The idea of a *classic* contains in itself something that has a consequence and consistency, that produces cohesion and tradition, that forms itself, that transmits itself and that endures." While it is perhaps too soon to say whether each of the problems Gorroochurn discusses could be described as a *monumentum ære perennius*, there is no doubt that some of the older ones have displayed the desired quality of endurance, and a number have led to later ones and may even be seen as precursors of modern research topics.

This book, the author notes, "is targeted primarily to readers who have had at least a basic course in probability. Readers in the history of probability might also find it useful" (p. ix).[1] Gorroochurn urges the reader not to focus on the problems and their solutions to the neglect of the discussions, and indeed I, for one, found these discussions the most useful and absorbing parts of the text. Some problems certainly require a more advanced knowledge than that to be gained in a basic course in probability for their full understanding and development (e.g., Borel's paradox and Jacob Bernoulli's Law of Large Numbers), but this in no way detracts from one's enjoyment of the text as a whole.

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[1] *References to page numbers without a citation are to the book being reviewed.*

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Many of the problems discussed here are well known, and the student of probability either will have been or certainly should be exposed to them. They are arranged in time order, ranging from one in Cardano's *Liber de ludo aleæ* (1539/1663) to Parrondo's game-theoretic paradox of 1996. We find here well-known curiosities (and sometimes perplexities) such as the de Méré paradoxes, Buffon's needle problem, Bertrand's chords, and birthday coincidences, and also those less well known in general, such as Montmort's matches problem, a question posed by Samuel Pepys to Isaac Newton, Newcomb's problem, and Simpson's paradox.

Some of the problems discussed here are described as "paradoxes". The more one thinks about this word, however, the less clear one becomes about its meaning. What *exactly* is a paradox? Székely [16, p. xii] says "It is important to distinguish paradoxes from fallacies. The first one is a true though surprising theorem while the second one is a false result obtained by reasoning that seems correct." Quoting one Phillips (probably Sir Richard Phillips, 1767–1840), de Morgan [5, vol. I, p. 3] finds added to the notion of strangeness the notion of absurdity, and he points out that a paradox is "contrary to common opinion." And if the touch of absurdity is to be preserved, then we must be grateful to the *Oxford English Dictionary* for advising us that, in the early nineteenth century, "paradox" was an alternative name for *Ornithorhynchus anatinus*, the duck-billed platypus.

De Morgan [5, vol. I, p. 31] can perhaps be seen as having anticipated Székely by writing:

> The counterpart of *paradox*, the isolated opinion of one or of few, is the general opinion held by all the rest; and the counterpart of false and absurd paradox is what is called the "vulgar error", the *pseudodox*.

The masterpiece on this last-mentioned topic is, of course, Sir Thomas Browne's *Pseudodoxia Epidemica*, first published in 1646.

Crudely speaking, one may classify the solutions of the problems discussed by Gorroochurn as the orthodox, the heterodox, and the paradox (using the latter word here as an obsolete adjective), for we have problems such as Cardano's (a simple one involving dice tossing and indisputable reasoning), d'Alembert's coin tossing problem (whose solution hinges heavily, I believe, on the acceptance of an appropriate, if unusual, sample space), and Simpson's paradox (in which, for example, a positive association between treatment and survival among men and among women may, somewhat surprisingly, be reversed or disappear altogether when the populations are combined).

Let's look at a few of Gorroochurn's problems.

De Méré's (first) problem is stated by Gorroochurn (p. 13) as follows:

> When a die is thrown four times, the probability of obtaining at least one six is a little more than 1/2. However, when two dice are thrown 24 times, the probability of getting at least one double-six is a little less than 1/2. Why are the two probabilities not the same, given the fact that Pr[double-six for a pair of dice] = $1/36 = 1/6 \cdot$ Pr[a six for a single die], and you compensate for the factor of 1/6 by throwing $6 \cdot 4 = 24$ times when using two dice?

The phrase "at least one" is used by many English authors who discuss this problem (e.g., Feller [8]). However, the original version, given in David [4, p. 137], runs as follows (my translation):

> If one undertakes to throw a six with one die, there is an advantage in undertaking to do it in 4 throws, as 671 to 625. If one undertakes to throw double-six with two dice there is a disadvantage in undertaking to do it in 24 throws.

The problem was later discussed by Christiaan Huygens in Propositions X and XI of his *De ratiociniis in ludo aleæ* of 1657 (an annotated reprint of this book was given by Jacob Bernoulli in his *Ars Conjectandi* of 1713). These propositions are translated by Arbuthnot [1, vol. II, pp. 273–274] as follows:

> To find at how many Times one may undertake to throw 6 with one Die …To find out how many Times one may undertake to throw 12 with two Dice.

Note that Arbuthnot gives, in the case of both four and five throws, the odds on a six as 671 against 625.

The question is then whether the original should be *interpreted* in the sense of "at least one". Independent of the formulation of the question, however, in all cases the solution to the second part of this problem is that he who undertakes to do it in 24 throws lacks an even chance of winning, while he who undertakes to do it in 25 throws has a better than even chance of winning.

In November 1693 Samuel Pepys asked Newton for help with the following problem:

> A—has 6 dyes in a box with which he is to fling a 6
> B—has in another box 12 dyes with which he is to fling 2 sixes
> C—has in another box 18 dyes with which he is to fling 3 sixes.
> Q—Whether B and C have not as easy a taske as A at even luck?

Chaundy and Bullard [3] note that Pepys had been asked to solve this problem by John Smith, writing master of Christ's Hospital in London, an institution of which Pepys was a governor. It has been suggested that Smith's interest was perhaps not altogether academic, since he was later dismissed from his post on being found to have charged the boys for the use of pens and paper.

Gorroochurn takes care to note that, while Pepys originally posed the problem in terms of an exact number of sixes, Newton pointed out that "in reading the Question it seemed to me at first to be ill stated," and he therefore changed it to "at least one six." It is interesting to note that a variation on this old problem has recently been applied to size-estimation problems (see Varagnolo et al. [17]).

In Bertrand [2, p. 2] we find the following problem (stated slightly differently by Gorroochurn):

> Three chests, identical in appearance, each have two drawers, each drawer containing one coin [*médaille*]. The coins in the first chest are gold, those in the second are silver, while the third chest has one gold and one silver. One chest is chosen. What is the probability that it contains one gold coin and one silver coin in its drawers?

Note that Bertrand does not say, as Gorroochurn does, that the chest is chosen *at random*, though that this is so emerges from the subsequent discussion (the answer is clearly 1/3). Then a drawer in the selected chest is chosen (again, it transpires, at random) and opened. It might be argued, suggests Bertrand, that no matter what coin is revealed, there are only two possible cases: the closed drawer contains either a coin of the same metal as the one displayed or a different one. Of these two cases only one is favorable to the event that the chest has different coins, and thus the probability that one has chosen the chest with different coins is 1/2.

Such an argument, Bertrand notes, although it may appear correct, is in fact false: the two possible cases after the chosen drawer has been opened are not equally probable. Using Bayes's Theorem (Problem 14 in Gorroochurn), any first-year student should be able to solve this problem. What is interesting, though, as Gorroochurn notes, is its connection to the Prisoner's Problem and the now notorious Monty Hall problem.

Simpson's paradox, Senn [15] has noted, is closely connected with the Will Rogers phenomenon. (Will Rogers was an American humorist who suggested during the depression of the 1930s that "When the Okies left Oklahoma and went to California, they raised the average intelligence level of both states.") This was perhaps first described in the 1980s by Feinstein et al. who found survival improvement stage by stage in different groups of cancer patients but no evidence of overall improvement.

A basic principle of rational behavior is the sure-thing principle, stated by Savage [14, p. 21] as follows:

> If the person would not prefer **f** to **g**, either knowing that the event B obtained, or knowing that the event $\sim B$ obtained, then he does not prefer **f** to **g**

(here **f** and **g** are possible acts). Put otherwise, the sure-thing principle says that one's preferences should not be affected by outcomes that occur regardless of which actions are taken (i.e., that are "sure-things") or that elements common to any pair of outcomes may be ignored. Simpson's paradox, like the intransitivity of some preference orderings in matters of social choice, violates this principle.

Finally, let us have a look at Parrondo's paradox, the solution of which requires some knowledge of game theory and Markov chains. The idea here is that two losing games can produce a winning expectation when they are played in an alternating sequence. Harmer and Abbott [9] have suggested that such games may have important applications in sociology, physics, genetics, and biology. Commenting on the counterintuitive nature of this paradox, Gorroochurn writes (p. 273), "by randomly playing two losing games, the player comes out a winner!" But before one gets too excited about this, one must remember that the idea of a "fair game" is known to be correctly formulated in terms of a martingale, where the "impossibility of gambling systems" holds (see Feller [8]).

It must be almost impossible to write a book with the wealth of detail that Gorroochurn has provided without a few slips. I mention two here: the first is in connection with the photograph of Adrien-Marie Legendre on page 98. This is now known to be of the French politician Louis Legendre, not the mathematician [6]. The second and more serious problem is on page 133. Here the myth is perpetuated that the person depicted is Thomas Bayes. The attribution apparently first occurred in Terence O'Donnell's book [12]; for remarks casting grave doubt on O'Donnell's attribution, see [10].

For those readers who already have copies of the books by Mosteller [11], Székely [16], and Whitworth [18] (any one of the many editions) on their shelves, this book will form a useful adjunct, perhaps particularly for the excellence of its coverage of modern references. Those who do not have easy access to these works will benefit enormously from *Classic Problems of Probability*.

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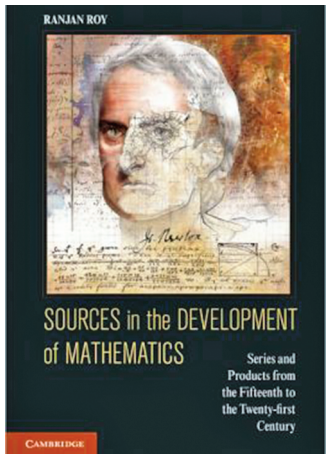
Book Review

Sources in the Development of Mathematics

Reviewed by Tom Archibald



Sources in the Development of Mathematics
Ranjan Roy
Cambridge University Press, 2011
US$89.10, 994 pages
ISBN-13: 978-0521114707

For much of the twentieth century, writing about the history of mathematics emphasized above all the development of pure mathematics—and pure mathematics seen in a certain light. Abstract mathematics, of both the Bourbaki and non-Bourbaki varieties, dominated the cultural landscape of twentieth-century mathematics and formed a natural focus for historians studying that period. The creation of abstract structures, new worlds such as those of non-Euclidean geometry, and the apparently progressive evolution of rigor all posed special challenges for historians. These developments also had significant philosophical resonance, as the names Russell and Gödel suffice to underline, and the importance of the history of mathematics for philosophy was well illustrated (*remains* well illustrated) by the work of Lakatos.

The world changes, as does its mathematics, and historians looking at the mathematical world now tend to see a somewhat different picture. Many of the same issues remain fundamentally important, but they are no longer seen as providing a complete account of all important aspects of mathematical activity. The consensus about what mathematics is, as seen in twentieth-century historical writings about mathematics, no longer dominates. Historical writers today need to encompass a larger range of mathematical activity in their studies.

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One way to achieve such a fresh and broad viewpoint is to seek unifying themes that cut across contemporary mathematical subfields. Ranjan Roy's erudite and broad study does just that, and in so doing provides an alternative thread through much historical mathematics of the last few centuries. Using series and products, both finite and infinite, as a leitmotif, Roy's forty-one chapters give us just short of one thousand pages in which mathematics is a concrete entity and mathematicians are working on a wide variety of problems. Calculations, formulas, manipulations, and brilliant insights into pattern are massed together by Roy to provide the "sources" of mathematical development described in the title. While most of the time the path of this thread remains close to analysis, the points of contact with many other major areas of mathematical research are plentiful, and the associations often both stimulating and surprising. The book is a personal view based on an evidently long immersion in both primary and secondary sources. It reads well and easily, and while there are many associations between the chapters, each one can be read as a self-contained vignette. It is broadly accessible, so that while some of the more recent or more technical developments described will perhaps be out of the reach of beginners, most people with mathematical training can read a great deal of the work and be both informed and entertained. It would be a great book to take on summer vacation (well, provided you are not kayaking or backpacking—it's a bit heavy).

The treatment is not strictly chronological over the course of the book, though chronology informs its organization: subjects that "started" later are typically treated later. Indeed, the care with which the subject has been divided in order to give both details and a big picture is one of

the real services of the work. Given the titles of chapters, the contents often surprise in a good way. Let's take an example: the short (sixteen-page) chapter on inequalities. This begins with a survey section, discussing the arithmetic-geometric mean inequality and its treatment by Thomas Harriot (before 1631!), Descartes, Newton, Maclaurin, and Cauchy; then noting that Cauchy's method inspired Jensen, tying this to Rogers, Hölder, and Schwarz; and concluding with Hilbert and Riesz. The chapter continues with individual sections that provide additional detail on aspects of the mathematical work on this subject by Harriot, Maclaurin, Jensen, and Riesz. For example, the section on Harriot introduces his own notation, then gives his own proof of the arithmetic-geometric mean inequality, while the section on Riesz gives his proof of the Minkowski inequality. A concluding section (there is one of these for every chapter) points to primary and secondary literature of high quality. Along the way, many other mathematicians are both referred to and quoted; one can savor here, for example, Harald Bohr's remark that "all analysts spend half their time hunting through the literature for inequalities which they want to use and cannot prove." The chapter also has five pages of exercises, usually with quite direct and explicit links to historical literature. This organization is typical of the book as a whole.

Since there are forty-one chapters, making a list of what is treated is not possible here. Roy is perhaps most widely known for his book with Richard Askey and George Andrews, so chapters on the hypergeometric series, q-series, and partitions are not surprising, nor are many other chapters that touch on closely related areas of classical analysis involving series and products. There is quite a bit of number theory (L-series, distribution of primes, transcendence), complex analysis (value distribution theory, for example), and there are even chapters on solvability by radicals and finite fields. We can remark on some things that are perhaps quite unexpected features. The first chapter is about power series in Kerala in the fifteenth century, for example—a nice addition. There are many places where items that are perhaps less well known than they should be are brought to light: I noted with pleasure Harkness and Morley's proof of the binomial theorem; Zolotarev's method for Lagrange inversion with remainder; Hermite on approximate integration; Lagrange's proof of Wilson's theorem; Bohr, Mollerup, and Artin on the Γ function. There are many, many more such instances. I just spent a semester teaching a seminar for seniors on classical analysis, and the book was tremendously useful as a resource.

Some of the longer survey chapters are in many cases attractive and motivating introductions to the subjects they treat. As an example, I'll mention the two chapters on elliptic functions in the eighteenth and nineteenth centuries. The two form a unified historical account at an introductory level to the basic ideas of the theory, culminating with a discussion of Eisenstein's application of the ideas to reciprocity laws. Much of the same material is covered (more succinctly, with more required input from the reader, and aiming squarely at modern results) by McKean and Moll in their lovely book *Elliptic Curves*. But in Roy's account the historical aspects are treated more fully, the pace is more leisurely, and the connections between the various developments are presented in a way that makes us more fully aware of the mathematical context of the developments at the time. Often Roy provides what feels like reliable insight into the innovations he describes, for example, with Euler's realization that $dt/\sqrt{1-t^4}$ could not be rationalized by substitution, since this would imply that the equation $z^2 = x^4 - y^4$ had integer solutions (as Euler knew from Fermat to be false).

Partly because this is material I find interesting—it is a *kind* of mathematics I particularly like and believe to be central to much mathematical endeavor that grew from these roots—I found the book charming. If I make a few minor points about what the work does not provide and indicate things that I could wish were otherwise, it does not detract from my overall view that this is a fine work. As an historian, I would love to have seen more thorough references, though the forest of citations that would result might have detracted from readability, and it can be argued that in some cases such references can be filled in with relative ease. For example, the statement (p. 83) that "some historians have suggested with some justification" that personal contact between Descartes and Faulhaber could have sent us to Kenneth Manders's paper of 2006, but it didn't, and the literature survey at the end of the chapter didn't either. Sometimes such statements contain an implicit historical analysis that may be correct but isn't provided: "one can see in the work of Newton, Leibniz, and others that they were implicitly aware of the method [of summation by parts]" (p. 195). A fair response to this kind of criticism is that "it is not that kind of book," but I decided to mention it given the many very welcome references to recent historical work that the author does bring to the reader's attention. There are a few typographical errors, even in proper names. Reisz and Frèchet should have been caught by the copy editors, who no longer seem to exist. The book's title might encapsulate the author's view of what he aims to do but unfortunately does not describe the work clearly; some variant of the subtitle using the words "series" and "products"

would have been better in my view. To counter these negative remarks, allow me to compliment the figures and the index, both of which are well done and useful.

I recommend this book to a wide audience. Undergraduates can learn of the truly vast amount of material that lies alongside some of their more standard endeavors, many of which involve only elementary matters: sums, products, limits, calculus. Graduate students and nonspecialist faculty can wonder at the ingenuity of their predecessors and the connections between now disparate areas that are afforded by this very classical view. They'll also get lots of good ideas for teaching (and they may waste a good deal of time on the problems, as well). Historians, philosophers, and others should read this book, if only for the view of mathematics it propounds. And specialized researchers in the area of special functions and related fields should simply have a good time. All of these readers can benefit from the remarkable expository talents of the author and his careful choice of material. Among personal views of mathematics that use history as a key to understanding, Roy's book stands out as a model.

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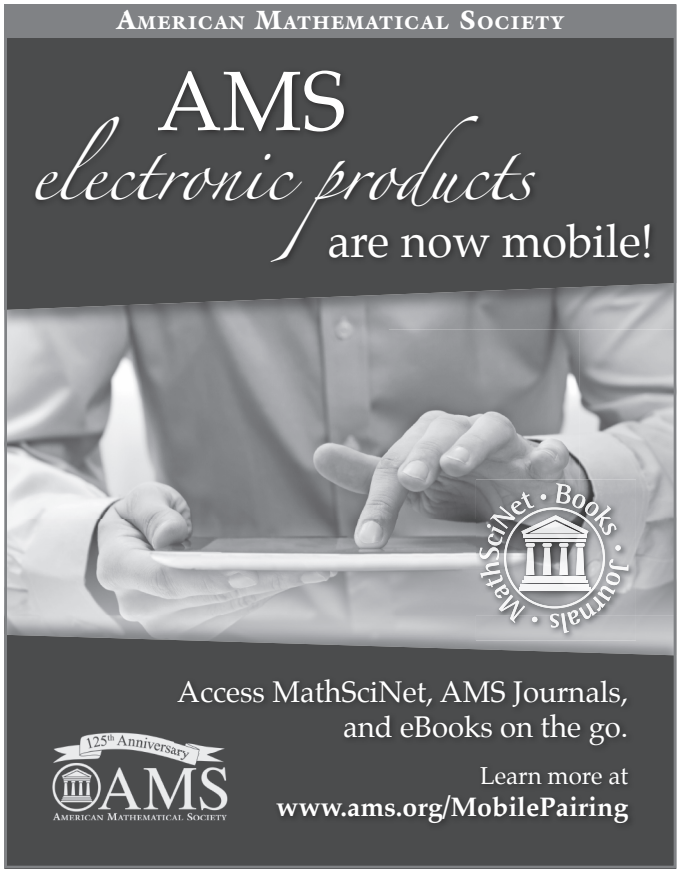

Stuck in the Middle: Cauchy's Intermediate Value Theorem and the History of Analytic Rigor

Michael J. Barany

Intermediate Values

With the restoration of King Louis XVIII of France in 1814, one revolution had come to an end, but another was just beginning. Historians often describe the French Revolution of 1789, along with its reactions and repercussions, as the start of the modern era. For many historians of mathematics, however, the modern era began with the Bourbon Restoration and the mathematics of Augustin-Louis Cauchy.

In a 1972 talk at a Mathematical Association of America sectional meeting, Judith Grabiner offered an important interpretation of this critical juncture in the history of mathematics [5]. Asking whether mathematical truth was time dependent, Grabiner argued that while truths themselves may not depend on time, our knowledge certainly does. She stressed the revolutionary character of Cauchy and his contemporaries' efforts to set mathematical analysis on a rigorous footing, which required applying a fundamentally new point of view to the problems and methods of their eighteenth-century forebears. One of Grabiner's leading illustrations of this point, both in her talk and in her 1981 book on Cauchy's calculus [6], is Cauchy's proof of the intermediate value theorem, that a continuous real-valued function f on an interval $[a, b]$ assumes every value between $f(a)$ and $f(b)$ on that interval.

Today the intermediate value theorem (IVT) is one of the first theorems about functions that advanced undergraduates learn in courses on mathematical analysis. These courses in turn are often the first places such students are comprehensively taught the methods of rigorous proof at the heart of contemporary mathematics. Here the theorem and its proof exemplify several important aspects of rigorous analysis. At first glance, the theorem seems obvious. Indeed, generations of mathematicians before Cauchy thought its idea so obvious as not to need explicit statement or justification. On the other hand, that the theorem can be proved with just some simple notions about continuity, convergence, and the system of real numbers is something quite remarkable. Students learn to take nothing for granted, to proceed systematically, and to use approximations and limiting principles to turn vague intuitions about the nature of functions into indubitable theorems.

Cauchy's undergraduate course in analysis at the École Royale Polytechnique, which he began teaching in 1816, was among the first to include a proof of the intermediate value theorem. His 1821 textbook [4] (recently released in full English translation [3]) was widely read and admired by a generation of mathematicians looking to build a new mathematics for a new era, and his proof of the intermediate value theorem in that textbook bears a striking resemblance to proofs of the

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theorem that continue to be taught almost two centuries later.

With this in mind you might be surprised to learn that the theorem was proved *twice* in Cauchy's textbook, and that his more famous proof was relegated to an appendix, while Cauchy's main proof has been mostly forgotten by mathematicians and historians alike. Putting these two proofs side by side, we can add a new dimension to Grabiner's story by asking just what rigorous analysis meant for Cauchy at the dawn of modern mathematics. When Cauchy's language and methods are carefully dissected, he begins to look less like a far-sighted revolutionary who simply saw profound new meanings in old results. Instead, I argue (see also [1]) that Cauchy was "stuck in the middle": struggling to reclaim what he saw to be a neglected approach to mathematics while (perhaps inadvertently) pushing mathematicians toward a particular understanding of analytic rigor that would help define their future.

A Mathematical Revolution

Underneath the slogans of liberty, equality, and fraternity and behind the barricades and the bluster of the French Revolution, there was a massive transformation in the organization of the French state and society. For the world of mathematics, these transformations meant that, for the first time, a large cadre of elite military and civil engineers began to receive a common training in Paris in the most advanced mathematics of the day. These engineers took their mathematics and applied it to the pressing problems of the modern world: mass infrastructure, navigation, mining, energy, and war. The flagship institution where these students learned to draw, compute Taylor expansions, and see the world through mathematical eyes was the École Polytechnique (renamed the École Royale Polytechnique after Napoleon's defeat and the monarchy's return), and it was there that Cauchy made his mark as a student and then as an instructor.

Despite his acclaim beyond the walls of the École, Cauchy was not the most popular instructor among either his students or his fellow faculty. He regularly overran his allotted lecture time; his courses could be dense and difficult to follow; he revised the curriculum with abandon, disregarding the pleas of those teaching courses for which his was a prerequisite. His foes among the faculty grumbled that Cauchy, a devout Catholic and staunch supporter of the monarchy, was a bitter reactionary who owed his job more to the changing winds of national politics than to his brilliance as a teacher.[1]

[1] *On Cauchy's interconnected politics, religion, and pedagogy, see* [2].

In Cauchy's view, however, a restoration was just as much due for mathematics as it had been after the regrettable revolution in France, and it was no use arguing with the misguided mathematical Jacobins or Bonapartists who would have it otherwise. When Cauchy looked at the mathematics of the eighteenth century, he saw a discipline that had lost its discipline. Undoubtedly, the century had witnessed a host of marvelous mathematical innovations, but at what cost? Mathematicians such as Leonhard Euler freely toyed with nonconvergent series and ungrounded formal expressions and did not bat an eyelash when these produced absurd conclusions. Amidst the swirl of infinities, heuristics, imaginary numbers and more, it was hard to know what to believe.

At stake for Cauchy was the proper relationship between algebra and geometry. Geometry, as most saw it, was the ancient and noble science of magnitudes initiated by the Greeks and particularly associated with Euclid.[2] On the one hand, geometry referred to a specific body of problems and techniques associated with shapes and magnitudes. On the other hand, however, geometry was an emblem of philosophical exactitude and precision. Mathematicians and philosophers alike sought to proceed in the *more geometrico*, or geometric way, stating their assumptions carefully and reasoning systematically in order to produce results with absolute certainty.

Algebra, like geometry, could refer to a body of problems and techniques. From Viète and Descartes to Laplace and Lagrange, mathematicians (not all of them French) had developed the symbolic methods of algebra into a powerful tool for studying a wide range of mathematical phenomena, including those traditionally associated with geometry.[3] Also, like geometry, algebra had an implicit philosophical meaning that tied it to the unrestrained pursuit of mathematical ideas, regardless of whether each individual step had a clear geometric or physical interpretation. Eighteenth-century mathematicians saw in algebra a versatile tool for obtaining deep understandings of the world around them.

Algebra and geometry thus represented competing values. Algebraic mathematicians valued the profound mathematical truths their methods could reveal and ridiculed geometric mathematicians for their overzealous commitment to tedious proofs at the expense of vital creativity. Geometric

[2] *When Cauchy wrote his textbook, non-Euclidean geometries were still just over the horizon of mathematical theory.*

[3] *The specific body of theory and techniques we now call abstract algebra was, like non-Euclidean geometry, still just beginning to emerge as Cauchy wrote. Some of Cauchy's earliest work was on problems we might now consider in this area.*

mathematicians like Cauchy, by contrast, reviled the monstrosities that algebraic mathematics occasionally produced and sought protection in the rigorous certainties of their methods. Cauchy's textbook famously declared his desire to give his methods "all the rigor one requires in geometry, in such a way as never to resort to reasons drawn from the generality of algebra." Rarely, of course, were the values of algebra and geometry so sharply delineated. It was often in polemical writings such as Montucla's monumental history of mathematics [7, e.g., pp. 11, 270] or the introduction to Cauchy's textbook rather than in everyday mathematical work or in the École's courses on drawing and practical mathematics that these stakes loomed large. Nevertheless, the tension was real, and (at least as Cauchy saw it) algebra was winning.

Two Proofs

Cauchy's textbook introduces the intermediate value theorem by noting a "remarkable property of continuous functions of a single variable": that they can represent the geometric ordinates of continuous curves [4, p. 43]. Contrary to our present emphasis on the theorem in terms of the analytic properties of continuous functions, for Cauchy the theorem is foremost about the relationship between functions and geometry. This, we shall see, was not just his motivation but the central idea in his proof.

The theorem's statement is recognizable to readers today, even if the precise wording and notation appear unusual:

Theorem (Cauchy's IVT)**.** *If the function $f(x)$ is continuous with respect to the variable x between the limits $x = x_0$ and $x = X$ and if b designates a quantity between $f(x_0)$ and $f(X)$, one can always satisfy the equation*

$$f(x) = b$$

for one or several real values of x between x_0 and X.

But Cauchy's main proof of the theorem looks nothing like the proof we now associate with him. Here is a rather literal translation:

Proof. To establish the preceding proposition, it suffices to see that the curve whose equation is

$$y = f(x)$$

meets one or more times the straight line whose equation is

$$y = b$$

in the interval between the ordinates that correspond to the abscissas x_0 and X. Yet it is clear that this will take place under our hypotheses. Indeed, as the function $f(x)$ is continuous between the limits $x = x_0$ [and] $x = X$, the curve whose equation is $y = f(x)$ passing first through the point with coordinates $x_0, f(x_0)$ and second through the point with coordinates X and $f(X)$ will be continuous between these two points; and, as the constant ordinate b of the line whose equation is $y = b$ is found between the ordinates $f(x_0)$ and $f(X)$ of the two points under consideration, the line [corresponding to $y = b$] will necessarily pass between these two points so that it cannot avoid crossing the above-mentioned curve [corresponding to $y = f(x)$] in the interval. □

The first thing to notice is that, while Cauchy employs several variables and equations, he uses these symbolic expressions purely to describe curves and lines in a plane. There are no algebraic manipulations whatsoever, much less sequences, bounds, or limits. He presents the continuous function $f(x)$ as an unbroken curve connecting two points, and his proof hinges on a claim that a level line corresponding to the desired intermediate value must cross this curve. The argument is vague and unsystematic by our standards. Even though Cauchy has just given a definition of continuity,[4] his proof makes no use of it. Instead, the notion of continuity in this proof means simply that the function's corresponding curve remains unbroken.

Was Cauchy sloppy, lazy, or inconsistent with this proof? I have found nothing to suggest that he or his contemporaries had second thoughts about it.[5] Instead, we should see this as evidence of Cauchy's faith in geometric reasoning and his lingering distrust of algebra. Arguments based on unbroken planar curves were sensible and trustworthy to Cauchy in a way that arguments based on symbols and equations were not. Because

[4] *Cauchy's definition of continuity will also appear unusual to those expecting epsilons, deltas, quantifiers, and convergence. He defines continuous functions as those for which the difference $f(x + \alpha) - f(x)$ is infinitesimally small when α is. See* [4, pp. 34–35]. *There is considerable secondary literature on Cauchy's "infinitesimally small quantities" and their relationship to various ideas about variables, continuity, and convergence. In particular, while some have argued his notions were ultimately equivalent to ideas developed in either "epsilontic" or nonstandard analysis, most agree that Cauchy omitted or left implicit many important ideas and intuitions about his infinitesimally small quantities.*

[5] *One might be tempted to dismiss this proof as merely a pedagogically oriented plausibility argument, but Cauchy himself makes no such excuse for it, and such a move would be exceptional in a textbook meant to showcase his model of rigor. His allusion to the "direct and purely analytic" proof in the appendix is sometimes read as an admission that the above proof is inadequate, but this view substitutes later values of analytic rigor where Cauchy's own priorities are at best unclear. The best evidence of Cauchy's view remains the fact that he calls this argument a proof (something he does not do for every argument following a stated theorem) and places it prominently in the body of his textbook.*

he could visualize two curves crossing, he needed no further argument to establish his theorem. Here the "rigor of geometry" involved not just careful systematic reasoning but the use of a fundamentally geometric argument.

Cauchy's more famous proof of the intermediate value theorem comes in an appendix on solving equations numerically. Here the above theorem becomes a corollary to the first theorem of the appendix, which states that if a function is continuous between $x = x_0$ and $x = X$ and if $f(x_0)$ and $f(X)$ have opposite signs, then there is at least one root satisfying $f(x) = 0$ between x_0 and X. One applies this result to the function $f(x) - b$ to obtain the familiar theorem.

Grabiner [5, p. 362] is among many who note that the proof in Cauchy's appendix is based on a method of approximating roots that was well known in Cauchy's time. Cauchy supposes that the interval between x_0 and X has length h and divides the interval into m parts of length h/m for some m greater than 1. Inspecting values of f for consecutive terms of this sequence and picking one pair of such terms where the corresponding values of f have opposite signs, Cauchy then subdivides this new interval of length h/m into m parts of length h/m^2 and repeats the process to produce two sequences of x values. The first, denoted $x_0, x_1, x_2, \ldots$, is increasing, while the second, $(X, X', X'', \ldots)$, is decreasing, with corresponding terms in the two sequences coming closer and closer together.

From this, Cauchy concludes that the sequences have a common limit a. Without citing his earlier theorem that continuous functions map convergent sequences to convergent sequences, he then simply stipulates that the sequences

$$f(x_0), f(x_1), f(x_2), \ldots$$

and

$$f(X), f(X'), f(X''), \ldots$$

must both converge to $f(a)$. Finally, Cauchy claims that, because corresponding terms of these two sequences have opposite signs, $f(a)$ must have the value 0.

At first glance, this is a pure example of the rigorous algebraic analysis for which Cauchy is known today. Nevertheless, we can still see Cauchy's preference for geometric reasoning. On the one hand, Cauchy's proof does more than one would expect if the goal were simply to prove the existence of a root. Why, for instance, carry out the argument with an arbitrary value of m when simply halving the interval each time is sufficient? Cauchy's rhetoric makes it clear that he continues to see his procedure primarily as a tool of approximation rather than as an existence proof. Thus he makes repeated reference to the possibility of there being multiple roots and elaborates on this point in two of the three scholia that follow the proof. The first such scholium is even more directly about approximation: it notes that the average of the terms x_n and $X^{(n)}$ is at most a distance $\frac{1}{2}\frac{X-x_0}{m^n}$ from the desired root a—an observation that is extraneous (in the context of Cauchy's argument) to the question of whether such a root exists but is important when one cares about rates of convergence for approximations.

Why, for that matter, did Cauchy try to find a root instead of an arbitrary intermediate value b? The proof would need few modifications to fit this more general case. Making this theorem about roots rather than arbitrary values allowed Cauchy to preserve it as an argument about a curve meeting a line (in this case, the x-axis). At the same time, while finding arbitrary values was (simply put) a rather arbitrary thing to do, the engineers-in-training at the École would have had many occasions to find roots in the course of their work and studies.

On the other hand, Cauchy leaves several potentially important ideas between the lines. We know, for instance, what it means for terms to be pairwise of opposite signs, but what does this mean in the limit of a sequence? Proofs today typically specify one sequence of values as approaching the intermediate value from below and the other from above. Indeed, it is striking that, though the proof discusses sequences and values with opposite signs, the only symbolic inequalities in the entire argument are used for values of x and never for values of $f(x)$. For both x and $f(x)$, Cauchy refers frequently not just to values but to *quantities*, implying that they have geometric magnitudes.

This explains, in part, why Cauchy so freely makes claims about the convergence and limits of the sequences obtained in his proof. As a pure matter of algebraic abstractions, one needs a lemma to assert that the common limit of the sequences $f(x_0), f(x_1), \ldots$ and $f(X), f(X'), \ldots$ would equal $f(a)$. As a matter of geometry, however, the identity might not strike one as requiring a separate argument or citation.

It would not be until several decades after Cauchy's course was published that mathematicians would systematically attempt to define teratological functions that defied the intuitions associated with the usual mechanical problems of polytechnical mathematics. In Cauchy's time, mathematical analysis remained first and foremost the mathematical study of the world—a world filled with complex phenomena but also a world exhibiting profound regularities. Cauchy's course, for instance, assumes that all continuous functions are differentiable; indeed, all the continuous functions he might care to differentiate were more or

less smooth. In a sense, then, Cauchy's preference for geometry reflected a desire to remain true to the world and to use only those mathematical techniques that genuinely reflected worldly magnitudes, even if this limited what he could say mathematically about that world.[6]

Stuck in the Middle

The peculiarities of Cauchy's proofs help us see that the rigor Cauchy prized was something quite different from the rigor we now associate with his name. When Cauchy objected to the mathematics of his predecessors, he did not find them lacking in their adherence to formal rules for symbolic manipulation. Quite the contrary, he felt mathematicians in the preceding century trusted such rules altogether too much. With this in mind, it is not surprising that Cauchy's project of reform was not, at its heart, based on carefully placed quantifiers, deftly manipulated sequences and inequalities, and meticulous logical exactitude.

To tame the dangerous fashion for algebra, Cauchy demanded a return to geometry in both its senses. He is remembered today for making his proofs systematic and logical, but his own proofs place a clearer emphasis on the geometry of magnitudes, not the geometry of methods. Cauchy sought to save mathematical analysis by ensuring that its powerful algebraic tools stayed true to the world of geometry, hence his insistence on convergence and his caution when defining imaginary and even negative numbers. Where he did not see any danger of symbols losing their geometric referents, as in his proofs of the intermediate value theorem, he could in fact be quite lax with their use.

In this sense, Cauchy's analysis appears surprisingly regressive. The rigor he advocated was a return to geometric reasoning that a century of mathematicians had rejected as stale, tedious, and counterproductive. His methods were difficult, and his students and colleagues frequently lamented their cumbersome impracticality. And yet, Cauchy seems now to have won the day.

How could such a reactionary mathematician so transform the mathematics of his generation in a way that now appears progressive and visionary? Cauchy realized he could not do away with algebra even in his own mathematics. Rather than throw algebra out entirely, he worked to endow algebra with the virtuous rigors of geometry by developing algebraic criteria to match geometric reasoning. In so doing, he advanced the idea that it was possible to have it both ways: to enjoy the power of algebraic thinking while still adhering to the discipline and certitude of geometry. All one needed was to put the demands of geometry in algebraic terms.

Thus Cauchy's rules for convergence and his attention to the limits of formal expressions' validity created new problems and new opportunities. He opened up ways of studying mathematical phenomena that remain vital nearly two centuries later. While his approach proved durable, its initial motivation could easily be forgotten. The ensuing generation of European mathematicians latched on to his disciplined way of studying the meanings of formal expressions while jettisoning his preoccupation with the geometry of magnitudes. From them, we have the beginnings of the set-theoretic foundations of analysis that undergraduates learn today.

Of course not even the set theorists had the final word on rigor. Mathematicians must constantly balance what methods are worthwhile, what arguments are convincing, and what values are worth conveying to students. Those dismayed by the lack of consensus on these points today or wishing that opponents could simply see that their positions are illogical, unrigorous, or counterproductive can take comfort in the fact that these debates are not just a normal part of the history of mathematics, but that they can help to spur new ideas and approaches, often in unexpected ways. Studying the history of mathematics, we can appreciate that in some ways we are all, like Cauchy, stuck in the middle between our discipline's past and its open-ended future.

[6] *I elaborate in* [1] *how this mathematical impulse relates to Cauchy's religious and political conservatism.*

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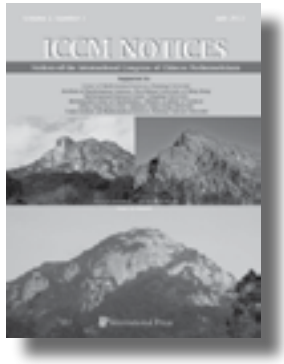

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Problem Solving: Moving from Routine to Nonroutine and Beyond

Barry Garelick

An important part of the job of teaching math in K–12 is to stretch students—to teach them creative and personal engagement with the material. At some point this must involve expecting students to come up with previously unfamiliar steps on their own for new problems that do not lend themselves to known algorithms, prescribed methods, and predictable approaches. An effective way of doing this is to extend routine problems that students know how to solve into nonroutine problems.

Over the past two decades, however, disagreements between advocates of traditional or conventional math teaching and the math reform movement have resulted in a fragmented approach to teaching math. A key area of disagreement centers on the distinction between "exercises" and "problems". Math reformers generally believe that conventional math teaching consists mainly of routine problems that are nonthinking, repetitive, tedious and do not lead to students learning to solve nonroutine problems.

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One math reform approach has been to present students with a steady diet of "challenging problems" that neither connect with the students' lessons and instruction nor develop any identifiable or transferrable skills. The following problem from Hjalmarson and Diefes-Dux (2008) is one example: How many boxes would be needed to pack and ship one million books collected in a school-based book drive? In this problem the size of the books is unknown and varied, and the size of the boxes is not stated. While some teachers consider the open-ended nature of the problem to be deep, rich, and unique, students will generally lack the skills required to solve such a problem, skills such as knowledge of proper experimental approaches, systematic and random errors, organizational skills, and validation and verification.

Based on my experiences as both student and teacher, as well as the experiences of veteran math teachers, I submit that a substantial education in mathematics should steer a middle course between the proliferation of routine problems and reliance upon unique, complex projects. Students should learn to apply basic principles in a much wider variety of situations than typically presented in texts. Such problems, however, should not be as complex or as time consuming as the example above. A math problem is not necessarily useful just because it requires outside-of-the-box insight

and/or inspiration and will generally not result in a problem-solving "habit of mind".

Extending Routine Algorithmic Problems to Nonroutine Problems

Problems that are extensions of routine problems, (as suggested by Henderson and Pingry (1953)) can effectively build upon prior knowledge and develop a larger problem-solving repertoire. Such extensions require students to synthesize ideas and procedures from two or more areas of learned procedures and are frequently multistep. For example, while most students have learned how to factor $a^2 - b^2$, they are likely to find the following difficult to factor: $a^2 - x^2 + 2bx - b^2$. This problem requires students to synthesize what they know about perfect square trinomials, how they are factored, and how these ultimately relate to factoring the difference between two squares. An intermediate problem may be introduced, such as $a^2 - (m - n)^2$, to serve as scaffolding for the more challenging version.

The factoring of the difference of two squares can be extended even further: Find two positive integers "a" and "b" such that $a^2 - b^2 = 2{,}011$. A student may first factor to obtain $(a + b)(a - b) = 2{,}011$. Some students may not be able to go any further. Others will see that expressing the right-hand side of the equation as the product of two factors xy puts them on the pathway to solving it. Students may be stumped and will overlook the fact that 2,011 and 1 can represent x and y.

Extending Routine Word Problems to Nonroutine Problems

A frequent criticism of word problems in textbooks is that they present a worked example/method for solving a particular type of problem, followed by a set of almost identical problems to solve. Students may experience the practice of applying a memorized technique and mechanically look for the data to plug in to the appropriate equations without having to read the problem. But what if you are given values with different units in a distance/rate problem? And what if you are given two legs and two different rates and need to find your average rate? Word problems can and should be varied for improving problem-solving ability.

This is, in fact, what is done in well-written algebra textbooks or in problem sets devised by teachers. Students are given instruction via worked examples and some initial practice problems. After that, the problems vary. For example, consider the following two distance/rate problems from Dolciani et al. (1962):

> A freight train left Beeville at 5 AM at 30 miles per hour. At 7 AM an express train traveling 50 miles per hour left the same station. When did the express overtake the freight?

> An airplane traveling 280 miles per hour leaves San Francisco 13½ hours after a steamship has sailed. If the plane overtakes the ship in 1½ hours, find the rate of the steamship.

While the variations between these two problems are slight (one asks for time traveled, the other speed), they present a challenge to beginning students. Varying the structure of the basic problem forces the student to read each problem carefully. They must identify what the question is, what data are provided, and how to transform it into an equation. The variation and difficulty increases so that the last problems of the set are more complex and nonroutine:

> A ship must average 22 miles per hour to make its ten-hour run on time. During the first four hours, bad weather caused it to reduce speed to 16 miles per hour. What should its speed be for the rest of the trip to keep the ship to its schedule?

Extending the nonroutine distance problem even further, students can be given the following problem in an Algebra 2 course:

> Two boys in a canoe are at a confluence of a lake and a river. A house upriver and a boulder on the other side of the lake are equidistant from the boys. Would it take the same amount of time to paddle across the lake to the boulder and back as it would to paddle to the house upriver and back (at the same speed relative to the water each way for both options)? If not, which option would take longer?

This problem does not allow a "plug-in" solution. Students must model the situation using symbols and apply their knowledge of expressing time as a function of rate and distance. Many students will assume that either route will take the same amount of time, reasoning that the amount that the canoe is slowed down by the current when traveling upstream is canceled by the additional speed the current imparts when traveling downstream. Proving or disproving the initial intuitive response, however, requires mathematics. Ultimately, it involves an inequality that does not lend itself to an algorithmic solution.

Building a Problem-Solving Repertoire

Students should routinely be presented with nonroutine problems. Even if a student fails to solve such a problem, seeing its solution opens up pathways in which they discover relationships between content and what they know about solving routine problems.

Sweller et al. (2010) state that problem solving cannot be taught independently of basic tools and basic thinking. Over time, students build up a repertoire of problem-solving techniques. Ultimately, the difference between someone who is good and someone who is bad at solving nonroutine problems is not that the good problem solver has learned to solve novel, previously unseen problems. It is more the case that, as students increase their expertise, more nonroutine problems appear to them as routine.

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In Memory of Professor Francisco Federico Raggi Cárdenas

María José Arroyo, Rogelio Fernández-Alonso González, Sergio R. López-Permouth, José Ríos Montes, and Carlos Signoret

Professor Francisco Federico Raggi Cárdenas passed away June 12, 2012, in Mexico City. Professor Raggi was born in Mexico City in 1940. He obtained his undergraduate degree from Universidad Nacional Autónoma de México (UNAM), a master's degree from Harvard, and a doctorate from UNAM. In 1962 he joined the Institute of Mathematics of UNAM, where he worked until his passing. He held visiting positions in universities throughout the world, including institutions in Germany, the United States, Belgium, Canada, Spain, and Italy.

Professor Raggi taught modern algebra at all levels to many generations of students in Mexico. In particular, he had four Ph.D. students. Raggi was author or coauthor of five books that are prominently used in universities throughout Mexico. As he traveled constantly and taught at many places throughout Mexico, Raggi's commitment to the

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Sweller et al. (2010) state that problem solving cannot be taught independently of basic tools and basic thinking. Over time, students build up a repertoire of problem-solving techniques. Ultimately, the difference between someone who is good and someone who is bad at solving nonroutine problems is not that the good problem solver has learned to solve novel, previously unseen problems. It is more the case that, as students increase their expertise, more nonroutine problems appear to them as routine.

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In Memory of Professor Francisco Federico Raggi Cárdenas

María José Arroyo, Rogelio Fernández-Alonso González, Sergio R. López-Permouth, José Ríos Montes, and Carlos Signoret

Professor Francisco Federico Raggi Cárdenas passed away June 12, 2012, in Mexico City. Professor Raggi was born in Mexico City in 1940. He obtained his undergraduate degree from Universidad Nacional Autónoma de México (UNAM), a master's degree from Harvard, and a doctorate from UNAM. In 1962 he joined the Institute of Mathematics of UNAM, where he worked until his passing. He held visiting positions in universities throughout the world, including institutions in Germany, the United States, Belgium, Canada, Spain, and Italy.

Professor Raggi taught modern algebra at all levels to many generations of students in Mexico. In particular, he had four Ph.D. students. Raggi was author or coauthor of five books that are prominently used in universities throughout Mexico. As he traveled constantly and taught at many places throughout Mexico, Raggi's commitment to the

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development of mathematics in his country was unequivocal.

Professor Raggi was a man of principles; he was widely recognized for his integrity and trustworthiness. He will be remembered as a fun-loving, friendly person who loved his family, art, good food, music, movies, and science fiction. Everyone who knew him agrees that he was a wonderful conversationalist with whom it was very enjoyable to talk for hours about any imaginable topic.

Professor Raggi was involved in the organization of special sessions of most joint meetings of the American Mathematical Society and the Sociedad Matemática Mexicana (SMM). Professor Raggi was one of the pioneers in the introduction of ring theory to Mexico; his focus on the subject was from a lattice-theoretic perspective. He was the author of thirty-eight research articles. His work had four main streams:

1) *Ring arithmetic theory and group rings*. Raggi's first works are dedicated to the study of the group of units of certain rings. They were published in Spanish and constituted the basis for his Ph.D. thesis. These papers have many citations, such as the classic books *Commutative group algebras*, by Karpilovski, and *Topics in group rings*, by Sehgal.
2) *Lattices associated with the category of R-modules and hereditary torsion theories*. Raggi was interested in the general theory of localization, introduced by Gabriel, and related concepts such as Gabriel topologies, hereditary torsion theories, and left exact radicals. Some of the papers are cited by Golan in his book *Torsion Theories*. Raggi also studied nonhereditary torsion theories, which form a lattice that is not necessarily a set, and related this lattice with the lattice of hereditary torsion theories.
3) *Dimension theory for rings, defined for several classes of modules*. Raggi was interested in the Krull dimension, as defined by Gordon and Robson. He defined the finite length dimension and compared it with the Krull dimension and the dual Krull dimension. He also studied Serre subcategories.
4) *The big lattice of preradicals over a ring*. In 2002 Raggi considered for the first time the big lattice of preradicals over a ring from the lattice theory point of view. In the paper "The lattice structure of preradicals" it is proven that the lattice of preradicals is atomic and coatomic, describing the sets of atoms and coatoms. Using this lattice structure, he characterized semisimple Artinian rings, V-rings, and rings which are a finite product of simple rings. In other papers Raggi studied operators and partitions induced by them. He also defined prime preradicals and prime submodules of a module, relating both concepts. In one of his last works, Raggi defined the concept of a main injective module, whose fully invariant submodules are in bijective correspondence with all the left exact preradicals. In another paper he considered the case when the ring itself is a main injective module and proved that this occurs precisely when it is a QF ring.

The Sociedad Matemática Mexicana (SMM) honored Raggi posthumously with a memorial in his honor during their national meeting in Queretaro, Mexico, on October 30, 2012.

About the Cover

Can mathematics help resolve serious conflicts?

The idea and some images for this month's cover were taken from the article "Principles for implementing a potential solution to the Middle East conflict" by Thomas L. Saaty and H. J. Zoffer in this issue. They make an intriguing proposal. In a way, it is just an application of the standard technique for solving mathematical problems: break a large problem down into smaller ones.

—Bill Casselman
Graphics Editor
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The photo of the Palestinian refugee camp (lower right) is © Mohammed Asad/ Apaimages/ZUMA Press/Corbis.

Mathematics People

Vogelius Named MPS Director

MICHAEL VOGELIUS of Rutgers, the State University of New Jersey, has been named Division Director of the Mathematics and Physical Sciences (MPS) directorate of the National Science Foundation (NSF). He will assume the position in January 2014.

Vogelius earned his Ph.D. in mathematics from the University of Maryland, College Park, in 1980. He has served on the faculty of the University of Maryland and has held visiting appointments at Stanford University, Ecole Polytechnique Federale de Lausanne, and the University of Copenhagen. He has been on the Rutgers faculty since 1989 and served as the department chair from 2009–2013. He has published more than ninety articles and is a Fellow of the American Mathematical Society, a Foreign Member of the Royal Danish Academy of Sciences and Letters, and a recipient of a Sloan Research Fellowship. He is an associate editor of the *SIAM Journal on Mathematical Analysis* and serves on the editorial boards of several other mathematical journals. His research interests include mathematical analysis, partial differential equations, and numerical analysis.

—From an NSF announcement

Vélez Receives AWM Humphreys Award

WILLIAM Y. VÉLEZ of the University of Arizona has been named the recipient of the fourth annual M. Gweneth Humphreys Award of the Association for Women in Mathematics (AWM).

The prize citation reads in part: "Vélez is legendary for his ability to encourage women to study mathematics and pursue mathematical careers. Particularly impressive is his success in instilling confidence in first-generation and minority students who are often struggling to overcome expectations based on culture and gender."

In 1988 he cofounded the Minority Calculus Advising Program at the University of Arizona, through which he encouraged students to continue taking mathematics courses. In 1997 he received a President's Award for Excellence in Science, Mathematics, and Engineering Mentoring.

The Humphreys Award is given annually to a mathematics teacher, female or male, who has encouraged female undergraduate students to pursue mathematical careers and/or the study of mathematics at the graduate level.

—From an AWM announcement

Beckmann Receives Louise Hay Award

SYBILLA BECKMANN of the University of Georgia has been named the recipient of the 2014 Louise Hay Award of the Association for Women in Mathematics (AWM). The award recognizes outstanding achievements in any area of mathematics education.

According to the prize citation, Beckmann was recognized for "her vision, persistence, and leadership in enhancing the teaching and learning of mathematics in this country and beyond. Her work is based on her insight that sustainable improvement in mathematics education can only occur when the mathematical culture in the schools and the universities is 'built on respect for the innate mathematical abilities that are the birthright of every student.' She has worked to energize every link of this chain, from the daily challenges that teachers face in their classrooms to the highest levels of the national discussions of K–12 education."

Beckmann received her Ph.D. in mathematics from the University of Pennsylvania and taught at Yale University before moving to the University of Georgia in 1988. She also spent a year teaching sixth grade and has written a textbook, *Mathematics for Elementary Teachers*. She created and directs the Mathematicians Educating Future Teachers program, funded by a Vertical Integration of Research and Education (VIGRE) grant from the National Science Foundation. She was one of the writers of the National Council for Teachers of Mathematics (NCTM) "Curriculum Focal Points for Pre-Kindergarten through Grade Eight" and two supplemental books and played a significant role in writing the Common Core State Standards in Mathematics. Her awards for teaching include the General Sandy Beaver Teaching Professorship of the College of Arts and Sciences at the University of Georgia; the Josiah Meigs Distinguished Teaching Professorship, the highest teaching honor at the University of Georgia; and the Regents' Teaching Award from the University System of Georgia. Her research interests include arithmetic geometry and algebraic number theory and Galois theory, as well as the mathematical education of teachers.

—From an AWM announcement

2013 International Mathematical Olympiad

More than five hundred young mathematicians from ninety-seven countries competed in the fifty-fourth International

Mathematical Olympiad (IMO), which was held in July 2013 in Santa Marta, Colombia. The IMO is the preeminent mathematical competition for high-school-age students from around the world. The IMO consists of solving six extremely challenging mathematical problems in a nine-hour competition administered over two days.

The team from the People's Republic of China finished first. The team from the Republic of Korea (South Korea) finished second, and the United States team finished third. Four members of the U.S. team won gold medals. In alphabetical order, the gold medal winners for the United States were: MARK SELKE, William Henry Harrison High School, Evansville, Indiana; BOBBY SHEN, Dulles High School, Sugar Land, Texas; JAMES TAO, Illinois Mathematics and Science Academy, Aurora, Illinois; and VICTOR WANG, Ladue Horton Watkins High School, St. Louis, Missouri. The silver medal recipients were RAY LI, Phillips Exeter Academy, Exeter, New Hampshire; and THOMAS SWAYZE, Canyon Crest Academy, San Diego, California. Shen and Swayze were gold medalists in the 2012 competition. The 2014 IMO will be held in Cape Town, South Africa, July 3–13, 2014.

—From an IMO announcement

Ford Foundation Fellowships Awarded

Three young mathematicians have been awarded National Research Council-Ford Foundation fellowships for 2013. MICHAEL L. JEMISON of Princeton University and MICHAEL SANTANA of the University of Illinois–Urbana-Champaign received predoctoral fellowships. ARNULFO PEREZ of Indiana University was awarded a dissertation fellowship.

—From a Ford Foundation announcement

Pi Mu Epsilon Student Paper Presentation Awards

Pi Mu Epsilon (PME), the U.S. honorary mathematics society, makes annual awards to recognize the best papers by undergraduate students presented at a PME student paper session. This year PME held a session in conjunction with the Mathematical Association of America MathFest held July 31–August 3 in Hartford, Connecticut. The AMS and the American Statistical Association sponsor awards to student speakers for excellence in exposition and research. Each awardee receives a check for US$150. The names, chapters, institutions, and paper titles of the award-winning students follow.

CAMRON BAGHERI, Ohio Xi Chapter, Youngstown State University, "Applications of linear algebra to the Fibonacci sequence"; MICHAEL BAKER, Ohio Xi Chapter, Youngstown State University, "A study of optical gain in three-component multilayered films"; MATTHEW BARRY, Texas Eta Chapter, Texas A&M University, "MathLex: A Web-based mathematical entry system"; LISA BORUM, Virginia Iota Chapter, Randolph-Macon College, "Pebbling chessboard and samurai Sudoku graphs"; JOSHUA BRAKENSIEK, Virginia Iota Chapter, home schooled, "Bounds on MSNs accepting directed trees"; CALVIN COCHRAN, Arkansas Beta Chapter, Hendrix College, "Shuffle posets and their Hasse diagrams"; KIM DO, Ohio Xi Chapter, Youngstown State University, "Introduction to combinatorial game theory and what lies underneath"; KARENNA GENZLINGER, Pennsylvania Alpha Alpha Chapter, Gettysburg College, "Minimum sumset size"; ALEX LEITHEISER, Wisconsin Delta Chapter, St. Norbert College, "On the atomisticity of supercharacter lattices of cyclic groups"; ASHLEY ORR, Ohio Xi Chapter, Youngstown State University, "Fourier and wavelet analysis: Extracting the business cycle"; DANIEL PERSIA, Ohio Iota Chapter, Denison University, "Modeling NBA player value from box score data"; SARAH RITCHEY, Ohio Xi Chapter, Youngstown State University, "Residue number system overflow detection algorithms for signed numbers"; ERIC SHEHADI, Ohio Xi Chapter, Youngstown State University, "Prioritizing vacant residential properties for demolition in Youngstown"; and LAURA STAVER, Wisconsin Delta Chapter, St. Norbert College, "Zero forcing for lattices".

—From a Pi Mu Epsilon announcement

Craig Appointed Director of the Fields Institute

WALTER CRAIG of McMaster University has been appointed director of the Fields Institute for Research in Mathematical Sciences. He received his Ph.D. from the Courant Institute of Mathematical Sciences in 1981 and has held positions at the California Institute of Technology, Stanford University, and Brown University. His research interests include partial differential equations, Hamiltonian dynamical systems, and their applications to the physical sciences. He is a fellow of the Royal Society of Canada, the American Association for the Advancement of Science, and the American Mathematical Society, as well as of the Fields Institute.

—From a Fields Institute announcement

Correction

Correction to the article "Voevodsky's univalence axiom in homotopy type theory" by S. Awodey, A. Pelayo, and M. Warren in the October 2013 issue: A misprint was introduced in press in the third footnote on page 1, where it should have read that M. Warren was a member of the School of Mathematics at the IAS from 2011 to 2013.

—Álvaro Pelayo

Mathematics Opportunities

American Mathematical Society Centennial Fellowship

Invitation for Applications for Awards for 2014–2015
Deadline December 1, 2013

Description: The AMS Centennial Research Fellowship Program makes awards annually to outstanding mathematicians to help further their careers in research. The number of fellowships to be awarded is small and depends on the amount of money contributed to the program. The Society supplements contributions as needed. One fellowship will be awarded for the 2014–2015 academic year. A list of previous fellowship winners can be found at http://www.ams.org/profession/prizes-awards/ams-awards/centennial-fellow.

Eligibility: The eligibility rules are as follows. The primary selection criterion for the Centennial Fellowship is the excellence of the candidate's research. Preference will be given to candidates who have not had extensive fellowship support in the past. Recipients may not hold the Centennial Fellowship concurrently with another research fellowship, such as a Sloan or NSF Postdoctoral fellowship. Under normal circumstances, the fellowship cannot be deferred. A recipient of the fellowship shall have held his or her doctoral degree for at least three years and not more than twelve years at the inception of the award (that is, received between September 1, 2002, and September 1, 2011). Applications will be accepted from those currently holding a tenured, tenure-track, postdoctoral, or comparable (at the discretion of the selection committee) position at an institution in North America. Applications should include a cogent plan indicating how the fellowship will be used. The plan should include travel to at least one other institution and should demonstrate that the fellowship will be used for more than reduction of teaching at the candidate's home institution. The selection committee will consider the plan in addition to the quality of the candidate's research and will try to award the fellowship to those for whom the award would make a real difference in the development of their research careers. Work in all areas of mathematics, including interdisciplinary work, is eligible.

Deadline: The deadline for receipt of applications is **December 1, 2013**. The award recipient will be announced in February 2014 or earlier if possible.

Application information: Find Centennial information and application form at http://www.ams.org/ams-fellowships/. For paper copies of the form, write to the Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; prof-serv@ams.org; 401-455-4105.

—AMS announcement

AMS Epsilon Fund

The AMS Epsilon Fund awards grants to summer mathematics programs that support and nurture mathematically talented high school students in the United States. The deadline to apply for funding for summer 2014 programs is **December 15, 2013**. Applications are now being taken online at MathPrograms.org (http://www.mathprograms.org). For more information about the program and updated application information, go to http://www.ams.org/programs/edu-support/epsilon/emp-epsilon. For more information contact the AMS Membership and Programs Department by email at prof-serv@ams.org or by telephone at 800-321-4267, ext. 4113.

—AMS announcement

Jefferson Science Fellows Program

The Jefferson Science Fellows (JSF) program at the U.S. Department of State is intended to involve the American academic science, technology, and engineering communities in the formulation and implementation of U.S. foreign policy. Each fellow will spend one year at the U.S. Department of State or the U.S. Agency for International Development (USAID) for an on-site assignment in Washington, D.C., that may also involve extended stays at U.S. foreign embassies and/or missions. Each fellow will receive a stipend of up to US$50,000. An additional US$10,000 is awarded for travel associated with assignments at the U.S. Department of State/USAID. Following the fellowship year, the Jefferson Science Fellow will return to his or her academic career but will remain available to the U.S. Department of State for short-term projects over the following five years. The JSF program is administered by the National Academies and is supported through a partnership of the U.S. science, technology, and academic communities, professional scientific societies, and the U.S. Department of State. The deadline for applications is **January 13, 2014**. For further information, email jsf@nas.edu, telephone 202-334-2643, or see the website http://sites.nationalacademies.org/PGA/Jefferson/PGA_046612.

—From a National Academies announcement

AMS Congressional Fellowship

The AMS, in conjunction with the American Association for the Advancement of Science (AAAS), will sponsor a Congressional Fellow from September 2014 through August 2015. The fellow will spend the year working on the staff

of a member of Congress or a congressional committee as a special legislative assistant in legislative and policy areas requiring scientific and technical input.

The fellowship is designed to provide a unique public policy learning experience, to demonstrate the value of science-government interaction, and to bring a technical background and external perspective to the decision-making process in Congress.

An AMS Fellowship Committee will select the AMS Congressional Fellow. The fellowship stipend is US$74,872 for the fellowship period, with allowances for relocation and professional travel and a contribution toward health insurance.

Deadline for applications is **February 15, 2014**. Applicants must have a Ph.D. or an equivalent doctoral-level degree in the mathematical sciences by the application deadline. For further information, please consult the webpage http://www.ams.org/programs/ams-fellowships/ams-aaas/ams-aaas-congressional-fellowship or contact the AMS Washington Office at 202-588-1100, email: amsdc@ams.org.

—AMS Washington Office

Research Opportunities for U.S. Graduate Students in Asia and Australia

The National Science Foundation (NSF) is sponsoring a summer research program in Australia, China, Japan, Korea, Taiwan, New Zealand, and Singapore for U.S. graduate students during the summer of 2014. The East Asia and Pacific Summer Institutes (EAPSI) provide U.S. graduate students in science and engineering with firsthand research experience in the aforementioned countries, an introduction to the science and science policy infrastructure of the respective locations, and orientation to the culture and language. The primary goals of EAPSI are to introduce students to East Asian and Pacific science and engineering in the context of a research laboratory and to initiate personal relationships that will better enable them to collaborate with foreign counterparts in the future. The institutes last approximately eight weeks (ten weeks in Japan) from June to August and are administered in the United States by the NSF.

Applicants must be U.S. citizens or permanent residents. They must be enrolled at U.S. institutions in a research-oriented master's or Ph.D. program (including joint degree programs) in fields of science or engineering research and education that are supported by the NSF and that also are represented among the potential host institutions. International travel will be provided, and each awardee will receive a stipend of US$5,000.

The deadline for full proposals is **November 14, 2013**. Proposers are required to prepare and submit all proposals for this announcement/solicitation through the FastLane system. Further information and detailed instructions are available at http://www.nsf.gov/pubs/2012/nsf12498/nsf12498.htm?WT.mc_id=USNSF_25&WT.mc_ev=click#awd_info (or http://tinyurl.com/cqgnexu).

—From an NSF announcement

NSF Graduate Research Fellowships

The National Science Foundation's Graduate Research Fellowship Program (GRFP) recognizes and supports outstanding graduate students in NSF-supported science, technology, engineering, and mathematics disciplines who are pursuing research-based master's and doctoral degrees at accredited U.S. institutions. The NSF welcomes applications from all qualified students and strongly encourages underrepresented populations, including women, underrepresented racial and ethnic minorities, and persons with disabilities, to apply for this fellowship.

Fellows benefit from a three-year annual stipend of US$32,000 along with a US$12,000 cost-of-education allowance to the institution for tuition and fees, opportunities for international research and professional development, and the freedom to conduct their own research at any accredited U.S. institution of graduate education they choose.

The next deadline to apply for the GRFP is **November 5, 2013**. For further information, visit the website http://www.nsfgrfp.org/.

—From NSF announcements

AAUW Educational Foundation Fellowships and Grants

The American Association of University Women (AAUW) has programs for supporting women students and scholars at various stages of their careers: American Fellowships, Career Development Grants, Community Action Grants, International Fellowships, International Project Grants, and Selected Professions Fellowships. The latter fellowships support women students in areas in which women's participation has traditionally been low, including computer/information sciences and mathematics/statistics.

For further information about the fellowships, application procedures, and deadlines, visit the website http://www.aauw.org/what-we-do/educational-funding-and-awards/. Questions by phone or postal mail must be directed to the Iowa City office of the AAUW. Please do not contact the AAUW office in Washington, D.C., or local branches for application information. Please call 319-337-1716, ext. 60; email aauw@act.org; or write to the customer service center at: AAUW Fellowships and Grants, c/o ACT, Inc., P.O. Box 4030, Iowa City, IA 52243-4030.

—From AAUW website

NRC-Ford Foundation Fellowships

Through its Fellowship Programs, the Ford Foundation seeks to increase the diversity of the nation's college and university faculties by increasing their ethnic and racial diversity, to maximize the educational benefits of diversity, and to increase the number of professors who can and will use diversity as a resource for enriching the education of all students. The fellowships are administered by the Fellowships Office of the National Research Council.

All citizens or nationals of the United States are eligible regardless of race, national origin, religion, gender, age, disability, or sexual orientation. The fellowships are awarded to individuals who demonstrate superior academic achievement (such as grade-point average, class rank, honors, or other designations) and who are committed to a career in teaching and research at the college or university level.

Sixty Predoctoral Fellowships will be awarded. These fellowships provide three years of support for individuals engaged in graduate study leading to a Doctor of Philosophy (Ph.D.) or Doctor of Science (Sc.D.) degree. The online application deadline is **November 20, 2013**.

Thirty-five Dissertation Fellowships will be awarded. These fellowships provide one year of support for individuals working to complete a dissertation leading to a Ph.D. or Sc.D. degree. The online application deadline is **November 15, 2013**.

Approximately twenty-four Postdoctoral Fellowships will be awarded. These fellowships provide one year of support for individuals engaged in postdoctoral study after the attainment of the Ph.D. or Sc.D. degree. The online application deadline is **November 15, 2013**.

Awards will be announced in April 2014. For further information visit `http://sites.nationalacademies.org/pga/fordfellowships/` or contact: Fellowships Office, Keck 576, National Research Council, 500 Fifth Street, NW, Washington, DC 20001; tel: 202-334-2872; fax: 202-334-3419; email: `infofell@nas.edu`.

—From the Ford Foundation Fellowships website

AWM Essay Contest

To increase awareness of women's ongoing contributions to the mathematical sciences, the Association for Women in Mathematics (AWM) and Math for America are cosponsoring an essay contest for biographies of contemporary women mathematicians and statisticians in academic, industrial, and government careers.

Each essay will be based primarily on an interview with a woman currently working in a mathematical sciences career. This contest is open to students in the following categories: Grades 6–8, Grades 9–12, and College Undergraduate. At least one winning submission will be chosen from each category. Winners will receive a prize, and their essays will be published online at the AWM website. Additionally, a grand prize winner will have his or her submission published in the *AWM Newsletter*.

The deadline for the 2013 AWM Essay Contest is **January 31, 2014**. AWM is also currently seeking women mathematicians to volunteer as the subjects of these essays. For more information or to sign up as a volunteer, contact the contest organizer, Heather Lewis, at `hlewis5@naz.edu`. See `https://sites.google.com/site/awmmath/home` for complete information.

—AWM announcement

AMS Department Chairs Workshop

The annual workshop for department chairs will be held a day before the start of the Joint Mathematics Meetings in Baltimore, Maryland, on Tuesday, January 14, 2014, from 8:00 a.m. to 6:30 p.m. This one-day session for mathematical sciences department chairs is organized in a workshop format so as to stimulate discussion among attendees. Sharing ideas and experiences with peers creates an environment that enables attending chairs to address departmental challenges from new perspectives.

Workshop leaders will be: William "Bus" Jaco, professor, Department of Mathematics, Oklahoma State University; Alex Smith, professor and chair, Department of Mathematics, University of Wisconsin-Eau Claire; Michel Smith, professor, Department of Mathematics and Statistics, Auburn University; and Judy Walker, professor and chair, Department of Mathematics, University of Nebraska-Lincoln.

Past workshop sessions have focused on a range of issues facing departments, including planning and budgeting, personnel management, assessment, outreach, faculty development, communications, student learning, and departmental leadership.

The workshop registration fee of US$100 is in addition to and separate from the Joint Meetings registration. An invitation to attend the workshop will be sent to department chairs this fall. Information will also be posted on the AMS website. For further information, please contact the AMS Washington Office at 202-588-1100 or `amsdc@ams.org`.

—AMS Washington Office

Mathematics Research Communities 2014

The AMS invites mathematicians just beginning their research careers—those who are close to finishing their doctorates or who have recently finished—to become part of Mathematics Research Communities, a unique and successful program that builds social and collaborative networks through which individuals inspire and sustain each other in their work. Women and underrepresented minorities are especially encouraged to participate. Supported by the National Science Foundation, the structured

program engages and guides all participants as they start their careers.

Those accepted into the program will receive support for the summer conference and will be partially supported for their participation in the Joint Mathematics Meetings that follow in January 2015. The summer conferences of the MRC are held in the breathtaking mountain setting of the Snowbird Resort, Utah, where participants can enjoy the natural beauty and a collegial atmosphere. The program also includes discussion networks by research topic and a longitudinal study of early-career mathematicians.

Four conferences will be held in summer 2014 on the following topics.

Week 1: June 8–14, 2014: **Cluster Algebras**. Organizers: Michael Gekhtman, University of Notre Dame; Mark Gross, University of California, San Diego; Gregg Musiker, University of Minnesota; David Speyer, University of Michigan; Gordana Todorov, Northeastern University.

Week 2: June 15–21, 2014: **Algebraic and Geometric Methods in Applied Discrete Mathematics**. Organizers: Carina Curto, University of Nebraska-Lincoln; Jesús A. DeLoera, University of California, Davis; Christine Heitsch, Georgia Institute of Technology; Michael Orrison, Harvey Mudd College; Francis Edward Su, Harvey Mudd College.

Week 3a: June 24–30, 2014: **Mathematics of Quantum Phases of Matter and Quantum Information**. Organizers: Siu-Hung Ng, Iowa State University; Eric C. Rowell, Texas A&M University; Zhenghan Wang, Microsoft Station Q and University of California Santa Barbara.

Week 3b: June 24–30, 2014: **Network Science**. Organizers: Aaron Clauset, University of Colorado, Boulder; David Kempe, University of Southern California; Mason A. Porter, University of Oxford.

Individuals within one to two years before the receipt of their Ph.D.'s or within one to three years after receipt of their Ph.D.'s are welcome to apply. The MRC program is open to individuals who are U.S. citizens, as well as to those who are affiliated with U.S. institutions. A few international participants may be accepted. Women and underrepresented minorities are especially encouraged to apply. All participants are expected to be active in the full MRC program. Detailed instructions and the online application will be available on **November 1, 2013**.

Situated in a breathtaking mountain setting, Snowbird Resort provides an extraordinary environment for the MRC. The atmosphere is comparable to the collegial gatherings at Oberwolfach and other conferences that combine peaceful natural ambience with stimulating meetings. MRC participants have access to a range of activities, such as a tram ride to the top of the mountain, guided hikes, swimming, mountain bike tours, rock climbing, plus heated outdoor pools. More than a dozen walking and hiking trails head deep into the surrounding mountains. Participants also enjoy the simpler pleasures of convening on the patios at the resort to read, work, and socialize. In the evenings colleagues enjoy informal gatherings to network and continue discussion of the day's sessions over refreshments. Within a half hour of the University of Utah, Snowbird is easily accessible from the Salt Lake City International Airport. For more information about Snowbird Resort, see `http://www.snowbird.com`.

For further information on Mathematics Research Communities, visit the website `http://www.ams.org/programs/research-communities/mrc-14` or contact Ellen J. Maycock at `ejm@ams.org`.

—AMS announcement

Free Grant-Writing Workshop Offered

The AMS, in conjunction with the National Science Foundation Directorate for Education and Human Resources (NSF-EHR), is pleased to offer a **FREE** workshop entitled "Writing a Competitive Grant Proposal to NSF-EHR". This grant-writing workshop will be held prior to the start of the Joint Mathematics Meetings on Monday, January 13, 2014, from 3:00 p.m. to 6:00 p.m. at the Marriott Inner Harbor Hotel in Baltimore, Maryland.

Workshop Goals:

- To familiarize participants with current direction/priorities in EHR
- To familiarize participants with key EHR education research and development programs
- To consider common issues of competitive proposals
- To prepare participants to write a competitive proposal

Topics covered will include: discussion of key programs in EHR, the merit review process and merit review criteria, discussion of scenarios—short passages drawn from proposals in the EHR portfolio designed to stimulate discussion about strengths and weaknesses of a proposal, opportunity to discuss possible proposal ideas with program officers.

This free workshop is open to all interested participants. The deadline for registration is **December 24, 2013**. To register see the website `http://tinyurl.com/ka4fcdu`.

—AMS Washington Office

Call for Nominations for the 2014 Alan T. Waterman Award

The National Science Foundation (NSF) is soliciting nominations for the 2014 Alan T. Waterman Award. The award recognizes an outstanding young researcher in any field of science or engineering supported by the NSF. The award consists of a US$1,000,000 grant over a five-year period for research at the institution of the recipient's choice. The deadline for nominations is **October 25, 2013**. Nominations must be submitted electronically using NSF's FastLane system at `https://www.fastlane.nsf.gov/honawards/index.jsp`. For more details about the award, see `http://www.nsf.gov/od/waterman/waterman.jsp`.

—From an NSF announcement

News From MSRI

With funding from the National Science Foundation (NSF), and the National Security Agency (NSA), the Mathematical Sciences Research Institute (MSRI) will hold six workshops in Model Theory, Arithmetic Geometry and Number Theory; and Algebraic Topology during the spring of 2014. Established researchers, postdoctoral fellows and graduate students are invited to apply for funding. It is the policy of MSRI to actively seek to achieve diversity in its workshops. Thus, a strong effort is made to remove barriers that hinder equal opportunity, particularly for those groups that have been historically underrepresented in the mathematical sciences. The workshops to be held are as follows:

January 23–24, 2014: Connections for Women: Algebraic Topology. http://www.msri.org/workshops/684.

January 27–31, 2014: Introductory Workshop: Algebraic Topology. http://www.msri.org/workshops/685.

February 3–7, 2014: Introductory Workshop: Model Theory, Arithmetic Geometry and Number Theory. http://www.msri.org/workshops/688.

February 10–11, 2014: Connections for Women: Model Theory and Its Interactions with Number Theory and Arithmetic Geometry. http://www.msri.org/workshops/687.

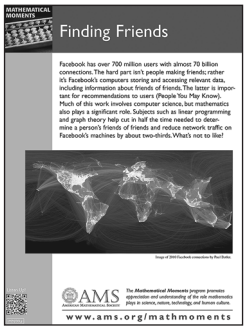
April–11, 2014: Reimagining the Foundations of Algebraic Topology. http://www.msri.org/workshops/689.

May 12–16, 2014: Model Theory in Geometry and Arithmetic. http://www.msri.org/workshops/686.

—From an MSRI announcement

Inside the AMS

From the AMS Public Awareness Office



Mathematical Moments. How has math helped us understand communication pathways in the brain? How does mathematics help architects design freeform buildings? Why is it important to understand the properties of bubbles and foam? These are some of the questions answered in recent Mathematical Moments. Hear podcast interviews with Frank Morgan, James Sethian, Helmut Portmann, Van Wedeen, and others; download and print the PDFs of these and more than one hundred other topics; and see translated versions at http://www.ams.org/mathmoments/.

AMS on Google+. The AMS joins the mathematical community on Google+ to engage with new and existing Google+ users by sharing research and publication content, membership and program news, meeting updates, and other subjects of interest to the mathematics research community. The AMS invites mathematicians worldwide to add AMS to your circles. Find AMS at +American Mathematical Society.

Math in the Media. This monthly online magazine is a centralized site at which to find coverage of mathematics and mathematicians in articles, radio spots, and television segments. Tony Phillips (Stony Brook University) offers his take on articles about mathematics in *Science, Nature*, newspapers, and other science journals, and previous AMS-AAAS Mass Media Fellows summarize media coverage of recent mathematics news, math education, mathematics and the arts, and mathematicians. AMS members are invited to email to paoffice@ams.org links to media coverage of mathematics, interviews with themselves or other mathematicians, and radio or television programs that highlight mathematics. *Math in the Media* also includes the Reviews section: links to reviews of recent books, plays, and films of general interest. http://www.ams.org/mathmedia .

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

Deaths of AMS Members

MICHAEL I. AISSEN, of Santa Cruz, California, died on January 7, 2013. Born on January 16, 1921, he was a member of the Society for 64 years.

Russell G. Bilyeu, of Chico, Texas, died on March 12, 2012. Born on January 22, 1930, he was a member of the Society for 53 years.

Jan Boal, of Atlanta, Georgia, died on January 16, 2013. Born on October 20, 1930, he was a member of the Society for 55 years.

Robert A. Clark, of Cleveland, Ohio, died on December 19, 2012. Born on May 3, 1923, he was a member of the Society for 68 years.

Marc Fontaine, of Houston, Texas, died on January 24, 2013. Born on March 27, 1926, he was a member of the Society for 58 years.

A. Raymond Harvey, of La Jolla, California, died on February 6, 2013. Born on January 12, 1921, he was a member of the Society for 69 years.

John E. Kimber, of Pittsburg, California, died on January 18, 2013. Born on August 5, 1925, he was a member of the Society for 59 years.

Reference and Book List

*The **Reference** section of the* Notices *is intended to provide the reader with frequently sought information in an easily accessible manner. New information is printed as it becomes available and is referenced after the first printing. As soon as information is updated or otherwise changed, it will be noted in this section.*

Contacting the *Notices*

The preferred method for contacting the *Notices* is electronic mail. The editor is the person to whom to send articles and letters for consideration. Articles include feature articles, memorial articles, communications, opinion pieces, and book reviews. The editor is also the person to whom to send news of unusual interest about other people's mathematics research.

The managing editor is the person to whom to send items for "Mathematics People", "Mathematics Opportunities", "For Your Information", "Reference and Book List", and "Mathematics Calendar". Requests for permissions, as well as all other inquiries, go to the managing editor.

The electronic-mail addresses are notices@math.wustl.edu in the case of the editor and smf@ams.org in the case of the managing editor. The fax numbers are 314-935-6839 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

November 1, 2013: Applications for November review for National Academies Research Associateship Programs. See the website http://sites.nationalacademies.org/PGA/RAP/PGA_050491 or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone: 202-334-2760; fax: 202-334-2759; email: rap@nas.edu.

November 5, 2013: Applications for NSF Graduate Research Fellowships. See "Mathematics Opportunities" in this issue.

November 12, 2013: Full proposals for NSF Program ADVANCE Institutional Transformation and Institutional Transformation Catalyst awards. See http://www.nsf.gov/pubs/2012/nsf12584/nsf12584.htm?WT.mc_id=USNSF_36&WT.mc_ev=click.

November 14, 2013: Full proposals for NSF East Asia and Pacific Summer Institutes (EAPSI). See "Mathematics Opportunities" in this issue.

November 15, 2013: Applications for NRC-Ford Foundation Dissertation and Postdoctoral Fellowships. See "Mathematics Opportunities" in this issue.

November 20, 2013: Applications for NRC-Ford Foundation Predoctoral Fellowships. See "Mathematics Opportunities" in this issue.

December 1, 2013: Applications for AMS Centennial Fellowship. See http://www.ams.org/ams-fellowships/. For paper copies of the form, write to the Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; prof-serv@ams.org; 401-455-4105.

December 1, 2013: Applications for MSRI research memberships and postdoctoral fellowships. See https://www.msri.org/web/msri/scientific/member-application.

December 1, 2013: Applications for PIMS postdoctoral fellowships. See the website http://www.pims.math.ca/scientific/postdoctoral, or contact assistant director@pims.math.ca.

December 2, 2013: Nominations for Ferran Sunyer i Balaguer Prize. See http://ffsb.iec.cat.

Where to Find It

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

AMS Bylaws—*January 2012, p. 73*

AMS Email Addresses—*February 2013, p. 249*

AMS Ethical Guidelines—*June/July 2006, p. 701*

AMS Officers 2012 and 2013 Updates—*May 2013, p. 646*

AMS Officers and Committee Members—*October 2012, p. 1290*

Contact Information for Mathematical Institutes—*August 2013, p. 629*

Conference Board of the Mathematical Sciences—*September 2013, p. 1067*

IMU Executive Committee—*December 2011, p. 1606*

Information for *Notices* Authors—*June/July 2013, p. 776*

National Science Board—*January 2013, p. 109*

NRC Board on Mathematical Sciences and Their Applications—*March 2013, p. 350*

NSF Mathematical and Physical Sciences Advisory Committee—*February 2013, p. 252*

Program Officers for Federal Funding Agencies—*October 2013, p. 1188 (DoD, DoE); December 2012, p. 1585 (NSF Mathematics Education)*

Program Officers for NSF Division of Mathematical Sciences—*November 2013, p. 1352*

December 15, 2013: Applications for AMS Epsilon Fund. See "Mathematics Opportunities" in this issue.

December 31, 2013: Nominations for Otto Neugebauer Prize. See the website http://www.euro-math-soc.eu/otto_neugebauer_prize.html.

January 13, 2014: Applications for Jefferson Science Fellowships. See "Mathematics Opportunities" in this issue.

January 15, 2014: Applications for AMS-AAAS Mass Media Summer Fellowships. See the website http://www.aaas.org/programs/education/MassMedia; or contact Dione Rossiter, Manager, Mass Media Program, AAAS Mass Media Science and Engineering Fellows Program, 1200 New York Avenue, NW, Washington, DC 20005; telephone: 202-326-6645; fax: 202-371-9849; email: drossite@aaas.org. Further information is also available at http://www.ams.org/programs/ams-fellowships/media-fellow/massmediafellow and through the AMS Washington Office, 1527 Eighteenth Street, NW, Washington, DC 20036; telephone: 202-588-1100; fax: 202-588-1853; email: amsdc@ams.org.

January 31, 2014: Entries for AWM Essay Contest. See "Mathematics Opportunities" in this issue.

February 1, 2014: Applications for AWM Travel Grants, Mathematics Education Research Travel Grants, Mathematics Mentoring Travel Grants, and Mathematics Education Research Mentoring Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; telephone: 703-934-0163; or email: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

February 15, 2014: Applications for AMS Congressional Fellowship. See "Mathematics Opportunities" in this issue.

February 15, 2014: Nominations for AWM-Joan & Joseph Birman Prize in Topology and Geometry. See the website http://www.awm-math.org.

April 15, 2014: Applications for fall 2014 semester of Math in Moscow. See http://www.mccme.ru/mathinmoscow, or contact: Math in Moscow, P. O. Box 524, Wynnewood, PA 19096; fax: +7095-291-65-01; email: mim@mccme.ru. Information and application forms for the AMS scholarships are available on the AMS website at http://www.ams.org/programs/travel-grants/mimoscow, or contact: Math in Moscow Program, Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence RI 02904-2294; email: student-serv@ams.org.

May 1, 2014: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; telephone: 703-934-0163; or email: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 1, 2014: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; telephone: 703-934-0163; or email: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

NSF Division of Mathematical Sciences

Listed below are names and email addresses for the program directors for the present academic year in the Division of Mathematical Sciences (DMS) of the National Science Foundation. The postal address is: Division of Mathematical Sciences, National Science Foundation, Room 1025, 4201 Wilson Boulevard, Arlington, VA 22230. The DMS webpage is http://www.nsf. gov/div/index.jsp?div=DMS. Phone numbers are available on the webpage.

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The DMS administrative staff includes:

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(as of January 2014)

Deputy Division Director (Acting Division Director through 12/31/13)
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(through 12/31/13)
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Program Specialist
Onica Andrews
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Book List

The Book List highlights recent books that have mathematical themes and are aimed at a broad audience potentially including mathematicians, students, and the general public. Suggestions for books to include on the list may be sent to notices-booklist@ams.org.

*Added to "Book List" since the list's last appearance.

An Accidental Statistician: The Life and Memories of George E. P. Box, by George E. P. Box. Wiley, April 2013. ISBN-13: 978-1-118-40088-3.

Algorithmic Puzzles, by Anany Levitin and Maria Levitin. Oxford University Press, October 2011. ISBN-13: 978-01997-404-44.

Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification, by the National Research Council. National Academies Press, 2012. ISBN-13: 978-0-309-25634-6.

The Best Writing on Mathematics 2012, edited by Mircea Pitici. Princeton University Press, November 2012. ISBN-13: 978-06911-565-52.

Charles S. Peirce on the Logic of Number, by Paul Shields. Docent Press, October 2012. ISBN-13: 978-0-9837004-7-0.

Classic Problems of Probability, by Prakash Gorroochurn. Wiley, May 2012. ISBN: 978-1-1180-6325-5. (Reviewed in this issue.)

Conflict in History, Measuring Symmetry, Thermodynamic Modeling and Other Work, by Dennis Glenn Collins. Author House, November 2011. ISBN-13: 978-1-4670-7641-8.

The Continuity Debate: Dedekind, Cantor, du Bois-Reymond, and Peirce on Continuity and Infinitesimals, by Benjamin Lee Buckley. Docent Press, December 2012. ISBN-13: 978-0-9837004-8-7.

Decoding the Heavens: A 2,000-Year-Old Computer—and the Century-Long Search to Discover Its Secrets, by Jo Marchant. Da Capo Press, February 2009. ISBN-13: 978-03068-174-27. (Reviewed June/July 2013).

Do I Count?: Stories from Mathematics, by Günter Ziegler (translation of *Darf ich Zahlen?: Geschichte aus der Mathematik,* Piper Verlag, 2010). CRC Press/A K Peters, July 2013. ISBN-13: 978-1466564916

Figures of Thought: A Literary Appreciation of Maxwell's Treatise on Electricity and Magnetism, by Thomas K. Simpson. Green Lion Press, February 2006. ISBN-13: 978-18880-093-16. (Reviewed October 2013.)

The Fractalist: Memoir of a Scientific Maverick, by Benoît Mandelbrot. Pantheon, October 2012. ISBN-13: 978-03073-773-57.

Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century, by the National Research Council. National Academies Press, 2012. ISBN-13: 978-0-309-25473-1.

Game Theory and the Humanities: Bridging Two Worlds, by Steven J. Brams. MIT Press, September 2012. ISBN-13: 978-02625-182-53.

Games and Mathematics: Subtle Connections, by David Wells. Cambridge University Press, November 2012. ISBN-13: 978-11076-909-12.

Girls Get Curves: Geometry Takes Shape, by Danica McKellar. Plume, July 2013. ISBN-13: 978-04522-987-43.

The Golden Ticket: P, NP, and the Search for the Impossible, by Lance Fortnow. Princeton University Press, March 2013. ISBN-13: 978-06911-564-91.

Google's PageRank and Beyond: The Science of Search Engine Rankings, by Amy Langville and Carl Meyer. Princeton University Press, February 2012. ISBN-13: 978-06911-526-60.

Gösta Mittag-Leffler: A Man of Conviction, by Arild Stubhaug (translated by Tiina Nunnally). Springer, November 2010. ISBN-13: 978-36421-167-11. (Reviewed September 2013.)

Heavenly Mathematics: The Forgotten Art of Spherical Trigonometry, by Glen Van Brummelen. Princeton University Press, December 2012. ISBN-13: 978-06911-489-22.

Henri Poincaré: Impatient Genius, by Ferdinand Verhulst. Springer, August 2012. ISBN-13: 978-14614-240-62.

Henri Poincaré: A Scientific Biography, by Jeremy Gray. Princeton University Press, November 2012. ISBN-13: 978-06911-527-14.

How to Study as a Mathematics Major, by Lara Alcock. Oxford University Press, March 2013. ISBN-13: 978-0199661312.

I Died for Beauty: Dorothy Wrinch and the Cultures of Science, by Marjorie Senechal. Oxford University Press, December 2012. ISBN-13:978-01997-325-93.

Ibn al-Haytham's Theory of Conics, Geometrical Constructions and Practical Geometry, by Roshdi Rashed. Routledge, February 2013. ISBN-13: 978-0-415-58215-5.

**Imagined Civilizations: China, the West, and Their First Encounter,* by Roger Hart. Johns Hopkins University Press, July 2013. ISBN-13:978-14214-060-60.

In Pursuit of the Unknown: 17 Equations That Changed the World, by Ian Stewart. Basic Books, March 2012. ISBN-13: 978-04650-297-30. (Reviewed December 2012.)

Infinity: New Research Frontiers, edited by Michael Heller and W. Hugh Woodin. Cambridge University Press, February 2011. ISBN-13: 978-11070-038-73.

Introduction to Mathematical Thinking, by Keith Devlin. Keith Devlin, July 2012. ISBN-13: 978-06156-536-31.

Invisible in the Storm: The Role of Mathematics in Understanding Weather, by Ian Roulstone and John Norbury. Princeton University Press, February 2013. ISBN-13: 978-06911-527-21. (Reviewed September 2013.)

The Joy of x: A Guided Tour of Math, from One to Infinity, by Steven Strogatz. Eamon Dolan/Houghton Mifflin Harcourt, October 2012. ISBN-13: 978-05475-176-50.

Late Style: Yuri I. Manin Looking Back on a Life in Mathematics. A DVD documentary by Agnes Handwerk and Harrie Willems. Springer, March 2012. ISBN NTSC: 978-3-642-24482-7; ISBN PAL: 978-3-642-24522-0. (Reviewed January 2013.)

Levels of Infinity: Selected Writings on Mathematics and Philosophy, by Hermann Weyl. Edited by Peter Pesic. Dover Publications, February 2013. ISBN-13: 978-0486489032.

The Logician and the Engineer: How George Boole and Claude Shannon Created the Information Age, by Paul J. Nahin, Princeton University Press, October 2012. ISBN-13: 978-06911-510-07. (Reviewed October 2013.)

Manifold Mirrors: The Crossing Paths of the Arts and Mathematics, by Felipe Cucker. Cambridge University Press, June 2013. ISBN-13: 978-05217-287-68.

Math Goes to the Movies, by Burkard Polster and Marty Ross. Johns Hopkins University Press, July 2012. ISBN-13: 978-14214-048-44.

Math on Trial: How Numbers Get Used and Abused in the Courtroom, by Leila Schneps and Coralie Colmez. Basic Books, March 2013. ISBN-13: 978-04650-329-21. (Reviewed August 2013.)

The Mathematical Writings of Évariste Galois, edited by Peter M. Neumann. European Mathematical Society, October 2011. ISBN-13: 978-3-03719-104-0. (Reviewed December 2012.)

A Mathematician Comes of Age, by Steven G. Krantz. Mathematical Association of America, December 2011. ISBN-13: 978-08838-557-82.

A Mathematician's Lament: How School Cheats Us Out of Our Most Fascinating and Imaginative Art Form, by Paul Lockhart. Bellevue Literary Press, April 2009. ISBN-13: 978-1-934137-17-8. (Reviewed April 2013.)

Mathematicians in Bologna 1861-1960, edited by Salvatore Coen. Springer, 2012. ISBN-13: 978-30348-0226-0.

Mathematics in Victorian Britain, by Raymond Flood, Adrian Rice, and Robin Wilson. Oxford University Press, October 2011. ISBN-13: 978-019-960139-4.

Maverick Genius: The Pioneering Odyssey of Freeman Dyson, by Phillip F. Schewe. Thomas Dunne Books, February 2013. ISBN-13:978-03126-423-58.

Meaning in Mathematics, edited by John Polkinghorne. Oxford University Press, July 2011. ISBN-13: 978-01996-050-57. (Reviewed May 2013.)

Measurement, by Paul Lockhart. Belknap Press of Harvard University Press, September 2012. ISBN-13: 978-06740-575-55.

The New York Times Book of Mathematics: More Than 100 Years of Writing by the Numbers, edited by Gina Kolata. Sterling, June 2013. ISBN-13: 978-14027-932-26.

The Noether Theorems: Invariance and Conservation Laws in the Twentieth Century, by Yvette Kosmann-Schwarzbach. Springer, December 2010. ISBN-13: 978-03878-786-76. (Reviewed August 2013.)

Paradoxes in Probability Theory, by William Eckhardt. Springer, September 2012. ISBN-13: 978-94007-513-92. (Reviewed March 2013.)

Peirce's Logic of Continuity: A Conceptual and Mathematical Approach, by Fernando Zalamea. Docent Press, December 2012. ISBN-13: 978-0-9837004-9-4.

Relations between Logic and Mathematics in the Work of Benjamin and Charles S. Peirce, by Allison Walsh. Docent Press, October 2012. ISBN-13: 978-0-9837004-6-3.

The Search for Certainty: A Journey through the History of Mathematics, 1800-2000, edited by Frank J. Swetz. Dover Publications, September 2012. ISBN-13: 978-04864-744-27.

Secrets of Triangles: A Mathematical Journey, by Alfred S. Posamentier and Ingmar Lehman. Prometheus Books, August 2012. ISBN-13: 978-16161-458-73.

Seduced by Logic: Emilie Du Châtelet, Mary Somerville and the Newtonian Revolution, by Robyn Arianrhod. Oxford University Press, September 2012. ISBN-13: 978-01999-316-13. (Reviewed June/July 2013).

Selected Papers: Volume II: On Algebraic Geometry, including Correspondence with Grothendieck, by David Mumford. Edited by Amnon Neeman, Ching-Li Chai, and Takahiro Shiota. Springer, July 2010. ISBN-13: 978-03877-249-11. (Reviewed February 2013.)

The Signal and the Noise: Why So Many Predictions Fail—But Some Don't, by Nate Silver. Penguin Press, September 2012. ISBN-13:978-15942-041-11.

Simon: The Genius in My Basement, by Alexander Masters. Delacorte Press, February 2012. ISBN-13: 978-03853-410-80.

Sources in the Development of Mathematics: Series and Products

from the Fifteenth to the Twenty-first Century, by Ranjan Roy. Cambridge University Press, June 2011. ISBN-13: 978-05211-147-07. (Reviewed in this issue.)

**Symmetry: A Very Short Introduction,* by Ian Stewart. Oxford University Press, July 2013. ISBN-13: 978-01996-519-86.

Thinking in Numbers: On Life, Love, Meaning, and Math, by Daniel Tammet. Little, Brown and Company, July 2013. ISBN-13: 978-03161-873-74.

Thinking Statistically, by Uri Bram. CreateSpace Independent Publishing Platform, January 2012. ISBN-13: 978-14699-123-32.

Transcending Tradition: Jewish Mathematicians in German Speaking Academic Culture, edited by Birgit Bergmann, Moritz Epple, and Ruti Ungar. Springer, January 2012. ISBN-13: 978-36422-246-38. (Reviewed February 2013.)

Turbulent Times in Mathematics: The Life of J. C. Fields and the History of the Fields Medal, by Elaine McKinnon Riehm and Frances Hoffman. AMS, November 2011. ISBN-13: 978-0-8218-6914-7.

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

The Universe in Zero Words: The Story of Mathematics as Told through Equations, by Dana Mackenzie. Princeton University Press, April 2012. ISBN-13: 978-06911-528-20. (Reviewed December 2012.)

Visions of Infinity: The Great Mathematical Problems, by Ian Stewart. Basic Books, March 2013. ISBN-13: 978-04650-224-03.

A Wealth of Numbers: An Anthology of 500 Years of Popular Mathematics Writing, edited by Benjamin Wardhaugh. Princeton University Press, April 2012. ISBN-13: 978-06911-477-58. (Reviewed March 2013.)

Who's #1?: The Science of Rating and Ranking, by Amy N. Langville and Carl D. Meyer. Princeton University Press, February 2012. ISBN-13: 978-06911-542-20. (Reviewed January 2013.)

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Sample eMR Section

MR2954056 03-03 01A70 68-03 81P68 94-03 94C10

Nahin, Paul J. (1-NH-ECE; Durham, NH)
The logician and the engineer; How George Boole and Claude Shannon created the information age.
Princeton University Press, Princeton, NJ, 2013. xiv+228 pp. $24.95.
ISBN 978-0-691-15100-7
Written in the lucid style of the author's many best-selling books "popularizing" mathematics, *The logician and the engineer* pays homage to the careers of George Boole and Claude Shannon in their pioneering work presaging the modern computer era. After two fascinating mini-biographies, the author turns his attention to switching circuits, combinatorial and sequential logic design, probability and information theory, each impacted by the significant contributions of Boole and Shannon. Interesting and informative chapter-ending notes enhance and expand the scope of the investigations, often providing technical details that would otherwise have impeded the flow of the narrative. Most valuable to this reviewer, and likely to many potential readers, is the closing chapter, aptly titled "Beyond Boole and Shannon". Here is provided an introduction to quantum computing and its logic, possibly portending the future of computers, yet unmistakably bearing the footprints of the two early pioneers. It is an unexpected yet fitting conclusion to this thoroughly enjoyable read.
Ronald E. Prather

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- ✦ Teaching load of 1 graduate course per year at POSTECH.
- ✦ Generous and flexible research grant.
- ✦ Can hire 1-2 tenure-track and 3-4 postdoctoral researchers for his/her research group. (Unlike Group Leader, researchers will not be given appointments at POSTECH.)
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A complete application packet should include:

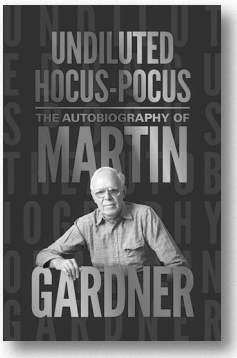
- Cover letter
- Curriculum vitae (including a publication list)
- Research statement
- At least 5 letters of recommendation

For full consideration, complete application packets must be submitted electronically to cgp@ibs.re.kr by **February 15, 2014.**

For more information: http://cgp.ibs.re.kr.

IBS and POSTECH encourage applications from individuals of diverse backgrounds. Non-Korean citizens are also welcome to apply.

ibs Institute for Basic Science POSTECH



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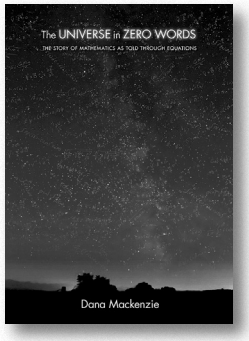

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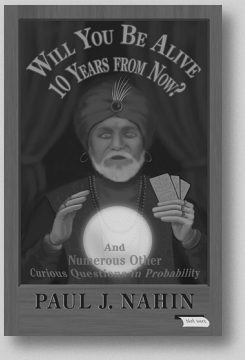

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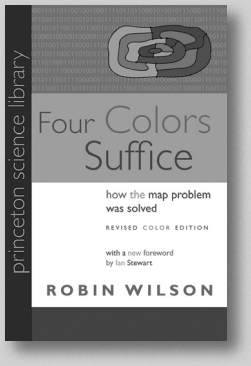

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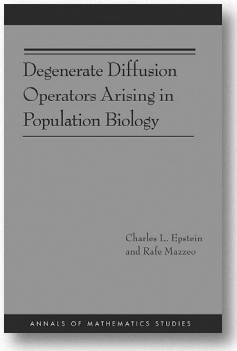

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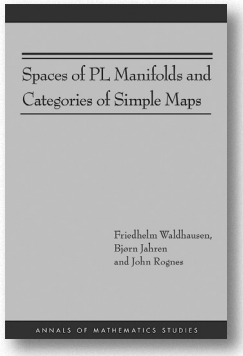

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Reciprocity Agreements

The American Mathematical Society has reciprocity agreements with a number of mathematical organizations around the world. A current list of the reciprocating societies appears here; for full details of the agreements, see www.ams.org/membership/individual/mem-reciprocity.

Allahabad Mathematical Society

Argentina Mathematical Society

Australian Mathematical Society

Austrian Mathematical Society

Azerbaijan Mathematical Society

Balkan Society of Geometers

Belgian Mathematical Society

Berliner Mathematische Gesellschaft

Bharata Ganita Parisad

Brazilian Mathematical Society

Brazilian Society of Computational and Applied Mathematics

Calcutta Mathematical Society

Canadian Mathematical Society

Catalan Mathematical Society

Chilean Mathematical Society

Columbian Mathematical Society

Croation Mathematical Society

Cyprus Mathematical Society

Danish Mathematical Society

Dutch Mathematical Society

Edinburgh Mathematical Society

Egyptian Mathematical Society

European Mathematical Society

Finnish Mathematical Society

German Mathematical Society

German Society for Applied Maths and Mechanics

Glasgow Mathematical Association

Hellenic Mathematical Society

Icelandic Mathematical Society

Indian Mathematical Society

Indonesian Mathematical Society

Iranian Mathematical Society

Irish Mathematical Society

Israel Mathematical Union

Italian Mathematical Union

János Bolyai Mathematical Society

Korean Mathematical Society

London Mathematical Society

Luxembourg Mathematical Society

Macedonian Society Association Mathematics/Computer Science

Malaysian Mathematical Science Society

Mathematical Society of France

Mathematical Society of Japan

Mathematical Society of the Philippines

Mathematical Society of the Republic of China

Mathematical Society of Serbia

Mexican Mathematical Society

Mongolian Mathematical Society

Nepal Mathematical Society

New Zealand Mathematical Society

Nigerian Mathematical Society

Norwegian Mathematical Society

Palestine Society for Mathematical Sciences

Parana's Mathematical Society

Polish Mathematical Society

Portuguese Mathematical Society

Punjab Mathematical Society

Ramanujan Mathematical Society

Romanian Mathematical Society

Romanian Society of Mathematicians

Royal Spanish Mathematical Society

Saudi Association for Mathematical Sciences

Singapore Mathematical Society

Sociedad Matemática de la Republica Dominicana

Sociedad Uruguaya de Matemática y Estadística

Société de Mathématiques Appliquées et Industrielles (SMAI)

Society of Mathematicians, Physicists, and Astronomers of Slovenia

South African Mathematical Society

Southeast Asian Mathematical Society

Spanish Society of Applied Mathematics

Swedish Mathematical Society

Swiss Mathematical Society

Tunisian Mathematical Society

Turkish Mathematical Society

Ukrainian Mathematical Society

Union of Bulgarian Mathematicians

Union of Czech Mathematicians and Physicists

Union of Slovak Mathematicians & Physicists

Vietnam Mathematical Society

Vijnana Parishad of India

From the AMS Secretary

Bylaws of the American Mathematical Society

Article I

Officers

Section 1. There shall be a president, a president elect (during the even-numbered years only), an immediate past president (during the odd-numbered years only), three vice presidents, a secretary, four associate secretaries, a treasurer, and an associate treasurer.

Section 2. It shall be a duty of the president to deliver an address before the Society at the close of the term of office or within one year thereafter.

Article II

Board of Trustees

Section 1. There shall be a Board of Trustees consisting of eight trustees, five trustees elected by the Society in accordance with Article VII, together with the president, the treasurer, and the associate treasurer of the Society *ex officio*. The Board of Trustees shall designate its own presiding officer and secretary.

Section 2. The function of the Board of Trustees shall be to receive and administer the funds of the Society, to have full legal control of its investments and properties, to make contracts, and, in general, to conduct all business affairs of the Society.

Section 3. The Board of Trustees shall have the power to appoint such assistants and agents as may be necessary or convenient to facilitate the conduct of the affairs of the Society and to fix the terms and conditions of their employment. The Board may delegate to the officers of the Society duties and powers normally inhering in their respective corporative offices, subject to supervision by the Board. The Board of Trustees may appoint committees to facilitate the conduct of the financial business of the Society and delegate to such committees such powers as may be necessary or convenient for the proper exercise of those powers. Agents appointed, or members of committees designated, by the Board of Trustees need not be members of the Board.

Nothing herein contained shall be construed to empower the Board of Trustees to divest itself of responsibility for, or legal control of, the investments, properties, and contracts of the Society.

Article III

Committees

Section 1. There shall be eight editorial committees as follows: committees for the *Bulletin*, for the *Proceedings*, for the *Colloquium Publications*, for the *Journal*, for *Mathematical Surveys and Monographs*, for *Mathematical Reviews*; a joint committee for the *Transactions* and the *Memoirs*; and a committee for *Mathematics of Computation*.

Section 2. The size of each committee shall be determined by the Council.

Article IV

Council

Section 1. The Council shall consist of fifteen members at large and the following *ex officio* members: the officers of the Society specified in Article I, except that it shall include only one associate secretary, the chairman of each of the editorial committees specified in Article III, any former secretary for a period of two years following the terms of office, and members of the Executive Committee (Article V) who remain on the Council by the operation of Article VII, Section 4.

The chairman of any committee designated as a Council member may name a deputy from the committee as substitute. The associate secretary shall be the one charged with the scientific program of the meeting at which the Council meets except that at a meeting associated with no scientific meeting of the Society the secretary may designate the associate secretary.

Section 2. The Council shall formulate and administer the scientific policies of the Society and shall act in an advisory capacity to the Board of Trustees.

Section 3. In the absence of the secretary from any meeting of the Council, a member may be designated as acting secretary for the meeting, either by written authorization of the secretary, or, failing that, by the presiding officer.

Section 4. All members of the Council shall be voting members. Each member, including deputies and the designated associate secretary, shall have one vote. The method for settling matters before the Council at any meeting shall be by majority vote of the members present. If the result of a vote is challenged, it shall be the duty of the presiding officer to determine the true vote by a roll call. In a roll call vote, each Council member shall vote only once (although possibly a member of the Council in several capacities).

Section 5. Any five members of the Council shall constitute a quorum for the transaction of business at any meeting of the Council.

Section 6. Between meetings of the Council, business may be transacted. Votes shall be counted as specified in Section 4 of this Article, "members present" being replaced by "members voting". An affirmative vote on any proposal shall be declared if, and only if, (a) more than half of the total number of possible votes is received by the time announced for the closing of the polls, and (b) at least three-quarters of the votes received by then are affirmative. If five or more members request postponement at the time of voting, action on the matter at issue shall be postponed until the next meeting of the Council, unless either (1) at the discretion of the secretary, the question is made the subject of a second vote, in connection with which brief statements of reason, for and against, are circulated; or (2) the Council places the matter at issue before the Executive Committee for action.

Section 7. The Council may delegate to the Executive Committee certain of its duties and powers. Between meetings of the Council, the Executive Committee shall act for the Council on such matters and in such ways as the Council may specify. Nothing herein contained shall be construed as empowering the Council to divest itself of responsibility for formulating and administering the scientific policies of the Society.

Section 8. The Council shall also have power to speak in the name of the Society with respect to matters affecting the status of mathematics or mathematicians, such as proposed or enacted federal or state legislation; conditions of employment in universities, colleges, or business, research or industrial organizations; regulations, policies, or acts of governmental agencies or instrumentalities; and other items which tend to affect the dignity and effective position of mathematics.

With the exception noted in the next paragraph, a favorable vote of two-thirds of the entire membership of the Council shall be necessary to authorize any statement in the name of the Society with respect to such matters. With the exception noted in the next paragraph, such a vote may be taken only if written notice shall have been given to the secretary by the proposer of any such resolution not later than one month prior to the Council meeting at which the matter is to be presented, and the vote shall be taken not earlier than one month after the resolution has been discussed by the Council.

If, at a meeting of the Council, there are present twelve members, then the prior notification to the secretary may be waived by unanimous consent. In such a case, a unanimous favorable vote by those present shall empower the Council to speak in the name of the Society.

The Council may also refer the matter to a referendum of the entire membership of the Society and shall make such reference if a referendum is requested, prior to final action by the Council, by two hundred or more members. The taking of a referendum shall act as a stay upon Council action until the votes have been canvassed, and thereafter no action may be taken by the Council except in accordance with a plurality of the votes cast in the referendum.

Article V

Executive Committee

Section 1. There shall be an Executive Committee of the Council, consisting of four elected members and the following *ex officio* members: the president, the secretary, the president elect (during even-numbered years), and the immediate past president (during odd-numbered years).

Section 2. The Executive Committee of the Council shall be empowered to act for the Council on matters which have been delegated to the Executive Committee by the Council. If three members of the Executive Committee request that any matter be referred to the Council, the matter shall be so referred. The Executive Committee shall be responsible to the Council and shall report its actions to the Council. It may consider the agenda for meetings of the Council and may make recommendations to the Council.

Section 3. Each member of the Executive Committee shall have one vote. An affirmative vote on any proposal before the Executive Committee shall be declared if, and only if, at least four affirmative votes are cast for the proposal. A vote on any proposal may be determined at a meeting of the Executive Committee, but it shall not be necessary to hold a meeting to determine a vote.

Article VI

Executive Director

Section 1. There shall be an Executive Director who shall be a paid employee of the Society. The Executive Director shall have charge of the offices of the Society, except for the office of the secretary, and shall be responsible for the general administration of the affairs of the Society in accordance with the policies that are set by the Board of Trustees and by the Council.

Section 2. The Executive Director shall be appointed by the Board of Trustees with the consent of the Council. The terms and conditions of employment shall be fixed by the Board of Trustees, and the performance of the Executive Director will be reviewed regularly by the Board of Trustees.

Section 3. The Executive Director shall be responsible to and shall consult regularly with a liaison committee consisting of the president as chair, the secretary, the treasurer, and the chair of the Board of Trustees.

Section 4. The Executive Director shall attend meetings of the Board of Trustees, the Council, and the Executive Committee, but shall not be a member of any of these bodies.

Article VII

Election of Officers and Terms of Office

Section 1. The term of office shall be one year in the case of the president elect and the immediate past president; two years in the case of the president, the secretary, the associate secretaries, the treasurer, and the associate treasurer; three years in the case of vice presidents and members at large of the Council, one vice president and five members at large retiring annually; and five years in the case of the trustees. In the case of members of the editorial committees and appointed members of the communications committees, the term of office shall be determined by the Council. The term of office for elected members of the Executive Committee shall be four years, one of the elected members retiring annually. All terms of office shall begin on February 1 and terminate on January 31, with the exception that the officials specified in Articles I, II, III, IV, and V (excepting the president elect and immediate past president) shall continue to serve until their successors have been duly elected or appointed and qualified.

Section 2. The president elect, the vice presidents, the trustees, and the members at large of the Council shall be elected by ballot. The secretary shall send notification to each member of the Society about the slate of candidates and the voting procedure on or before October 10, and legitimate ballots received by an established deadline at least 30 days later will be counted. Each ballot shall contain one or more names proposed by the Council for each office to be filled, with blank spaces in which the voter may substitute other names. A plurality of all votes cast shall be necessary for election. In case of failure to secure a plurality for any office, the Council shall choose by ballot among the members having the highest number of votes. The secretary, the associate secretaries, the treasurer, and the associate treasurer shall be appointed by the Council in a manner designated by the Council. Each committee named in Article III shall be appointed by the Council in a manner designated by the Council. Each such committee shall elect one of its members as chairman in a manner designated by the Council.

Section 3. The president becomes immediate past president at the end of the term of office and the president elect becomes president.

Section 4. On or before February 15, the secretary shall send to all members of the Council a ballot containing two names for each place to be filled on the Executive Committee. The nominees shall be chosen by a committee appointed by the president. Members of the Council may vote for persons not nominated. Any member of the Council who is not an *ex officio* member of the Executive Committee (see Article V, Section 1) shall be eligible for election to the Executive Committee. In case a member is elected to the Executive Committee for a term extending beyond the regular term on the Council, that person shall automatically continue as a member of the Council during the remainder of that term on the Executive Committee.

Section 5. The president and vice presidents shall not be eligible for immediate re-election to their respective offices. A member at large or an *ex officio* member of the Council shall not be eligible for immediate election (or re-election) as a member at large of the Council.

Section 6. If the president of the Society should die or resign while a president elect is in office, the president elect shall serve as president for the remainder of the year and thereafter shall serve the regular two-year term. If the president of the Society should die or resign when no president elect is in office, the Council, with the approval of the Board of Trustees, shall designate one of the vice presidents to serve as president for the balance of the regular presidential term. If the president elect of the Society should die or resign before becoming president, the office shall remain vacant until the next regular election of a president elect, and the Society shall, at the next annual meeting, elect a president for a two-year term. If the immediate past president should die or resign before expiration of the term of office, the Council, with the approval of the Board of Trustees, shall designate a former president of the Society to serve as immediate past president during the remainder of the regular term of the immediate past president. Such vacancies as may occur at any time in the group consisting of the vice presidents, the secretary, the associate secretaries, the treasurer, and the associate treasurer shall be filled by the Council with the approval of the Board of Trustees. If a member of an editorial or communications committee should take temporary leave from duties, the Council shall then appoint a substitute. The Council shall fill from its own membership any vacancy in the elected membership of the Executive Committee.

Section 7. If any elected trustee should die while in office or resign, the vacancy thus created shall be filled for the unexpired term by the Board of Trustees.

Section 8. If any member at large of the Council should die or resign more than one year before the expiration of the term, the vacancy for the unexpired term shall be filled by the Society at the next annual meeting.

Section 9. In case any officer should die or decline to serve between the time of election and the time to assume office, the vacancy shall be filled in the same manner as if that officer had served one day of the term.

Article VIII

Members and Their Election

Section 1. Election of members shall be by vote of the Council or of its Executive Committee.

Section 2. There shall be four classes of members, namely, ordinary, contributing, corporate, and institutional.

Section 3. Application for admission to ordinary membership shall be made by the applicant on a blank provided

by the secretary. Such applications shall not be acted upon until at least thirty days after their presentation to the Council (at a meeting or by mail), except in the case of members of other societies entering under special action of the Council approved by the Board of Trustees.

Section 4. An ordinary member may become a contributing member by paying the dues for such membership. (See Article IX, Section 3.)

Section 5. A university or college, or a firm, corporation, or association interested in the support of mathematics may be elected a corporate or an institutional member.

Article IX

Dues and Privileges of Members

Section 1. Any applicant shall be admitted to ordinary membership immediately upon election by the Council (Article VIII) and the discharge within sixty days of election of the first annual dues. Dues may be discharged by payment or by remission when the provision of Section 7 of this Article is applicable. The first annual dues shall apply to the year of election, except that any applicant elected after August 15 of any year may elect to have the first annual dues apply to the following year.

Section 2. The annual dues of an ordinary member of the Society shall be established by the Council with the approval of the Trustees. The Council, with the approval of the Trustees, may establish special rates in exceptional cases and for members of an organization with which the Society has a reciprocity agreement.

Section 3. The minimum dues for a contributing member shall be three-halves of the dues of an ordinary member per year. Members may, upon their own initiative, pay larger dues.

Section 4. The minimum dues of an institutional member shall depend on the scholarly activity of that member. The formula for computing these dues shall be established from time to time by the Council, subject to approval by the Board of Trustees. Institutions may pay larger dues than the computed minimum.

Section 5. The privileges of an institutional member shall depend on its dues in a manner to be determined by the Council, subject to approval by the Board of Trustees. These privileges shall be in terms of Society publications to be received by the institution and of the number of persons it may nominate for ordinary membership in the Society.

Section 6. Dues and privileges of corporate members of the Society shall be established by the Council subject to approval by the Board of Trustees.

Section 7. The dues of an ordinary member of the Society shall be remitted for any years during which that member is the nominee of an institutional member.

Section 8. After retirement from active service on account of age or on account of long-term disability, any ordinary or contributing member who is not in arrears of dues and with membership extending over at least twenty years may, by giving proper notification to the secretary, have dues remitted. Such a member shall receive the *Notices* and may request to receive *Bulletin* as privileges of membership during each year until membership ends.

Section 9. An ordinary or contributing member shall receive the *Notices* and *Bulletin* as privileges of membership during each year for which dues have been discharged.

Section 10. The annual dues of ordinary, contributing, and corporate members shall be due by January 1 of the year to which they apply. The Society shall submit bills for dues. If the annual dues of any member remain undischarged beyond what the Board of Trustees deems to be a reasonable time, the name of that member shall be removed from the list of members after due notice. A member wishing to discontinue membership at any time shall submit a resignation in writing to the Society.

Section 11. An eligible member may become a life member by making a one-time payment of dues. The criteria for eligibility and the amount of dues shall be established by the Council, subject to approval by the Board of Trustees. A life member is subsequently relieved of the obligation of paying dues. The status and privileges are those of ordinary members.

An eligible member of the Society by reciprocity who asserts the intention of continuing to be a member by reciprocity may purchase a life membership by a one-time payment of dues. The criteria for eligibility and the amount of dues shall be established by the Council, subject to approval by the Board of Trustees.

Article X

Meetings

Section 1. The annual meeting of the Society shall be held between the fifteenth of December and the tenth of February next following. Notice of the time and place of this meeting shall be sent by the secretary or an associate secretary to each member of the Society. The times and places of the annual and other meetings of the Society shall be designated by the Council.

Section 2. There shall be a business meeting of the Society only at the annual meeting. The agenda for the business meeting shall be determined by the Council. A business meeting of the Society can take action only on items notified to the full membership of the Society in the call for the meeting. A business meeting can act on items recommended to it jointly by the Council and the Board of Trustees; a majority of members present and voting is required for passage of such an item. A business meeting of the Society can place action items on the agenda for a future business meeting. Final action on an item proposed by a previous business meeting can be taken only provided there is a quorum of 400 members, a majority of members at a business meeting with a quorum being required for passage of such an item.

Section 3. Meetings of the Executive Committee may be called by the president. The president shall call a meeting at any time upon the written request of two of its members.

Section 4. The Council shall meet at the annual meeting of the Society. Special meetings of the Council may be called by the president. The president shall call a special meeting at any time upon the written request of five of its members. No special meeting of the Council shall be held unless written notice of it shall have been sent to all

members of the Council at least ten days before the day set for the meeting.

Section 5. The Board of Trustees shall hold at least one meeting in each calendar year. Meetings of the Board of Trustees may be called by the president, the treasurer, or the secretary of the Society upon three days' notice of such meetings sent to each trustee. The secretary of the Society shall call a meeting upon the receipt of a written request of two of the trustees. Meetings may also be held by common consent of all the trustees.

Section 6. Papers intended for presentation at any meeting of the Society shall be passed upon in advance by a program committee appointed by or under the authority of the Council, and only such papers shall be presented as shall have been approved by such committee. Papers in form unsuitable for publication, if accepted for presentation, shall be referred to on the program as preliminary communications or reports.

Article XI

Publications

Section 1. The Society shall publish an official organ called the *Bulletin of the American Mathematical Society*. It shall publish four journals, known as the *Journal of the American Mathematical Society*, the *Transactions of the American Mathematical Society*, the *Proceedings of the American Mathematical Society*, and *Mathematics of Computation*. It shall publish a series of mathematical papers known as the *Memoirs of the American Mathematical Society*. The object of the *Journal*, *Transactions*, *Proceedings*, *Memoirs*, and *Mathematics of Computation* is to make known important mathematical researches. It shall publish a periodical called *Mathematical Reviews*, containing abstracts or reviews of current mathematical literature. It shall publish a series of volumes called *Colloquium Publications* which shall embody in book form new mathematical developments. It shall publish a series of monographs called *Mathematical Surveys and Monographs* which shall furnish expositions of the principal methods and results of particular fields of mathematical research. It shall publish a news periodical known as the *Notices of the American Mathematical Society*, containing programs of meetings, items of news of particular interest to mathematicians, and such other materials as the Council may direct.

Section 2. The editorial management of the publications of the Society listed in Section 1 of this article, with the exception of the *Notices*, shall be in the charge of the respective editorial committees as provided in Article III, Section 1. The editorial management of the *Notices* shall be in the hands of a committee chosen in a manner established by the Council.

Article XII

Indemnification

Any person who at any time serves or has served as a trustee or officer of the Society, or as a member of the Council, or, at the request of the Society, as a director or officer of another corporation, whether for profit or not for profit, shall be indemnified by the Society and be reimbursed against and for expenses actually and necessarily incurred in connection with the defense or reasonable settlement of any action, suit, legal or administrative proceeding, whether civil, criminal, administrative or investigative, threatened, pending or completed, to which that person is made a party by reason of being or having been such trustee, officer or director or Council member, except in relation to matters as to which the person shall be adjudged in such action, suit, or proceeding to be liable for negligence or misconduct in the performance of official duties. Such right of indemnification and reimbursement shall also extend to the personal representatives of any such person and shall be in addition to and not in substitution for any other rights to which such person or personal representatives may now or hereafter be entitled by virtue of the provisions of applicable law or of any other agreement or vote of the Board of Trustees, or otherwise.

Article XIII

Amendments

These bylaws may be amended or suspended on recommendation of the Council and with the approval of the membership of the Society, the approval consisting of an affirmative vote by two-thirds of the members present at a business meeting or of two-thirds of the members voting in a mail ballot in which at least ten percent of the members vote, whichever alternative shall have been designated by the Council, and provided notice of the proposed action and of its general nature shall have been given in the call for the meeting or accompanies the ballot in full.

As amended December 2003

AMS Lecturers, Officers, Prizes, and Funds

Colloquium Lecturers
James Pierpont, 1896
Maxime Bôcher, 1896
W. F. Osgood, 1898
A. G. Webster, 1898
Oskar Bolza, 1901
E. W. Brown, 1901
H. S. White, 1903
F. S. Woods, 1903
E. B. Van Vleck, 1903
E. H. Moore, 1906
E. J. Wilczynski, 1906
Max Mason, 1906
G. A. Bliss, 1909
Edward Kasner, 1909
L. E. Dickson, 1913
W. F. Osgood, 1913
G. C. Evans, 1916
Oswald Veblen, 1916
G. D. Birkhoff, 1920
F. R. Moulton, 1920
L. P. Eisenhart, 1925
Dunham Jackson, 1925
E. T. Bell, 1927
Anna Pell-Wheeler, 1927
A. B. Coble, 1928
R. L. Moore, 1929
Solomon Lefschetz, 1930
Marston Morse, 1931
J. F. Ritt, 1932
R. E. A. C. Paley, 1934
Norbert Wiener, 1934
H. S. Vandiver, 1935
E. W. Chittenden, 1936
John von Neumann, 1937
A. A. Albert, 1939
M. H. Stone, 1939
G. T. Whyburn, 1940
Oystein Ore, 1941
R. L. Wilder, 1942
E. J. McShane, 1943
Einar Hille, 1944
Tibor Radó, 1945
Hassler Whitney, 1946
Oscar Zariski, 1947
Richard Brauer, 1948
G. A. Hedlund, 1949
Deane Montgomery, 1951
Alfred Tarski, 1952
Antoni Zygmund, 1953
Nathan Jacobson, 1955
Salomon Bochner, 1956
N. E. Steenrod, 1957
J. L. Doob, 1959
S. S. Chern, 1960
G. W. Mackey, 1961
Saunders Mac Lane, 1963
C. B. Morrey, Jr., 1964
A. P. Calderón, 1965
Samuel Eilenberg, 1967
D. C. Spencer, 1968
J. W. Milnor, 1968
Raoul H. Bott, 1969
Harish-Chandra, 1969
R. H. Bing, 1970
Lipman Bers, 1971
Armand Borel, 1971
Stephen Smale, 1972
John T. Tate, 1972
M. F. Atiyah, 1973
E. A. Bishop, 1973
F. E. Browder, 1973
Louis Nirenberg, 1974
John G. Thompson, 1974
H. Jerome Keisler, 1975
Ellis R. Kolchin, 1975
Elias M. Stein, 1975
I. M. Singer, 1976
Jürgen K. Moser, 1976
William Browder, 1977
Herbert Federer, 1977
Hyman Bass, 1978
Philip A. Griffiths, 1979
George D. Mostow, 1979
Julia B. Robinson, 1980
Wolfgang M. Schmidt, 1980
Mark Kac, 1981
Serge Lang, 1981
Dennis Sullivan, 1982
Morris W. Hirsch, 1982
Charles L. Fefferman, 1983
Bertram Kostant, 1983
Barry Mazur, 1984
Paul H. Rabinowitz, 1984
Daniel Gorenstein, 1985
Karen K. Uhlenbeck, 1985
Shing-Tung Yau, 1986
Peter D. Lax, 1987
Edward Witten, 1987
Victor W. Guillemin, 1988
Nicholas Katz, 1989
William P. Thurston, 1989
Shlomo Sternberg, 1990
Robert D. MacPherson, 1991
Robert P. Langlands, 1992
Luis A. Caffarelli, 1993
Sergiu Klainerman, 1993
Jean Bourgain, 1994
Clifford H. Taubes, 1995
Andrew W. Wiles, 1996
Daniel W. Stroock, 1997
Gian-Carlo Rota, 1998
Helmut H. Hofer, 1999
Curtis T. McMullen, 2000
János Kollár, 2001
L. Craig Evans, 2002
Peter Sarnak, 2003
Sun-Yung Alice Chang, 2004
Robert K. Lazarsfeld, 2005
Hendrik W. Lenstra Jr., 2006
Andrei Okounkov, 2007
Wendelin Werner, 2008
Gregory Margulis, 2009
Richard P. Stanley, 2010
Alexander Lubotsky, 2011
Edward Frenkel, 2012
Alice Guionnet, 2013

Gibbs Lecturers
M. I. Pupin, 1923
Robert Henderson, 1924
James Pierpont, 1925
H. B. Williams, 1926
E. W. Brown, 1927
G. H. Hardy, 1928
Irving Fisher, 1929
E. B. Wilson, 1930
P. W. Bridgman, 1931
R. C. Tolman, 1932
Albert Einstein, 1934
Vannevar Bush, 1935
H. N. Russell, 1936
C. A. Kraus, 1937
Theodore von Kármán, 1939
Sewall Wright, 1941
Harry Bateman, 1943
John von Neumann, 1944
J. C. Slater, 1945
S. Chandrasekhar, 1946
P. M. Morse, 1947
Hermann Weyl, 1948
Norbert Wiener, 1949
G. E. Uhlenbeck, 1950
Kurt Gödel, 1951
Marston Morse, 1952
Wassily Leontief, 1953
K. O. Friedrichs, 1954
J. E. Mayer, 1955
M. H. Stone, 1956
H. J. Muller, 1958
J. M. Burgers, 1959
Julian Schwinger, 1960
J. J. Stoker, 1961
C. N. Yang, 1962
C. E. Shannon, 1963
Lars Onsager, 1964
D. H. Lehmer, 1965
Martin Schwarzschild, 1966
Mark Kac, 1967
E. P. Wigner, 1968
R. L. Wilder, 1969
W. H. Munk, 1970
E. F. F. Hopf, 1971
F. J. Dyson, 1972

J. K. Moser, 1973
Paul A. Samuelson, 1974
Fritz John, 1975
Arthur S. Wightman, 1976
Joseph B. Keller, 1977
Donald E. Knuth, 1978
Martin D. Kruskal, 1979
Kenneth G. Wilson, 1980
Cathleen Synge Morawetz, 1981
Elliott W. Montroll, 1982
Samuel Karlin, 1983
Herbert A. Simon, 1984
Michael O. Rabin, 1985
L. E. Scriven, 1986
Thomas C. Spencer, 1987
David P. Ruelle, 1988
Elliott H. Lieb, 1989
George B. Dantzig, 1990
Michael F. Atiyah, 1991
Michael E. Fisher, 1992
Charles S. Peskin, 1993
Robert M. May, 1994
Andrew J. Majda, 1995
Steven Weinberg, 1996
Persi Diaconis, 1997
Edward Witten, 1998
Nancy Kopell, 1999
Roger Penrose, 2000
Ronald L. Graham, 2001
Michael V. Berry, 2002
David B. Mumford, 2003
Eric Lander, 2004
Ingrid Daubechies, 2005
Michael Savageau, 2006
Peter D. Lax, 2007
Avi Wigderson, 2008
Percy Deift, 2009
Petre W. Shor, 2010
George Papanicolaou, 2011
Bradley Efron, 2012
Cédric Villani, 2013

Presidents
J. H. Van Amringe, 1889, 1890
J. E. McClintock, 1891-1894
G. W. Hill, 1895, 1896
Simon Newcomb, 1897, 1898
R. S. Woodward, 1899, 1900
E. H. Moore, 1901, 1902
T. S. Fiske, 1903, 1904
W. F. Osgood, 1905, 1906
H. S. White, 1907, 1908
Maxime Bôcher, 1909, 1910
H. B. Fine, 1911, 1912
E. B. Van Vleck, 1913, 1914
E. W. Brown, 1915, 1916
L. E. Dickson, 1917, 1918
Frank Morley, 1919, 1920
G. A. Bliss, 1921, 1922
Oswald Veblen, 1923, 1924
G. D. Birkhoff, 1925, 1926
Virgil Snyder, 1927, 1928
E. R. Hedrick, 1929, 1930
L. P. Eisenhart, 1931, 1932
A. B. Coble, 1933, 1934
Solomon Lefschetz, 1935, 1936
R. L. Moore, 1937, 1938
G. C. Evans, 1939, 1940
Marston Morse, 1941, 1942
M. H. Stone, 1943, 1944
T. H. Hildebrandt, 1945, 1946
Einar Hille, 1947, 1948
J. L. Walsh, 1949, 1950
John von Neumann, 1951, 1952
G. T. Whyburn, 1953, 1954
R. L. Wilder, 1955, 1956
Richard Brauer, 1957, 1958
E. J. McShane, 1959, 1960
Deane Montgomery, 1961, 1962
J. L. Doob, 1963, 1964
A. A. Albert, 1965, 1966
C. B. Morrey, Jr., 1967, 1968
Oscar Zariski, 1969, 1970
Nathan Jacobson, 1971, 1972
Saunders Mac Lane, 1973, 1974
Lipman Bers, 1975, 1976
R. H. Bing, 1977, 1978
Peter D. Lax, 1979, 1980
Andrew M. Gleason, 1981, 1982
Julia B. Robinson, 1983, 1984
Irving Kaplansky, 1985, 1986
George Daniel Mostow, 1987, 1988
William Browder, 1989, 1990
Michael Artin, 1991, 1992
Ronald L. Graham, 1993, 1994
Cathleen Synge Morawetz, 1995, 1996
Arthur M. Jaffe, 1997, 1998
Felix E. Browder, 1999, 2000
Hyman Bass, 2001, 2002
David Eisenbud, 2003, 2004
James G. Arthur, 2005, 2006
James G. Glimm, 2007, 2008
George E. Andrews, 2009, 2010
Eric M. Friedlander, 2011, 2012
David A. Vogan Jr., 2013, 2014

Secretaries
T. S. Fiske, 1888-1895
F. N. Cole, 1896-1920
R. G. D. Richardson, 1921-1940
J. R. Kline, 1941-1950
E. G. Begle, 1951-1956
J. W. Green, 1957-1966
Everett Pitcher, 1967-1988
Robert M. Fossum, 1989-1998
Robert J. Daverman, 1999-2012
Carla D. Savage, 2013-

Treasurers
T. S. Fiske, 1890, 1891
Harold Jacoby, 1892-1894
R. S. Woodward, 1895, 1896
Harold Jacoby, 1897-1899
W. S. Dennett, 1900-1907
J. H. Tanner, 1908-1920
W. B. Fite, 1921-1929
G. W. Mullins, 1930-1936
P. A. Smith, 1937
B. P. Gill, 1938-1948
A. E. Meder, Jr., 1949-1964
W. T. Martin, 1965-1973
Franklin P. Peterson, 1974-1998
John M. Franks, 1999-2010
Jane M. Hawkins, 2011-

Prizes

The George David Birkhoff Prize in Applied Mathematics

This prize was established in 1967 in honor of Professor George David Birkhoff. The initial endowment was contributed by the Birkhoff family and there have been subsequent additions by others. It is awarded to a member of either the AMS or SIAM for an outstanding contribution to "applied mathematics in the highest and broadest sense." Currently, the prize amount is US$5,000, and it is awarded every three years. The award is made jointly by the American Mathematical Society and the Society for Industrial and Applied Mathematics.

First award, 1968: To Jürgen K. Moser for his contributions to the theory of Hamiltonian dynamical systems, especially his proof of the stability of periodic solutions of Hamiltonian systems having two degrees of freedom and his specific applications of the ideas in connection with this work.

Second award, 1973: To Fritz John for his outstanding work in partial differential equations, in numerical analysis, and, particularly, in nonlinear elasticity theory; the latter work has led to his study of quasi–isometric mappings as well as functions of bounded mean oscillation, which have had impact in other areas of analysis.

Third award, 1973: To James B. Serrin for his fundamental contributions to the theory of nonlinear partial differential equations, especially his work on existence and regularity theory for nonlinear elliptic equations, and applications of his work to the theory of minimal surfaces in higher dimensions.

Fourth award, 1978: To Garrett Birkhoff for bringing the methods of algebra and the highest standards of mathematics to scientific applications.

Fifth award, 1978: To Mark Kac for his important contributions to statistical mechanics and to probability theory and its applications.

Sixth award, 1978: To Clifford A. Truesdell for his outstanding contributions to our understanding of the subjects of rational mechanics and nonlinear materials, for his efforts to give precise mathematical formulation to these classical subjects, for his many contributions to applied mathematics in the fields of acoustic theory, kinetic theory, and nonlinear elastic theory, and the thermodynamics of mixtures, and for his major work in the history of mechanics.

Seventh award, 1983: To Paul R. Garabedian for his important contributions to partial differential equations, to the mathematical analysis of problems of transonic flow and airfoil design by the method of complexification, and to the development and application of scientific computing to problems of fluid dynamics and plasma physics.

Eighth award, 1988: To Elliott H. Lieb for his profound analysis of problems arising in mathematical physics.

Ninth award, 1994: To Ivo Babuška for important contributions to the reliability of finite element methods, the development of a general framework for finite element error estimation, and the development of p and h-p finite element methods; and to S. R. S. Varadhan for important contributions to the martingale characterization of diffusion processes, to the theory of large deviations for functionals of occupation times of Markov processes, and to the study of random media.

Tenth award, 1998: To Paul H. Rabinowitz for his deep influence on the field of nonlinear analysis.

Eleventh award, 2003: To John Mather for being a mathematician of exceptional depth, power, and originality; and to Charles S. Peskin for devoting much of his career to understanding the dynamics of the human heart and bringing an extraordinarily broad range of expertise to bear on this problem.

Twelfth award, 2006: To Cathleen Synge Morawetz for her deep and influential work in partial differential equations, most notably in the study of shock waves, transonic flow, scattering theory, and conformally invariant estimates for the wave equation.

Thirteenth award, 2009: To Joel Smoller for his leadership, originality, depth, and breadth of work in dynamical systems, differential equations, mathematical biology, shock wave theory, and general relativity.

Fourteenth award, 2012: To Bjorn Engquist for his contributions to a wide range of powerful computational methods over more than three decades.

Next award: January 2015

The Bôcher Memorial Prize

This prize, the first to be offered by the AMS, was founded in memory of Professor Maxime Bôcher, who served as president of the AMS 1909–1910. The original endowment was contributed by members of the Society. It is awarded for a notable paper in analysis published during the preceding six years. To be eligible, the author should be a member of the American Mathematical Society or the paper should have been published in a recognized North American journal. Currently, the US$5,000 prize is awarded every three years.

First (preliminary) award, 1923: To G. D. Birkhoff for his memoir *Dynamical systems with two degrees of freedom*. Transactions of the American Mathematical Society **18** (1917), pp. 199–300.

Second award, 1924: To E. T. Bell for his memoir *Arithmetical paraphrases. I, II*, Transactions of the American Mathematical Society **22** (1921), pp. 1–30, 198–219; and to Solomon Lefschetz for his memoir *On certain numerical invariants with applications to Abelian varieties*, Transactions of the American Mathematical Society **22** (1921), pp. 407–482.

Third award, 1928: To J. W. Alexander for his memoir *Combinatorial analysis situs*, Transactions of the American Mathematical Society **28** (1926), pp. 301–329.

Fourth award, 1933: To Marston Morse for his memoir *The foundations of a theory of the calculus of variations in the large in m-space*, Transactions of the American Mathematical Society **31** (1929), pp. 379–404; and to Norbert Wiener for his memoir, *Tauberian theorems*, Annals of Mathematics, Series 2, **33** (1932), pp. 1–100.

Fifth award, 1938: To John von Neumann for his memoir *Almost periodic functions and groups. I, II*, Transactions of the American Mathematical Society **36** (1934), pp. 445–492; and **37** (1935), pp. 21–50.

Sixth award, 1943: To Jesse Douglas for his memoirs *Green's function and the problem of Plateau*, American Journal of Mathematics **61** (1939), pp. 545–589; *The most general form of the problem of Plateau*, American Journal of Mathematics **61** (1939), pp. 590–608; and *Solution of the inverse problem of the calculus of variations*, Proceedings of the National Academy of Sciences **25** (1939), pp. 631–637.

Seventh award, 1948: To A. C. Schaeffer and D. C. Spencer for their memoir *Coefficients of schlicht functions. I, II, III, IV*, Duke Mathematical Journal **10** (1943), pp. 611–635; **12** (1945), pp. 107–125; and the Proceedings of the National Academy of Sciences **32** (1946), pp. 111–116; **35** (1949), pp. 143–150.

Eighth award, 1953: To Norman Levinson for his contributions to the theory of linear, nonlinear, ordinary, and partial differential equations contained in his papers of recent years.

Ninth award, 1959: To Louis Nirenberg for his work in partial differential equations.

Tenth award, 1964: To Paul J. Cohen for his paper *On a conjecture of Littlewood and idempotent measures*, American Journal of Mathematics **82** (1960), pp. 191–212.

Eleventh award, 1969: To I. M. Singer in recognition of his work on the index problem, especially his share in two

joint papers with Michael F. Atiyah, *The index of elliptic operators. I, III*, Annals of Mathematics, Series 2, **87** (1968), pp. 484–530, 546–604.

Twelfth award, 1974: To Donald S. Ornstein in recognition of his paper *Bernoulli shifts with the same entropy are isomorphic*, Advances in Mathematics **4** (1970), pp. 337–352.

Thirteenth award, 1979: To Alberto P. Calderón in recognition of his fundamental work on the theory of singular integrals and partial differential equations, and in particular for his paper *Cauchy integrals on Lipschitz curves and related operators*, Proceedings of the National Academy of Sciences, USA, **74** (1977), pp. 1324–1327.

Fourteenth award, 1984: To Luis A. Caffarelli for his deep and fundamental work in nonlinear partial differential equations, in particular his work on free boundary problems, vortex theory, and regularity theory.

Fifteenth award, 1984: To Richard B. Melrose for his solution of several outstanding problems in diffraction theory and scattering theory and for developing the analytical tools needed for their resolution.

Sixteenth award, 1989: To Richard M. Schoen for his work on the application of partial differential equations to differential geometry, in particular his completion of the solution to the Yamabe Problem in *Conformal deformation of a Riemannian metric to constant scalar curvature*, Journal of Differential Geometry **20** (1984), pp. 479–495.

Seventeenth award, 1994: To Leon Simon for his profound contributions toward understanding the structure of singular sets for solutions of variational problems.

Eighteenth award, 1999: To Demetrios Christodoulou for his contributions to the mathematical theory of general relativity, to Sergiu Klainerman for his contributions to nonlinear hyperbolic equations, and to Thomas Wolff for his work in harmonic analysis.

Nineteenth award, 2002: To Daniel Tataru for his fundamental paper *On global existence and scattering for the wave maps equations*, Amer. Jour. Math. **123** (2001), no. 1, pp. 37–77; and to Terence Tao for his recent fundamental breakthrough on the problem of critical regularity in Sobolev spaces of the wave maps equations, *Global regularity of wave maps I. Small critical Sobolev norm in high dimensions*, Int. Math. Res. Notices (2001), no. 6, pp. 299–328, and *Global regularity of wave maps II. Small energy in two dimensions*, to appear in Comm. Math. Phys. (2001) no. 2, pp. 443–544; and to Fanghua Lin for his fundamental contributions to our understanding of the Ginzburg-Landau (GL) equations with a small parameter.

Twentieth award, 2005: To Frank Merle for his fundamental work in the analysis of nonlinear dispersive equations.

Twenty-first award, 2008: To Alberto Bressan for his fundamental works on hyperbolic conservation laws; and to Charles Fefferman for his many fundamental contributions to different areas of analysis; and to Carlos Kenig for his important contributions to harmonic analysis, partial differential equations, and nonlinear dispersive PDE.

Twenty-second award, 2011: To Gunther Uhlmann for his fundamental work on inverse problems; and to Assaf Naor for introducing new invariants of metric spaces and for applying his new understanding of the distortion between various metric structures to theoretical computer science.

Next award: January 2014.

The Frank Nelson Cole Prize in Algebra

This prize (and the Frank Nelson Cole Prize in Number Theory) was founded in honor of Professor Frank Nelson Cole on the occasion of his retirement as secretary of the American Mathematical Society after twenty-five years of service and as editor-in-chief of the *Bulletin* for twenty-one years. The original fund was donated by Professor Cole from moneys presented to him on his retirement and was augmented by contributions from members of the Society. The fund was later doubled by his son, Charles A. Cole. The prize is for a notable paper in algebra published during the preceding six years. To be eligible, the author should be a member of the American Mathematical Society or the paper should have been published in a recognized North American journal. Currently, the US$5,000 prize is awarded every three years.

First award, 1928: To L. E. Dickson for his book *Algebren und ihre Zahlentheorie*, Orell Füssli, Zürich and Leipzig, 1927.

Second award, 1939: To A. Adrian Albert for his papers on the construction of Riemann matrices published in the Annals of Mathematics, Series 2, **35** (1934) and **36** (1935).

Third award, 1944: To Oscar Zariski for four papers on algebraic varieties published in the American Journal of Mathematics **61** (1939) and **62** (1940), and in the Annals of Mathematics, Series 2, **40** (1939) and **41** (1940).

Fourth award, 1949: To Richard Brauer for his paper *On Artin's L-series with general group characters*, Annals of Mathematics, Series 2, **48** (1947), pp. 502–514.

Fifth award, 1954: To Harish–Chandra for his papers on representations of semisimple Lie algebras and groups, and particularly for his paper *On some applications of the universal enveloping algebra of a semisimple Lie algebra*, Transactions of the American Mathematical Society **70** (1951), pp. 28–96.

Sixth award, 1960: To Serge Lang for his paper *Unramified class field theory over function fields in several variables*, Annals of Mathematics, Series 2, **64** (1956), pp. 285–325; and to Maxwell A. Rosenlicht for his papers *Generalized Jacobian varieties*, Annals of Mathematics, Series 2, **59** (1954), pp. 505–530, and *A universal mapping property of generalized Jacobians*, Annals of Mathematics, Series 2, **66** (1957), pp. 80–88.

Seventh award, 1965: To Walter Feit and John G. Thompson for their joint paper *Solvability of groups of odd order*, Pacific Journal of Mathematics **13** (1963), pp. 775–1029.

Eighth award, 1970: To John R. Stallings for his paper *On torsion-free groups with infinitely many ends*, Annals of Mathematics, Series 2, **88** (1968), pp. 312–334; and to Richard G. Swan for his paper *Groups of cohomological dimension one*, Journal of Algebra **12** (1969), pp. 585–610.

Ninth award, 1975: To Hyman Bass for his paper *Unitary algebraic K-theory*, Springer Lecture Notes in Mathematics 343, 1973; and to Daniel G. Quillen for his

paper *Higher algebraic K-theories*, Springer Lecture Notes in Mathematics 341, 1973.

Tenth award, 1980: To Michael Aschbacher for his paper *A characterization of Chevalley groups over fields of odd order*, Annals of Mathematics, Series 2, **106** (1977), pp. 353–398; and to Melvin Hochster for his paper *Topics in the homological theory of commutative rings*, CBMS Regional Conference Series in Mathematics, Number 24, American Mathematical Society, 1975.

Eleventh award, 1985: To George Lusztig for his fundamental work on the representation theory of finite groups of Lie type. In particular for his contributions to the classification of the irreducible representations in characteristic zero of the groups of rational points of reductive groups over finite fields, appearing in *Characters of Reductive Groups over Finite Fields*, Annals of Mathematics Studies 107, Princeton University Press, 1984.

Twelfth award, 1990: To Shigefumi Mori for his outstanding work on the classification of algebraic varieties and, in particular, for his paper *Flip theorem and the existence of minimal models for 3-folds*, Journal of the American Mathematical Society **1** (1988), pp. 117–253.

Thirteenth award, 1995: To Michel Raynaud and David Harbater for their solution of Abhyankar's conjecture. This work appeared in the papers *Revêtements de la droite affine en caractéristique $p > 0$*, Invent. Math. **116** (1994), pp. 425–462 (Raynaud); and *Abhyankar's conjecture on Galois groups over curves*, Invent. Math. **117** (1994), pp. 1–25 (Harbater).

Fourteenth award, 2000: To Andrei Suslin for his work on motivic cohomology, and to Aise Johan de Jong for his important work on the resolution of singularities by generically finite maps.

Fifteenth award, 2003: To Hiraku Nakajima for his work in representation theory and geometry.

Sixteenth award, 2006: To János Kollár for his outstanding achievements in the theory of rationally connected varieties and for his illuminating work on a conjecture of Nash.

Seventeenth award, 2009: To Christopher Hacon and James McKernan for their groundbreaking joint work on higher-dimensional birational algebraic geometry.

Eighteenth award, 2012: To Alexander S. Merkurjev for his work on the essential dimension of groups.

Next award: January 2015.

The Frank Nelson Cole Prize in Number Theory

This prize (and the Frank Nelson Cole Prize in Algebra) was founded in honor of Professor Frank Nelson Cole on the occasion of his retirement as secretary of the American Mathematical Society after twenty-five years of service and as editor-in-chief of the *Bulletin* for twenty-one years. The original fund was donated by Professor Cole from moneys presented to him on his retirement and was augmented by contributions from members of the Society. The fund was later doubled by his son, Charles A. Cole. The prize is for a notable paper in number theory published during the preceding six years. To be eligible, the author should be a member of the American Mathematical Society or the paper should have been published in a recognized North American journal. Currently, the US$5,000 prize is awarded every three years.

First award, 1931: To H. S. Vandiver for his several papers on Fermat's last theorem published in the *Transactions of the American Mathematical Society* and in the *Annals of Mathematics* during the preceding five years, with special reference to a paper entitled *On Fermat's last theorem*, Transactions of the American Mathematical Society 31 (1929), pp.-613–642.

Second award, 1941: To Claude Chevalley for his paper *La théorie du corps de classes*, Annals of Mathematics, Series 2, 41 (1940), pp.-394–418.

Third award, 1946: To H. B. Mann for his paper *A proof of the fundamental theorem on the density of sums of sets of positive integers*, Annals of Mathematics, Series 2, 43 (1942), pp.-523–527.

Fourth award, 1951: To Paul Erdős for his many papers in the theory of numbers, and in particular for his paper *On a new method in elementary number theory which leads to an elementary proof of the prime number theorem*, Proceedings of the National Academy of Sciences 35 (1949), pp.-374–385.

Fifth award, 1956: To John T. Tate for his paper *The higher dimensional cohomology groups of class field theory*, Annals of Mathematics, Series 2, **56** (1952), pp. 294–297.

Sixth award, 1962: To Kenkichi Iwasawa for his paper *Gamma extensions of number fields*, Bulletin of the American Mathematical Society **65** (1959), pp. 183–226; and to Bernard M. Dwork for his paper *On the rationality of the zeta function of an algebraic variety*, American Journal of Mathematics **82** (1960), pp. 631–648.

Seventh award, 1967: To James B. Ax and Simon B. Kochen for a series of three joint papers: *Diophantine problems over local fields. I, II, III*, American Journal of Mathematics **87** (1965), pp. 605–630, 631–648; and Annals of Mathematics, Series 2, **83** (1966), pp. 437–456.

Eighth award, 1972: To Wolfgang M. Schmidt for the following papers: *On simultaneous approximation of two algebraic numbers by rationals*, Acta Mathematica (Uppsala) **119** (1967), pp. 27–50; *T-numbers do exist*, Symposia Mathematica, IV, Academic Press, 1970, pp. 1–26; *Simultaneous approximation to algebraic numbers by rationals*, Acta Mathematica (Uppsala) **125** (1970), pp. 189–201; *On Mahler's T-numbers*, Proceedings of Symposia in Pure Mathematics 20, American Mathematical Society, 1971, pp. 275–286.

Ninth award, 1977: To Goro Shimura for his two papers *Class fields over real quadratic fields and Heche operators*, Annals of Mathematics, Series 2, **95** (1972), pp. 130–190; and *On modular forms of half integral weight*, Annals of Mathematics, Series 2, **97** (1973), pp. 440–481.

Tenth award, 1982: To Robert P. Langlands for pioneering work on automorphic forms, Eisenstein series and product formulas, particularly for his paper *Base change for GL(2)*, Annals of Mathematics Studies 96, Princeton University Press, 1980; and to Barry Mazur for outstanding work on elliptic curves and Abelian varieties, especially on rational points of finite order, and his paper *Modular curves and the Eisenstein ideal*, Publications Mathematiques

de l'Institut des Hautes Études Scientifiques **47** (1977), pp. 33–186.

Eleventh award, 1987: To Dorian M. Goldfeld for his paper *Gauss's class number problem for imaginary quadratic fields*, Bulletin of the American Mathematical Society **13** (1985), pp. 23–37; and to Benedict H. Gross and Don B. Zagier for their paper *Heegner points and derivatives of L-series*, Inventiones Mathematicae **84** (1986), pp. 225–320.

Twelfth award, 1992: To Karl Rubin for his work in the area of elliptic curves and Iwasawa theory, with particular reference to his papers *Tate-Shafarevich groups and L-functions of elliptic curves with complex multiplication* and *The "main conjectures" of Iwasawa theory for imaginary quadratic fields;* and to Paul Vojta for his work on Diophantine problems, with particular reference to his paper *Siegel's theorem in the compact case*.

Thirteenth award, 1997: To Andrew J. Wiles for his work on the Shimura-Taniyama conjecture and Fermat's Last Theorem, published in *Modular elliptic curves and Fermat's Last Theorem*, Ann. of Math. 141 (1995), pp. 443–551.

Fourteenth award, 2002: To Henryk Iwaniec for his fundamental contributions to analytic number theory, and to Richard Taylor for several outstanding advances in algebraic number theory.

Fifteenth award, 2005: To Peter Sarnak for his fundamental contributions to number theory and in particular his book *Random Matrices, Frobenius Eigenvalues and Monodromy*, written jointly with his Princeton colleague Nicholas Katz.

Sixteenth award, 2008: To Manjul Bhargava for his revolutionary work on higher composition laws.

Seventeenth award, 2011: To Chandrashekhar Khare and Jean-Pierre Wintenberger for their remarkable proof of Serre's modularity conjecture.

Next award: January 2014.

The Levi L. Conant Prize

This prize was established in 2000 in honor of Levi L. Conant to recognize the best expository paper published in either the *Notices of the AMS* or the *Bulletin of the AMS* in the preceding five years. Levi L. Conant was a mathematician at Worcester Polytechnic Institute. His will provided for funds to be donated to the AMS upon his wife's death. The US$1,000 prize is awarded annually.

First award, 2001: To Carl Pomerance for his paper "A tale of two sieves", *Notices of the AMS* **43**, no. 12 (1996), pp. 1473–1485.

Second award, 2002: To Elliott H. Lieb and Jakob Yngvason for their article "A guide to entropy and the Second Law of Thermodynamics", *Notices of the AMS* **45**, no. 5 (1998), pp. 571–581.

Third award, 2003: To Nicholas Katz and Peter Sarnak for their expository paper "Zeroes of zeta functions and symmetry", *Bulletin of the AMS* **36** (1999), pp. 1–26.

Fourth award, 2004: To Noam D. Elkies for his enlightening two-part article "Lattices, linear codes, and invariants", *Notices of the AMS* **47**, no. 10 (2000), Part I, pp. 1238–1245; no. 11, Part II, pp. 1382–1391.

Fifth award, 2005: To Allen Knutson and Terence Tao for their stimulating article "Honeycombs and sums of Hermitian matrices", *Notices of the AMS* **48**, no. 2 (2001), pp. 175–186.

Sixth award, 2006: To Ronald Solomon for his article "A brief history of the classification of the finite simple groups", *Bulletin of the AMS* **38** (2001), no. 3, 315–352.

Seventh award, 2007: To Jeffrey Weeks for his article "The Poincare dodecahedral space and the mystery of the missing fluctuations," *Notices of the AMS* **51** (2004) no. 6, 610–619.

Eighth award, 2008: To J. Brian Conrey for his article "The Riemann Hypothesis", *Notices of the AMS* **50** (2003) no. 3, 341-353; and to Shlomo Hoory, Nathan Linial, and Avi Wigderson for their article "Expander graphs and their applications", *Bulletin of the AMS* **43** (2006), no. 4, 439-561.

Ninth award, 2009: To Jeffrey Weeks for his article "The Poincaré dodecahedral space and the mystery of the missing fluctuations", *Notices of the AMS* **51** (2004) no. 6, 610-619.

Ninth award, 2009: To Jeffrey Weeks for his article "The Poincaré dodecahedral space and the mystery of the missing fluctuations", *Notices of the AMS* **51** (2004) no. 6, 610-619.

Tenth award, 2010: To Bryna Kra for her article, "The Green-Tao Theorem on arithmetic progressions in the primes: An ergodic point of view", *Bull. Amer. Math. Soc. (N.S.)* **43** (2006), no. 1, 3–23.

Eleventh award, 2011: To David Vogan for his article, "The character table for E8", *Notices of the AMS* **54** (2007), no. 9, 1122-1134.

Twelfth award, 2012: To Perci Diaconis for his article, "The Markov chain Monte Carlo revolution", *Bulletin Amer. Math. Soc.* **46** (2009), no. 2, 179-205.

Thirteenth award, 2013: To John Baez and John Huerta for their article, "The algebra of grand unified theories", *Bulletin Amer. Math. Soc.* **47** (2010), no. 3, 483–552.

Next award: January 2014.

Joseph L. Doob Prize

This prize was established by the AMS in 2003 to recognize a single, relatively recent, outstanding research book that makes a seminal contribution to the research literature, reflects the highest standards of research exposition, and promises to have a deep and long-term impact in its area. The book must have been published within the six calendar years preceding the year in which it is nominated. Books may be nominated by members of the Society, by members of the selection committee, by members of AMS editorial committees, or by publishers. The US$5,000 prize is awarded every three years.

The prize (originally called the Book Prize) was endowed in 2005 by Paul and Virginia Halmos and renamed in honor of Joseph L. Doob. Paul Halmos (Professor Emeritus at Santa Clara University) was Doob's first Ph.D. student. Doob received his Ph.D. from Harvard in 1932 and three years later joined the faculty at the University of Illinois, where he remained until his retirement in 1978. He worked in probability theory and measure theory, served as AMS president in 1963–1964, and received the AMS

Steele Prize in 1984 "for his fundamental work in establishing probability as a branch of mathematics." Doob passed away on June 7, 2004, at the age of ninety-four.

First award, 2005: To William P. Thurston for his book *Three-Dimensional Geometry and Topology*, edited by Silvio Levy.

Second award, 2008: To Enrico Bombieri and Walter Gubler for their book *Heights in Diophantine Geometry* (Cambridge University Press, 2006).

Third award, 2011: To Peter Kronheimer and Tomasz Mrowka for their book *Monopoles and Three-Manifolds* (Cambridge University Press, 2007).

Next award: January 2014.

Leonard Eisenbud Prize for Mathematics and Physics

This prize was established in 2006 in memory of the mathematical physicist, Leonard Eisenbud (1913–2004), by his son and daughter-in-law, David and Monika Eisenbud. Leonard Eisenbud was a student of Eugene Wigner. He was particularly known for the book, *Nuclear Structure* (1958), which he co-authored with Wigner. A friend of Paul Erdős, he once threatened to write a dictionary of "English to Erdős and Erdős to English." He was one of the founders of the Physics Department at SUNY Stony Brook, where he taught from 1957 until his retirement in 1983. In later years he became interested in the foundations of quantum mechanics and in the interaction of physics with culture and politics, teaching courses on the anti-science movement. His son, David, was President of the American Mathematical Society 2003–2004.

The prize will honor a work or group of works that brings the two fields closer together. Thus, for example, the prize might be given for a contribution to mathematics inspired by modern developments in physics or for the development of a physical theory exploiting modern mathematics in a novel way.

The US$5,000 prize will be awarded every three years for a work published in the preceding six years.

First award, 2008: To Hirosi Ooguri, Andrew Strominger, and Cumrun Vafa for their paper "Black hole attractors and the topological string", *Physical Review D* (3) **70** (2004), 106007.

Second award, 2011: To Herbert Spohn for his group of works on stochastic growth processes.

Next award: January 2014.

The Delbert Ray Fulkerson Prize

The Fulkerson Prize for outstanding papers in the area of discrete mathematics is sponsored jointly by the Mathematical Programming Society (MPS) and the American Mathematical Society (AMS). Up to three awards of US$1,500 each are presented at each (triennial) International Symposium of the MPS. Originally, the prizes were paid out of a memorial fund administered by the AMS that was established by friends of the late Delbert Ray Fulkerson to encourage mathematical excellence in the fields of research exemplified by his work. The prizes are now funded by an endowment administered by the MPS.

First award, 1979: To Richard M. Karp for *On the computational complexity of combinatorial problems*, Networks, **5** (1975), pp. 45–68; to Kenneth Appel and Wolfgang Haken for *Every planar map is four colorable*, Part I: *Discharging*, Illinois Journal of Mathematics **21** (1977), pp. 429–490; and to Paul D. Seymour for *The matroids with the max-flow min-cut property*, Journal of Combinatorial Theory, Series B, **23** (1977), pp. 189–222.

Second award, 1982: To D. B. Judin and A. S. Nemirovskii for *Informational complexity and effective methods of solution for convex extremal problems*, Ekonomika i Matematicheskie Metody **12** (1976), pp. 357–369; to L. G. Khachiyan for *A polynomial algorithm in linear programming*, Akademiia Nauk SSSR. Doklady **244** (1979), pp. 1093–1096; to G. P. Egorychev for *The solution of van der Waerden's problem for permanents*, Akademiia Nauk SSSR. Doklady **258** (1981), pp. 1041–1044; D. I. Falikman for *A proof of the van der Waerden conjecture on the permanent of a doubly stochastic matrix*, Matematicheskie Zametki **29** (1981), pp. 931–938; and to M. Grötschel, L. Lovasz, and A. Schrijver for *The ellipsoid method and its consequences in combinatorial optimization*, Combinatorica **1** (1981), pp. 169–197.

Third award, 1985: To Jozsef Beck, for *Roth's estimate of the discrepancy of integer sequences is nearly sharp*, Combinatorica **1** (4) (1981), pp. 319–325; to H. W. Lenstra Jr. for *Integer programming with a fixed number of variables*, Mathematics of Operations Research **8** (4) (1983), pp. 538–548; and to Eugene M. Luks for *Isomorphism of graphs of bounded valence can be tested in polynomial time*, Journal of Computer and System Sciences **25** (1) (1982), pp. 42–65.

Fourth award, 1988: To Éva Tardos for *A strongly polynomial minimum cost circulation algorithm*, Combinatorica **5** (1985), pp. 247–256; and to Narendra Karmarkar for *A new polynomial-time algorithm for linear programming*, Combinatorica **4** (1984), pp. 373–395.

Fifth award, 1991: To Martin Dyer, Alan Frieze, and Ravi Kannan for *A random polynomial time algorithm for approximating the volume of convex bodies*, Journal of the Association for Computing Machinery **38**/1 (1991), pp. 1–17; to Alfred Lehman for *The width-length inequality and degenerate projective planes*, W. Cook and P. D. Seymour (eds.), *Polyhedral Combinatorics*, DIMACS Series in Discrete Mathematics and Theoretical Computer Science 1, American Mathematical Society, 1990, pp. 101–105; and to Nikolai E. Mnev for *The universality theorems on the classification problem of configuration varieties and convex polytope varieties*, O. Ya. Viro (ed.), *Topology and Geometry–Rohlin Seminar*, Lecture Notes in Mathematics 1346, Springer–Verlag, Berlin, 1988, pp. 527–544.

Sixth Award, 1994: To Lou Billera for *Homology of smooth splines: Generic triangulations and a conjecture of Strang*, Transactions of the AMS **310** (1988), pp. 325–340; to Gil Kalai for *Upper bounds for the diameter and height of graphs of the convex polyhedra*, Discrete and Computational Geometry **8** (1992), pp. 363–372; and to Neil Robertson, Paul D. Seymour, and Robin Thomas for *Hadwiger's conjecture for K6; free graphs*, Combinatorica **13** (1993), pp. 279–361.

Seventh award, 1997: To Jeong Han Kim for *The Ramsey number $R(3,t)$ has order of magnitude*, which appeared in

Random Structures and Algorithms **7** (1995) no. 3, pp. 173–207.

Eighth award, 2000: To Michel X. Goemans and David P. Williamson for *Improved approximation algorithms for the maximum cut and satisfiability problems using semi-definite programming*, Journal of the Association for Computing Machinery **42** (1995), no. 6, pp. 1115–1145; and to Michele Conforti, Gerard Cornuejols, and M. R. Rao for *Decomposition of balanced matrices*, Journal of Combinatorial Theory, Series B **77** (1999), no. 2, pp. 292–406.

Ninth award, 2003: To J. F. Geelen, A. M. H. Gerards, and A. Kapoor for *The excluded minors for GF(4)-representable matroids*, Journal of Combinatorial Theory Series B, **79** (2000), no. 2, pp. 247–299; to Bertrand Guenin for *A characterization of weakly bipartite graphs*, Journal of Combinatorial Theory Series B, **83** (2001), no. 1, pp. 112–168; to Satoru Iwata, Lisa Fleischer, and Satoru Fujishige for *A combinatorial strongly polynomial algorithm for minimizing submodular functions*, Journal of the ACM, **48** (July 2001), no. 4, pp. 761–777; and to Alexander Schrijver for *A combinatorial algorithm minimizing submodular functions in strongly polynomial time,* Journal of Combinatorial Theory, Series B, **80** (2000), no. 2, pp. 346–355.

Tenth award, 2006: To Manindra Agrawal, Neeraj Kayal and Nitin Saxena, *PRIMES is in P*, Annals of Mathematics, Volume 160, issue 2, 2004, Pp. 781–793; and to Mark Jerrum, Alistair Sinclair and Eric Vigoda, *A polynomial-time approximation algorithm for the permanent of a matrix with nonnegative entries*, J. ACM, Volume 51, Issue 4, 2004, pp. 671–697; and to Neil Robertson and Paul D. Seymour, *Graph Minors. XX. Wagner's conjecture*, Journal of Combinatorial Theory, Series B, **92** (2004), no. 2, pp. 325–357.

Eleventh award, 2009: To M. Chudnovsky, N. Robertson, P. Seymour, and R. Thomas, *The strong perfect graph theorem*, Annals of Mathematics **164** (2006) 51-229; and to D. A. Spielman and S.-H. Teng, *Smoothed analysis of algorithms: Why the simplex algorithm usually takes polynomial time*, Journal of ACM **51** (2004) 385-463; and to Thomas C. Hales, *A proof of the Kepler conjecture*, Annals of Mathematics **162** (2005) 1063-1183; and to Samuel P. Ferguson, *Sphere Packings, V. Pentahedral Prisms*, Discrete and Computational Geometry **33** (2006) 167-204.

Twelfth award, 2012: Sanjeev Arora, Satish Rao, and Umesh Vazirani for improving the approximation ratio for graph separators and related problems from $O(\log n)$ to .

Anders Johansson, Jeff Kahn, and Van H. Vu for determining the threshold of edge density above which a random graph can be covered by disjoint copies of a given smaller graph.

László Lovász and Balázs Szegedy for characterizing subgraph multiplicity in sequences of dense graphs.

Next award: August 2015.

E. H. Moore Research Article Prize

This prize was established in 2002 in honor of E. H. Moore. Among other activities, Moore founded the Chicago branch of the American Mathematical Society, served as the Society's sixth president (1901–1902), delivered the Colloquium Lectures in 1906, and founded and nurtured the *Transactions of the AMS*. The US$5,000 prize will be awarded every three years for an outstanding research article to have appeared 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 *Electronic Journal of Representation Theory*) during the six calendar years ending a full year before the meeting at which the prize is awarded.

First award, 2004: To Mark Haiman for *Hilbert schemes, polygraphs, and the Macdonald positivity conjecture*, Journal of the AMS **14** (2001), pp. 941–1006.

Second award, 2007: To Ivan Shestakov and Ualbai Umirbaev for their two ground-breaking papers, both published in the Journal of the American Mathematical Society: *The tame and the wild automorphisms of polynomial rings in three variables*, **17** (2004), no. 1, 197–227; and *Poisson brackets and two-generated subalgebras of rings of polynomials*, **17** (2004), no. 1, 181–196.

Third award, 2010: To Sorin Popa for his article "On the superrigidity of malleable actions with spectral gap", *J. Amer. Math. Soc.* **21** (2008), no. 4, 981–1000.

Fourth award, 2013: To Michael Larsen and Richard Pink for their article "Finite subgroups of algebraic groups", J. *Amer. Math. Soc.* **24** (2011), no. 4, 1105–1158.

Next award: January 2016.

The Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student

This prize, which was established in 1995, is to be awarded to an undergraduate student (or students having submitted joint work) for outstanding research in mathematics. It is entirely endowed by a gift from Mrs. Frank (Brennie) Morgan. Any student who is an undergraduate in a college or university in Canada, Mexico, or the United States or its possessions is eligible to be considered for this US$1,200 prize, which is to be awarded annually. The award is made jointly by the American Mathematical Society, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics.

First award, 1995: To Kannan Soundararajan for truly exceptional research in analytic number theory. Honorable mention: Kiran Kedlaya.

Second award, 1996: To Manjul Bhargava for truly outstanding mathematical research in algebra. Honorable mention: Lenhard L. Ng.

Third award, 1997: To Jade Vinson for wide-ranging research in analysis and geometry. Honorable mention: Vikaas Sohal.

Fourth award, 1998: To Daniel Biss for his remarkable breadth, as well as depth. The most exciting aspect of his submission was his extension of a category which more closely binds the associations between combinatorial group theory and combinatorial topology. Honorable mention: Aaron E. Archer.

Fifth award, 1999: To Sean McLaughlin for his proof of the Dodecahedral Conjecture, a major problem in discrete geometry related to, but distinct from, Kepler's

sphere packing problem and a conjecture that has resisted the efforts of the strongest workers in this area for nearly sixty years. Honorable mention: Samit Dasgupta.

Sixth award, 2000: To Jacob Lurie for his paper "On simply laced Lie algebras and their miniscule representations". Honorable mention: Wai Ling Yee.

Seventh award, 2001: To Ciprian Manolescu for making a fundamental advance in the field by giving an elegant construction of Floer homology. Honorable mention: Michael A. Levin.

Eighth award, 2002: To Joshua Greene for his work in combinatorics.

Ninth award, 2003: To Melanie Wood for research on Belyi-extending maps and *P*-orderings. Honorable mention: Karen Yeats.

Tenth award, 2004: To Reid W. Barton for his paper "Packing densities of patterns". Honorable mention: Po-Shen Loh.

Eleventh award, 2006: To Jacob Fox for a most astounding collection of research papers by any undergraduate mathematician.

Twelfth award, 2007: To Daniel Kane for establishing a research record that would be the envy of many professional mathematicians.

Thirteenth award, 2008: To Aaron Pixton for five impressive papers he has written, in addition to his Princeton senior thesis.

Fourteenth award, 2009: To Nathan Kaplan for four impressive papers in algebraic number theory.

Fifteenth award, 2010: To Scott Duke Kominers for his outstanding and prolific record of undergraduate research spanning a broad range of topics, including number theory, computational geometry, and mathematical economics.

Sixteenth award, 2011: To Maria Monks for her impressive work in combinatorics and number theory, which has appeared in *Advances in Applied Mathematics*, *Proceedings of the AMS*, *Electronic Journal of Combinatoric*s, *Discrete Mathematics*, and *Journal of Combinatorial Theory, Series A*.

Seventeenth award, 2012: To John Pardon for solving a problem on distortion of knots posed in 1983 by Mikhail Gromov.

Eighteenth award, 2013: To Fan Wei for her wide range of scholarly contributions.

Next award: January 2014.

David P. Robbins Prize

This prize was established in 2005 in memory of David P. Robbins by members of his family. Robbins, who died in 2003, received his Ph.D. in 1970 from MIT. He was a long-time member of the Institute for Defense Analysis Center for Communications Research and a prolific mathematician whose work (much of it classified) was in discrete mathematics. The prize is 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; and it shall be on a topic which is broadly accessible and shall provide a simple statement of the problem and clear exposition of the work. The US$5,000 prize will be awarded every three years.

First award, 2007: To Samuel P. Ferguson and Thomas C. Hales, for the paper *A proof of the Kepler conjecture*, by Thomas C. Hales, Annals of Mathematics, **162** (2005), 1065–1185 (Section 5 of this paper is jointly authored with Ferguson).

Second award, 2010: To Ileana Streinu of Smith College for her paper "Pseudo-triangulations, rigidity and motion planning", *Discrete Comput. Geom.* **34** (2005), no. 4, 587–635.

Third award, 2013: To Alexander Razborov, of the University of Chicago for his paper "On the minimal density of triangles in graphs" *Combinatorics, Probability and Computing* **17** (2008), no. 4, 603–618, and for introducing a new powerful method, flag algebras, to solve problems in extremal combinatorics.

Next award: January 2016.

The Ruth Lyttle Satter Prize in Mathematics

The prize was established in 1990 using funds donated by Joan S. Birman in memory of her sister, Ruth Lyttle Satter. Professor Birman requested that the prize be established to honor her sister's commitment to research and to encouraging women in science. The US$5,000 prize is awarded every two years to recognize an outstanding contribution to mathematics research by a woman in the previous six years.

First award, 1991: To Dusa McDuff for her outstanding work during the past five years on symplectic geometry.

Second award, 1993: To Lai-Sang Young for her leading role in the investigation of the statistical (or ergodic) properties of dynamical systems.

Third award, 1995: To Sun-Yung Alice Chang for her deep contributions to the study of partial differential equations on Riemannian manifolds and in particular for her work on extremal problems in spectral geometry and the compactness of isospectral metrics within a fixed conformal class on a compact 3-manifold.

Fourth award, 1997: To Ingrid Daubechies for her deep and beautiful analysis of wavelets and their applications.

Fifth award, 1999: To Bernadette Perrin-Riou for her number theoretical research on *p*-adic *L*-functions and Iwasawa Theory.

Sixth award, 2001: To Karen E. Smith for her outstanding work in commutative algebra, and to Sijue Wu for her work on a long-standing problem in the water wave equation.

Seventh award, 2003: To Abigail Thompson for her outstanding work in 3-dimensional topology.

Eighth award, 2005: To Svetlana Jitomirskaya for her pioneering work on nonpertubative quasiperiodic localization, in particular for results in her papers (1) *Metal-insulator transition for the almost Mathieu operator*, Ann. of Math. (2) **150** (1999), no. 3, pp. 1159–1175; and (2) with J. Bourgain, *Absolutely continuous spectrum for 1D quasiperiodic operators*, Invent. Math. **148** (2002), no. 3, pp. 453–463.

Ninth award, 2007: To Claire Voisin for her deep contributions to algebraic geometry, and in particular for her recent solutions to two long-standing open problems:

the Kodaira problem (*On the homotopy types of compact Kähler and complex projective manifolds*, Inventiones Mathematicae, **157** (2004), no. 2, 329–343) and Green's Conjecture (*Green's canonical syzygy conjecture for generic curves of odd genus*, Compositio Mathematica, **141** (2005), no. 5, 1163–1190; and *Green's generic syzygy conjecture for curves of even genus lying on a K3 surface*, Journal of the European Mathematical Society, **4** (2002), no. 4, 363–404).

Tenth award, 2009: To Laure Saint-Raymond for her fundamental work on the hydrodynamic limits of the Boltzmann equation in the kinetic theory of gases.

Eleventh award, 2011: To Amie Wilkinson for her remarkable contributions to the field of ergodic theory of partially hyperbolic dynamical systems.

Twelfth award, 2013: To Maryam Mirzakhani for her deep contributions to the theory of moduli spaces of Riemann surfaces.

Next award: January 2015.

The Leroy P. Steele Prize for Lifetime Achievement
The Leroy P. Steele Prize for Mathematical Exposition
The Leroy P. Steele Prize for Seminal Contribution to Research

These prizes were established in 1970 in honor of George David Birkhoff, William Fogg Osgood, and William Caspar Graustein and are endowed under the terms of a bequest from Leroy P. Steele. From 1970 to 1976 one or more prizes were awarded each year for outstanding published mathematical research; most favorable consideration was given to papers distinguished for their exposition and covering broad areas of mathematics. In 1977 the Council of the AMS modified the terms under which the prizes are awarded. Since then, up to three prizes have been awarded each year in the following categories: (1) for the cumulative influence of the total mathematical work of the recipient, high level of research over a period of time, particular influence on the development of a field, and influence on mathematics through Ph.D. students; (2) for a book or substantial survey or expository research paper; (3) for a paper, whether recent or not, that has proved to be of fundamental or lasting importance in its field, or a model of important research. In 1993 the Council formalized the three categories of the prize by naming each of them: (1) The Leroy P. Steele Prize for Lifetime Achievement, (2) The Leroy P. Steele Prize for Mathematical Exposition, and (3) The Leroy P. Steele Prize for Seminal Contribution to Research. Each of these three US$5,000 prizes is awarded annually.

Special Note: Beginning with the 1994 prize, there has been a five-year cycle of fields for the Seminal Contribution to Research Award. That cycle would have the 2008 prize awarded in discrete mathematics (discrete mathematics alternates with logic every five years), then analysis in 2009, algebra in 2010, applied mathematics in 2011, geometry/topology in 2012, and then logic in 2013, renewing the cycle.

August 1970: To Solomon Lefschetz for his paper *A page of mathematical autobiography*, Bulletin of the American Mathematical Society **74** (1968), pp. 854–879.

August 1971: To James B. Carrell for his paper, written jointly with Jean A. Dieudonne, *Invariant theory, old and new*, Advances in Mathematics **4** (1970), pp. 1–80.

August 1971: To Jean A. Dieudonné for his paper *Algebraic geometry*, Advances in Mathematics **3** (1969), pp. 223–321; and for his paper, written jointly with James B. Carrell, *Invariant theory, old and new*, Advances in Mathematics **4** (1970), pp. 1–80.

August 1971: To Phillip A. Griffiths for his paper *Periods of integrals on algebraic manifolds*, Bulletin of the American Mathematical Society **76** (1970), pp. 228–296.

August 1972: To Edward B. Curtis for his paper *Simplicial homotopy theory*, Advances in Mathematics **6** (1971), pp. 107–209.

August 1972: To William J. Ellison for his paper *Waring's problem*, American Mathematical Monthly **78** (1971), pp. 10–36.

August 1972: To Lawrence F. Payne for his paper *Isoperimetric inequalities and their applications*, SIAM Review **9** (1967), pp. 453–488.

August 1972: To Dana S. Scott for his paper *A proof of the independence of the continuum hypothesis*, Mathematical Systems Theory **1** (1967), pp. 89–111.

January 1975: To Lipman Bers for his paper *Uniformization, moduli, and Kleinian groups*, Bulletin of the London Mathematical Society **4** (1972), pp. 257–300.

January 1975: To Martin D. Davis for his paper *Hilbert's tenth problem is unsolvable*, American Mathematical Monthly **80** (1973), pp. 233–269.

January 1975: To Joseph L. Taylor for his paper *Measure algebras*, CBMS Regional Conference Series in Mathematics, Number 16, American Mathematical Society, 1972.

August 1975: To George W. Mackey for his paper *Ergodic theory and its significance for statistical mechanics and probability theory*, Advances in Mathematics **12** (1974), pp. 178–286.

August 1975: To H. Blaine Lawson for his paper *Foliations*, Bulletin of the American Mathematical Society **80** (1974), pp. 369–418.

1976, 1977, 1978: No awards were made.

January 1979: To Salomon Bochner for his cumulative influence on the fields of probability theory, Fourier analysis, several complex variables, and differential geometry.

January 1979: To Hans Lewy for three fundamental papers: *On the local character of the solutions of an atypical linear differential equation in three variables and a related theorem for regular functions of two complex variables*, Annals of Mathematics, Series 2, **64** (1956), pp. 514–522; *An example of a smooth linear partial differential equation without solution*, Annals of Mathematics, Series 2, **66** (1957), pp. 155–158; and *On hulls of holomorphy*, Communications in Pure and Applied Mathematics **13** (1960), pp. 587–591.

August 1979: To Antoni Zygmund for his cumulative influence on the theory of Fourier series, real variables, and related areas of analysis.

August 1979: To Robin Hartshorne for his expository research article *Equivalence relations on algebraic cycles and subvarieties of small codimension*, Proceedings of Symposia in Pure Mathematics, volume 29, American

Mathematical Society, 1975, pp. 129–164; and his book *Algebraic Geometry*, Springer–Verlag, Berlin and New York, 1977.

August 1979: To Joseph J. Kohn for his fundamental paper *Harmonic integrals on strongly convex domains. I, II*, Annals of Mathematics, Series 2, **78** (1963), pp. 112–248; and 79 (1964), pp.-450–472.

August 1980: To André Weil for the total effect of his work on the general course of twentieth-century mathematics, especially in the many areas in which he has made fundamental contributions.

August 1980: To Harold M. Edwards for mathematical exposition in his books *Riemann's Zeta Function*, Pure and Applied Mathematics, number 58, Academic Press, New York and London, 1974; and *Fermat's Last Theorem*, Graduate Texts in Mathematics, number 50, Springer-Verlag, New York and Berlin, 1977.

August 1980: To Gerhard P. Hochschild for his significant work in homological algebra and its applications.

August 1981: To Oscar Zariski for his work in algebraic geometry, especially his fundamental contributions to the algebraic foundations of this subject.

August 1981: To Eberhard Hopf for three papers of fundamental and lasting importance: *Abzweigung einer periodischen Lösung von einer stationären Lösung eines Differential systems*, Berichte über die Verhandlungen der Sächsischen Akademie der Wissenschaften zu Leipzig. Mathematisch–Naturwissenschaftliche Klasse **95** (1943), pp. 3–22; *A mathematical example displaying features of turbulence*, Communications on Applied Mathematics **1** (1948), pp. 303–322; and *The partial differential equation* $u_t+uu_x=u_{xx}$, Communications on Pure and Applied Mathematics **3** (1950), pp. 201–230.

August 1981: To Nelson Dunford and Jacob T. Schwartz for their expository book *Linear Operators*, Part I, *General Theory*, 1958; Part II, *Spectral Theory*, 1963; Part III, *Spectral Operators*, 1971, Interscience Publishers, New York.

August 1982: To Lars V. Ahlfors for his expository work in *Complex Analysis,* McGraw-Hill Book Company, New York, 1953; and in *Lectures on Quasiconformal Mappings,* D. Van Nostrand Co., Inc., New York, 1966; and *Conformal Invariants,* McGraw-Hill Book Company, New York, 1973.

August 1982: To Tsit-Yuen Lam for his expository work in his book *Algebraic Theory of Quadratic Forms* (1973), and four of his papers: *K_0 and K_1—an introduction to algebraic K-theory* (1975), *Ten lectures on quadratic forms over fields* (1977), *Serre's conjecture* (1978), and *The theory of ordered fields* (1980).

August 1982: To John W. Milnor for a paper of fundamental and lasting importance, *On manifolds homeomorphic to the -sphere*, Annals of Mathematics (2) **64** (1956), pp. 399–405.

August 1982: To Fritz John for the cumulative influence of his total mathematical work, high level of research over a period of time, particular influence on the development of a field, and influence on mathematics through Ph.D. students.

August 1983: To Paul R. Halmos for his many graduate texts in mathematics and for his articles on how to write, talk, and publish mathematics.

August 1983: To Steven C. Kleene for three important papers which formed the basis for later developments in generalized recursion theory and descriptive set theory: *Arithmetical predicates and function quantifiers*, Transactions of the American Mathematical Society **79** (1955), pp. 312–340; *On the forms of the predicates in the theory of constructive ordinals (second paper)*, American Journal of Mathematics **77** (1955), pp. 405–428; and *Hierarchies of number-theoretic predicates*, Bulletin of the American Mathematical Society **61** (1955), pp. 193–213.

August 1983: To Shiing-Shen Chern for the cumulative influence of his total mathematical work, high level of research over a period of time, particular influence on the development of the field of differential geometry, and influence on mathematics through Ph.D. students.

August 1984: To Elias M. Stein for his book *Singular Integrals and the Differentiability Properties of Functions*, Princeton University Press, 1970.

August 1984: To Lennart Carleson for his papers *An interpolation problem for bounded analytic functions*, American Journal of Mathematics **80** (1958), pp. 921– 930; *Interpolation by bounded analytic functions and the Corona problem*, Annals of Mathematics (2) **76** (1962), pp. 547–559; and *On convergence and growth of partial sums of Fourier series*, Acta Mathematica **116** (1966), pp. 135–157.

August 1984: To Joseph L. Doob for his fundamental work in establishing probability as a branch of mathematics and for his continuing profound influence on its development.

August 1985: To Michael Spivak for his five-volume set *A Comprehensive Introduction to Differential Geometry* (second edition), Publish or Perish, 1979.

August 1985: To Robert Steinberg for three papers on various aspects of the theory of algebraic groups: *Representations of algebraic groups*, Nagoya Mathematical Journal **22** (1963), pp. 33–56; *Regular elements of semisimple algebraic groups*, Institut des Hautes Études Scientifiques Publications Mathématiques **25** (1965), pp. 49–80; and *Endomorphisms of linear algebraic groups*, Memoirs of the American Mathematical Society **80** (1968).

August 1985: To Hassler Whitney for his fundamental work on geometric problems, particularly in the general theory of manifolds, in the study of differentiable functions on closed sets, in geometric integration theory, and in the geometry of the tangents to a singular analytic space.

January 1986: To Donald E. Knuth for his expository work *The Art of Computer Programming*, 3 volumes (first edition, 1968; second edition, 1973).

January 1986: To Rudolf E. Kalman for his two fundamental papers: *A new approach to linear filtering and prediction problems*, Journal of Basic Engineering **82** (1960), pp. 35–45; and *Mathematical description of linear dynamical systems,* SIAM Journal on Control and Optimization **1** (1963), pp. 152–192; and for his contribution to a third paper (with R. S. Bucy), *New results in linear filtering and prediction theory*, Journal of Basic Engineering **83D** (1961), pp. 95–108.

January 1986: To Saunders Mac Lane for his many contributions to algebra and algebraic topology, and in

particular for his pioneering work in homological and categorical algebra.

August 1987: To Martin Gardner for his many books and articles on mathematics and particularly for his column "Mathematical Games" in *Scientific American*.

August 1987: To Herbert Federer and Wendell Fleming for their pioneering paper *Normal and integral currents*, Annals of Mathematics **72** (1960), pp. 458–520.

August 1987: To Samuel Eilenberg for his fundamental contributions to topology and algebra, in particular for his classic papers on singular homology and his work on axiomatic homology theory, which had a profound influence on the development of algebraic topology.

August 1988: To Sigurdur Helgason for his books *Differential Geometry and Symmetric Spaces*, Academic Press, 1962; *Differential Geometry, Lie Groups, and Symmetric Spaces,* Academic Press, 1978; and *Groups and Geometric Analysis,* Academic Press, 1984.

August 1988: To Gian-Carlo Rota for his paper *On the foundations of combinatorial theory, I. Theory of Möbius functions*, Zeitschrift für Wahrscheinlichkeitstheorie und Verwandte Gebiete, volume 2 (1964), pp. 340–368.

August 1988: To Deane Montgomery for his lasting impact on mathematics, particularly mathematics in America. He is one of the founders of the modern theory of transformation groups and is particularly known for his contributions to the solution of Hilbert's fifth problem.

August 1989: To Daniel Gorenstein for his book *Finite Simple Groups, An Introduction to Their Classification,* Plenum Press, 1982; and his two survey articles, *The classification of finite simple groups* and *Classifying the finite simple groups*, Bulletin of the American Mathematical Society **1** (1979), pp. 43–199; and **14** (1986), pp. 1–98, respectively.

August 1989: To Alberto P. Calderón for his paper *Uniqueness in the Cauchy problem for partial differential equations*, American Journal of Mathematics **80** (1958), pp. 16–36.

August 1989: To Irving Kaplansky for his lasting impact on mathematics, particularly mathematics in America. By his energetic example, his enthusiastic exposition, and his overall generosity, he has made striking changes in mathematics and has inspired generations of younger mathematicians.

August 1990: To R. D. Richtmyer for his book *Difference Methods for Initial-Value Problems*, Interscience, first edition, 1957; and second edition, with K. Morton, 1967.

August 1990: To Bertram Kostant for his paper *On the existence and irreducibility of certain series of representations*, Lie Groups and Their Representations (1975), pp. 231–329.

August 1990: To Raoul Bott for having been instrumental in changing the face of geometry and topology with his incisive contributions to characteristic classes, *K*-theory, index theory, and many other tools of modern mathematics.

August 1991: To Jean-François Trèves for *Pseudodifferential and Fourier Integral Operators*, Volumes 1 and 2, Plenum Press, 1980.

August 1991: To Eugenio Calabi for his fundamental work on global differential geometry, especially complex differential geometry.

August 1991: To Armand Borel for his extensive contributions in geometry and topology, the theory of Lie groups, their lattices and representations and the theory of automorphic forms, the theory of algebraic groups and their representations, and extensive organizational and educational efforts to develop and disseminate modern mathematics.

January 1993: To Jacques Dixmier for his books *von Neumann Algebras* (*Algèbres de von Neumann*), Gauthier-Villars, Paris, 1957; *C*-Algebras* (*Les C*-Algèbres et leurs Representations*), Gauthier-Villars, Paris, 1964; and *Enveloping Algebras* (*Algèbres Enveloppantes*), Gauthier-Villars, Paris, 1974.

January 1993: To James Glimm for his paper *Solution in the large for nonlinear hyperbolic systems of conservation laws*, Communications on Pure and Applied Mathematics, **XVIII** (1965), pp. 697–715.

January 1993: To Peter D. Lax for his numerous and fundamental contributions to the theory and applications of linear and nonlinear partial differential equations and functional analysis, for his leadership in the development of computational and applied mathematics, and for his extraordinary impact as a teacher.

August 1993 – Mathematical Exposition: To Walter Rudin for his books *Principles of Mathematical Analysis*, McGraw-Hill, 1953, 1964, and 1976; and *Real and Complex Analysis*, McGraw-Hill, 1966, 1974, and 1976.

August 1993 – Seminal Contribution to Research: To George Daniel Mostow for his paper *Strong rigidity of locally symmetric spaces*, Annals of Mathematics Studies, number **78**, Princeton University Press, 1973.

August 1993 – Lifetime Achievement: To Eugene B. Dynkin for his foundational contributions to Lie algebras and probability theory over a long period and his production of outstanding research students in both Russia and the United States, countries to whose mathematical life he has contributed so richly.

August 1994 – Mathematical Exposition: To Ingrid Daubechies for her book *Ten Lectures on Wavelets*, CBMS, volume 61, SIAM, 1992.

August 1994 – Seminal Contribution to Research: To Louis de Branges for his proof of the Bieberbach Conjecture.

August 1994 – Lifetime Achievement: To Louis Nirenberg for his numerous basic contributions to linear and nonlinear partial differential equations and their application to complex analysis and differential geometry.

August 1995 – Mathematical Exposition: To Jean-Pierre Serre for his 1970 book *Cours d'Arithmétique*, with its English translation, published in 1973 by Springer Verlag, *A Course in Arithmetic*.

August 1995 – Seminal Contribution to Research: To Edward Nelson for the following two papers in mathematical physics, characterized by leaders of the field as extremely innovative: *A quartic interaction in two dimensions* in *Mathematical Theory of Elementary Particles*, MIT Press, 1966, pp. 69–73; and *Construction of quantum fields from Markoff fields* in Journal of Functional Analysis **12** (1973),

pp. 97–112. In these papers he showed for the first time how to use the powerful tools of probability theory to attack the hard analytic questions of constructive quantum field theory, controlling renormalizations with estimates in the first paper, and in the second turning Euclidean quantum field theory into a subset of the theory of stochastic processes.

August 1995 – Lifetime Achievement: To John T. Tate for scientific accomplishments spanning four and a half decades. He has been deeply influential in many of the important developments in algebra, algebraic geometry, and number theory during this time.

August 1996 – Mathematical Exposition: To Bruce C. Berndt for the four volumes, *Ramanujan's Notebooks*, Parts I, II, III, and IV (Springer, 1985, 1989, 1991, and 1994).

August 1996 – Mathematical Exposition: To William Fulton for his book *Intersection Theory*, Springer-Verlag, Ergebnisse series, 1984.

August 1996 – Seminal Contribution to Research: To Daniel Stroock and S. R. S. Varadhan for their four papers: *Diffusion processes with continuous coefficients I and II*, Comm. Pure Appl. Math. **22** (1969), pp. 345–400, pp. 479–530; *On the support of diffusion processes with applications to the strong maximum principle*, Sixth Berkeley Sympos. Math. Statist. Probab., vol. III, 1970, pp. 333–360; *Diffusion processes with boundary conditions*, Comm. Pure Appl. Math. **34** (1971), pp. 147–225; *Multidimensional diffusion processes*, Springer-Verlag, 1979.

August 1996 – Lifetime Achievement: To Goro Shimura for his important and extensive work on arithmetical geometry and automorphic forms; concepts introduced by him were often seminal and fertile ground for new developments, as witnessed by the many notations in number theory that carry his name and that have long been familiar to workers in the field.

January 1997 – Mathematical Exposition: To Anthony W. Knapp for his book *Representation Theory of Semisimple Groups (An overview based on examples)*, Princeton University Press, 1986, a beautifully written book which starts from scratch but takes the reader far into a highly developed subject.

January 1997 – Seminal Contribution to Research: To Mikhael Gromov for his paper *Pseudo-holomorphic curves in symplectic manifolds*, Inventiones Math. **82** (1985), pp. 307–347, which revolutionized the subject of symplectic geometry and topology and is central to much current research activity, including quantum cohomology and mirror symmetry.

January 1997 – Lifetime Achievement: To Ralph S. Phillips for being one of the outstanding analysts of our time. His early work was in functional analysis: his beautiful theorem on the relation between the spectrum of a semigroup and its infinitesimal generator is striking as well as very useful in the study of PDEs. His extension theory for dissipative linear operators predated the interpolation approach to operator theory and robust control. He made major contributions to acoustical scattering theory in his joint work with Peter Lax, proving remarkable results on local energy decay and the connections between poles of the scattering matrix and the analytic properties of the resolvent. He later extended this work to a spectral theory for the automorphic Laplace operator, relying on the Radon transform on horospheres to avoid Eisenstein series. In the last fifteen years, Ralph Phillips has done brilliant work, in collaboration with others, on spectral theory for the Laplacian on symmetric spaces, on the existence and stability of cusp forms for general noncompact quotients of the hyperbolic plane, on the explicit construction of sparse optimal expander graphs, and on the structure of families of isospectral sets in two dimensions (the collection of drums that sound the same).

January 1998 – Lifetime Achievement: To Nathan Jacobson for his many contributions to research, teaching, exposition, and the mathematical profession. Few mathematicians have been as productive over such a long career or have had as much influence on the profession as has Professor Jacobson.

January 1998 – Seminal Contribution to Research: To Herbert Wilf and Doron Zeilberger for their joint paper *Rational functions certify combinatorial identities*, Journal of the American Mathematical Society **3** (1990), pp. 147–158.

January 1998 – Mathematical Exposition: To Joseph Silverman for his books *The Arithmetic of Elliptic Curves*, Graduate Texts in Mathematics, volume 106, Springer-Verlag, New York and Berlin, 1986; and *Advanced Topics in the Arithmetic of Elliptic Curves*, Graduate Texts in Mathematics, volume 151, Springer-Verlag, New York, 1994.

January 1999 – Lifetime Achievement: To Richard V. Kadison. For almost half a century, Professor Kadison has been one of the world leaders in the subject of operator algebras, and the tremendous flourishing of this subject in the last thirty years is largely due to his efforts.

January 1999 – Seminal Contribution to Research: To Michael G. Crandall for two seminal papers: *Viscosity solutions of Hamilton-Jacobi equations* (joint with P.-L. Lions), Trans. Amer. Math. Soc. **277** (1983), pp. 1–42; and *Generation of semi-groups of nonlinear transformations on general Banach spaces* (joint with T. M. Liggett), Amer. J. Math. **93** (1971), pp. 265–298.

January 1999 – Seminal Contribution to Research: To John F. Nash for his remarkable paper *The embedding problem for Riemannian manifolds*, Ann. of Math. (2) **63** (1956), pp. 20–63.

January 1999 – Mathematical Exposition: To Serge Lang for his many books. Among Lang's most famous texts are *Algebra*, Addison-Wesley, Reading, MA, 1965; second edition, 1984; third edition, 1993; and *Algebraic Number Theory,* Addison-Wesley, Reading, MA, 1970; second edition, Graduate Texts in Mathematics, volume 110, Springer-Verlag, New York, 1994.

January 2000 – Lifetime Achievement: To Isadore M. Singer. Singer's series of five papers with Michael F. Atiyah on the Index Theorem for elliptic operators (which appeared in 1968–71) and his three papers with Atiyah and V. K. Patodi on the Index Theorem for manifolds with boundary (which appeared in 1975–76) are among the great classics of global analysis.

January 2000 – Seminal Contribution to Research: To Barry Mazur for his paper *Modular curves and the Eisen-*

stein ideal in Publications Mathematiques de l'Institut des Hautes Études Scientifiques, **47** (1978), pp. 33–186.

January 2000 – Mathematical Exposition: To John H. Conway in recognition of his many expository contributions in automata, the theory of games, lattices, coding theory, group theory, and quadratic forms.

January 2001 – Lifetime Achievement: To Harry Kesten for his many and deep contributions to probability theory and its applications.

January 2001 – Seminal Contribution to Research: To Leslie F. Greengard and Vladimir Rokhlin for the paper *A fast algorithm for particle simulations*, J. Comput. Phys. **73**, no. 2 (1987), pp. 325–348.

January 2001 – Mathematical Exposition: To Richard P. Stanley in recognition of the completion of his two-volume work *Enumerative Combinatorics*.

January 2002 – Lifetime Achievement: To Michael Artin for helping to weave the fabric of modern algebraic geometry and to Elias Stein for making fundamental contributions to different branches of analysis.

January 2002 – Seminal Contribution to Research: To Mark Goresky and Robert MacPherson for the papers *Intersection homology theory*, Topology **19** (1980), no. 2, pp. 135–162 (IH1); and *Intersection homology. II*, Invent. Math. **72** (1983), no. 1, pp. 77–129 (IH2).

January 2002 – Mathematical Exposition: To Yitzhak Katznelson for his book on harmonic analysis.

January 2003 – Lifetime Achievement: To Ron Graham for being one of the principal architects of the rapid development worldwide of discrete mathematics in recent years and to Victor Guillemin for playing a critical role in the development of a number of important areas in analysis and geometry.

January 2003 – Seminal Contribution to Research: To Ronald Jensen for his paper *The fine structure of the constructible hierarchy*, Annals of Mathematical Logic **4** (1972), 229–308 pp.; and to Michael Morley for his paper *Categoricity in power*, Transactions of the AMS **114** (1965), pp. 514–538.

January 2003 – Mathematical Exposition: To John B. Garnett for his book *Bounded Analytic Functions*, Pure and Applied Mathematics, volume 96, Academic Press, Inc. [Harcourt Brace Jovanovich, Publishers], New York and London, 1981.

January 2004 – Lifetime Achievement: To Cathleen Synge Morawetz for greatly influencing mathematics in the broad sense throughout her long and distinguished career.

January 2004 – Seminal Contribution to Research: To Lawrence C. Evans and Nicolai V. Krylov for the "Evans-Krylov theorem", as first established in the papers: Lawrence C. Evans, *Classical solutions of fully nonlinear convex, second order elliptic equations*, Communications in Pure and Applied Mathematics **35** (1982), no. 3, pp. 333–363; and N. V. Krylov, *Boundedly inhomogeneous elliptic and parabolic equations*, Izvestiya Akad. Nauk SSSR, Ser. Mat. **46** (1982), no. 3, pp. 487–523; translated in Mathematics of the USSR, Izvestiya **20** (1983), no. 3, pp. 459–492.

January 2004 – Mathematical Exposition: To John W. Milnor in recognition of a lifetime of expository contributions ranging across a wide spectrum of disciplines, including topology, symmetric bilinear forms, characteristic classes, Morse theory, game theory, algebraic K-theory, iterated rational maps,…and the list goes on.

January 2005 – Lifetime Achievement: To Israel M. Gelfand for profoundly influencing many fields of research through his own work and through his interactions with other mathematicians and students.

January 2005 – Seminal Contribution to Research: To Robert P. Langlands for his paper *Problems in the theory of automorphic forms*, Springer Lecture Notes in Math., volume 170, 1970, pp. 18–86. This is the paper that introduced what are now known as the Langlands conjectures.

January 2005 – Mathematical Exposition: To Branko Grünbaum for his book *Convex Polytopes*.

January 2006 – Lifetime Achievement: To Frederick W. Gehring for being a leading figure in the theory of quasiconformal mappings for over fifty years; and to Dennis P. Sullivan for his fundamental contributions to many branches of mathematics.

January 2006 – Seminal Contribution to Research: To Clifford S. Gardner, John M. Greene, Martin D. Kruskal, and Robert M. Miura for their paper *KortewegdeVries equation and generalizations. VI. Methods for exact solution*, Comm. Pure Appl. Math. **27** (1974), 97–133.

January 2006 – Mathematical Exposition: To Lars V. Hörmander for his book, *The Analysis of Linear Partial Differential Operators*.

January 2007 – Lifetime Achievement: To Henry P. McKean for his rich and magnificent mathematical career and for his work in analysis, which has a strong orientation towards probability theory.

January 2007 – Seminal Contribution to Research: To Karen Uhlenbeck for her foundational contributions in analytic aspects of mathematical gauge theory. These results appeared in the two papers: *Removable singularities in Yang-Mills fields*, Communications in Mathematical Physics, **83** (1982), 11–29 and *Connections with L:P bounds on curvature*, Communications in Mathematical Physics, **83** (1982), 31–42.

January 2007 – Mathematical Exposition: To David Mumford for his beautiful expository accounts of a host of aspects of algebraic geometry, including *The Red Book of Varieties and Schemes* (Springer, 1988).

January 2008 – Lifetime Achievement: To George Lusztig for entirely reshaping representation theory, and, in the process, changing much of mathematics.

January 2008 – Seminal Contribution to Research: To Endre Szemerédi for his paper *On sets of integers containing no k elements in arithmetic progression*, Acta Arithmetica XXVII (1975), 199-245.

January 2008 – Mathematical Exposition: To Neil Trudinger for his book *Elliptic Partial Differential Equations of Second Order*, written with the late David Gilbarg.

January 2009 – Lifetime Achievement: To Luis Caffarelli, one of the world's greatest mathematicians studying nonlinear partial differential equations (PDE).

January 2009 – Seminal Contribution to Research: To Richard Hamilton for his paper *Three-manifolds with positive Ricci curvature*, J. Differential Geom. **17** (1982), 255-306.

January 2009 – Mathematical Exposition: To I. G. MacDonald for his book *Symmetric Functions and Hall Polynomials* (second edition, Clarendon Press, Oxford University Press, 1995).

January 2010 – Lifetime Achievement: To William Fulton for playing a pivotal role in shaping the direction of algebraic geometry, forging and strengthening ties between algebraic geometry and adjacent fields, and teaching and mentoring several generations of younger mathematicians.

January 2010 – Seminal Contribution to Research: To Robert L. Griess Jr. for his construction of the "Monster" sporadic finite simple group, which he first announced in "A construction of F1 as automorphisms of a 196,883-dimensional algebra" (*Proc. Nat. Acad. Sci. U.S.A.* **78** (1981), no. 2, part 1, 686–691) with details published in "The friendly giant" (*Invent. Math.* **69** (1982), no. 1, 1–102).

January 2010 – Mathematical Exposition: To David Eisenbud for his book, *Commutative Algebra: With a View Toward Algebraic Geometry* (Graduate Texts in Mathematics, 150, Springer-Verlag, New York, 1995. xvi+785 pp.).

January 2011 – Lifetime Achievement: To John W. Milnor for standing out from the list of great mathematicians in terms of his overall achievements and his influence on mathematics in general, both through his work and through his excellent books.

January 2011 – Seminal Contribution to Research: To Ingrid Daubechies for her paper, "Orthonormal bases of compactly supported wavelets" (*Communications on Pure and Applied Mathematics* **41** (1988), no. 7, 909-996).

January 2011 – Mathematical Exposition: To Henryk Iwaniec for his long record of excellent exposition, both in books and in classroom notes.

January 2012 – Lifetime Achievement: To Ivo M. Babuška for his many pioneering advances in the numerical solution of partial differential equations over the last half century.

January 2012 – Seminal Contribution to Research: To William Thurston for his contributions to low-dimensional topology, and in particular for a series of highly original papers, starting with "Hyperbolic structures on 3-manifolds. I. Deformation of acylindrical manifolds" *Ann. of Math. (2)* **124** (1986), no. 2, 203–246, that revolutionized 3-manifold theory.

January 2012 – Mathematical Exposition: To Michael Aschbacher, Richard Lyons, Steve Smith, and Ronald Solomon for their work, *The Classification of Finite Simple Groups: Groups of Characteristic 2 Type,* Mathematical Surveys and Monographs, 172, American Mathematical Society, Providence, RI, 2011.

January 2013 – Lifetime Achievement: To Yakov Sinai for his pivotal role in shaping the theory of dynamical systems and for his groundbreaking contributions to ergodic theory, probability theory, statistical mechanics, and mathematical physics.

January 2013 – Seminal Contribution to Research: To John Guckenheimer and Philip Holmes in recognition of their book, *Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields (Applied Mathematical Sciences*, 42, Springer-Verlag, New York, 1983; reprinted with revisions and corrections, 1990).

January 2013 – Mathematical Exposition: Saharon Shelah for his book, *Classification Theory and the Number of Nonisomorphic Models* (Studies in Logic and the Foundations of Mathematics, 92, North-Holland Publishing Co., Amsterdam–New York, 1978; 2nd edition, 1990).

Next awards: January 2014.

The Oswald Veblen Prize in Geometry

This prize was established in 1961 in memory of Professor Oswald Veblen through a fund contributed by former students and colleagues. The fund was later doubled by the widow of Professor Veblen. It is awarded in recognition of a notable research memoir in geometry or topology published in the preceding six years. To be considered, either the nominee should be a member of the Society or the memoir should have been published in a recognized North American journal. Currently, the US$5,000 prize is awarded every three years.

First award, 1964: To C. D. Papakyriakopoulos for his papers *On solid tori*, Annals of Mathematics, Series 2, **66** (1957), pp. 1–26; and *On Dehn's lemma and the asphericity of knots*, Proceedings of the National Academy of Sciences **43** (1957), pp. 169–172.

Second award, 1964: To Raoul Bott for his papers *The space of loops on a Lie group*, Michigan Mathematical Journal **5** (1958), pp. 35–61; and *The stable homotopy of the classical groups*, Annals of Mathematics, Series 2, **70** (1959), pp. 313–337.

Third award, 1966: To Steven Smale for his contributions to various aspects of differential topology.

Fourth award, 1966: To Morton Brown and Barry Mazur for their work on the generalized Schoenflies theorem.

Fifth award, 1971: To Robion C. Kirby for his paper *Stable homeomorphisms and the annulus conjecture*, Annals of Mathematics, Series 2, **89** (1969), pp. 575–582.

Sixth award, 1971: To Dennis P. Sullivan for his work on the Hauptvermutung summarized in the paper *On the Hauptvermutung for manifolds*, Bulletin of the American Mathematical Society **73** (1967), pp. 598–600.

Seventh award, 1976: To William P. Thurston for his work on foliations.

Eighth award, 1976: To James Simons for his work on minimal varieties and characteristic forms.

Ninth award, 1981: To Mikhael Gromov for his work relating topological and geometric properties of Riemannian manifolds.

Tenth award, 1981: To Shing-Tung Yau for his work in nonlinear partial differential equations, his contributions to the topology of differentiable manifolds, and for his work on the complex Monge-Ampère equation on compact complex manifolds.

Eleventh award, 1986: To Michael H. Freedman for his work in differential geometry and, in particular, the solution of the four-dimensional Poincaré conjecture.

Twelfth award, 1991: To Andrew J. Casson for his work on the topology of low-dimensional manifolds and to Clifford H. Taubes for his foundational work in Yang-Mills theory.

Thirteenth award, 1996: To Richard Hamilton for his continuing study of the Ricci flow and related parabolic equations for a Riemannian metric, and to Gang Tian for his contributions to geometric analysis.

Fourteenth award, 2001: To Jeff Cheeger for his work in differential geometry, to Yakov Eliashberg for his work in symplectic and contact topology, and to Michael J. Hopkins for his work in homotopy theory.

Fifteenth award, 2004: To David Gabai in recognition of his work in geometric topology, in particular, the topology of 3-dimensional manifolds.

Sixteenth award, 2007: To Peter Kronheimer and Tomasz Mrowka for their joint contributions to both three- and four-dimensional topology through the development of deep analytical techniques and applications; and to Peter Ozsváth and Zoltán Szabó for their contributions to 3- and 4-dimensional topology through their Heegaard Floer homology theory.

Seventeenth award, 2010: To Tobias H. Colding and William P. Minicozzi II for their profound work on minimal surfaces; and to Paul Seidel for his fundamental contributions to symplectic geometry.

Eighteenth award, 2013: To Ian Agol, for his many fundamental contributions to hyperbolic geometry, 3-manifold topology, and geometric group theory and to Daniel Wise, for his deep work establishing subgroup separability (LERF) for a wide class of groups and for introducing and developing with Frédéric Haglund the theory of special cube complexes which are of fundamental importance for the topology of three-dimensional manifolds.

Next award: January 2016.

The Albert Leon Whiteman Memorial Prize

This prize was established in 1998 using funds donated by Mrs. Sally Whiteman in memory of her husband, Albert Leon Whiteman, to recognize notable exposition and exceptional scholarship in the history of mathematics. Starting in 2009, the US$5,000 prize will be awarded every three years.

First award, 2001: To Thomas Hawkins to recognize an outstanding historian of mathematics whose current research and numerous publications display the highest standards of mathematical and historical sophistication.

Second award, 2005: To Harold M. Edwards to pay tribute to his many publications over several decades that have fostered a greater understanding and appreciation of the history of mathematics, expecially the theory of algebraic numbers.

Third award, 2009: To Jeremy John Gray for his many historical works, which have not only shed great light on the history of modern mathematics but also have given an example of the ways in which historical scholarship can contribute to the understanding of mathematics and its philosophy.

Fourth award, 2013: To Joseph Warren Dauben for his contributions to the history of Western and Chinese mathematics, and for deepening and broadening the international mathematical community's awareness and understanding of its history and culture.

Next award: January 2015.

The Norbert Wiener Prize in Applied Mathematics

This prize was established in 1967 in honor of Professor Norbert Wiener and was endowed by a fund from the Department of Mathematics of the Massachusetts Institute of Technology. The prize is awarded for an outstanding contribution to "applied mathematics in the highest and broadest sense". The award 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 and a resident of the United States, Canada, or Mexico. Beginning in 2004, the US$5,000 prize will be awarded every three years.

First award, 1970: To Richard E. Bellman for his pioneering work in the area of dynamic programming and for his related work on control, stability, and differential-delay equations.

Second award, 1975: To Peter D. Lax for his broad contributions to applied mathematics, in particular, for his work on numerical and theoretical aspects of partial differential equations and on scattering theory.

Third award, 1980: To Tosio Kato for his distinguished work in the perturbation theory of quantum mechanics.

Fourth award, 1980: To Gerald B. Whitham for his broad contributions to the understanding of fluid dynamical phenomena and his innovative contributions to the methodology through which that understanding can be constructed.

Fifth award, 1985: To Clifford S. Gardner for his contributions to applied mathematics in the areas of supersonic aerodynamics, plasma physics and hydromagnetics, and especially for his contributions to the truly remarkable development of inverse scattering theory for the solution of nonlinear partial differential equations.

Sixth award, 1990: To Michael Aizenman for his outstanding contribution of original and nonperturbative mathematical methods in statistical mechanics, by means of which he was able to solve several long open important problems concerning critical phenomena, phase transitions, and quantum field theory; and to Jerrold E. Marsden for his outstanding contributions to the study of differential equations in mechanics: he proved the existence of chaos in specific classical differential equations; his work on the momentum map, from abstract foundations to detailed applications, has had great impact.

Seventh award, 1995: To Hermann Flaschka for deep and original contributions to our understanding of completely integrable systems, and to Ciprian Foias for basic contributions to operator theory, analysis, and dynamics and their applications.

Eighth award, 2000: To Alexandre J. Chorin in recognition of his seminal work in computational fluid dynamics, statistical mechanics, and turbulence; and to Arthur T. Winfree in recognition of his profound impact on the field of biological rhythms, otherwise known as coupled nonlinear oscillators.

Ninth award, 2004: To James A. Sethian for his seminal work on the computer representation of the motion of curves, surfaces, interfaces, and wave fronts, and for his brilliant applications of mathematical and computational ideas to problems in science and engineering.

Tenth award, 2007: To Craig Tracy and Harold Widom for their deep and original work on Random Matrix Theory, a subject which has remarkable applications across the scientific spectrum, from the scattering of neutrons off large nuclei to the behavior of the zeros of the Riemann zeta-function.

Eleventh award, 2010: To David L. Donoho for introducing novel fundamental and powerful mathematical tools in signal processing and image analysis.

Twelfth award, 2013: To Andrew Majda for his groundbreaking work in theoretical fluid mechanics and its application to problems in atmospheric science and oceanography.

Next award: January 2016.

Awards

AMS Centennial Fellowships

A Research Fellowship Fund was established by the AMS in 1973 to provide one-year fellowships for research in mathematics. In 1988 the Fellowship was renamed to honor the AMS Centennial. The number of fellowships granted each year depends on the contributions received; the Society supplements contributions as needed. The primary selection criterion for the Centennial Fellowship is the excellence of the candidate's research. A recipient of the fellowship shall have held his or her doctoral degree for at least three years and not more than twelve years at the inception of the award. Applications will be accepted from those currently holding a tenured, tenure-track, postdoctoral, or comparable (at the discretion of the selection committee) position at an institution in North America. The amount of the fellowship varies each year. See the last entry on the list below to find the amount and number of fellowships awarded most recently. To make a contribution to the Centennial Fellowship Fund, see `http://www.ams.org/development/centennialfund.html`. To apply for a Centennial Fellowship, see `http://www.ams.org/employment/centflyer.html`.

First award, 1974–1975: Fred G. Abramson, James Li-Ming Wang.

Second award, 1975–1976: Terence J. Gaffney, Paul Nèvai, George M. Reed.

Third award, 1976–1977: Fredric D. Ancel, Joseph A. Sgro.

Fourth award, 1977–1978: Steven Kalikow, Charles Patton, Duong-Hong Phong, David Vogan.

Fifth award, 1978–1979: Alan Dankner, David Harbater, Howard Hiller, Steven P. Kerckhoff, Robert C. McOwen.

Sixth award, 1979–1980: Scott W. Brown, Jeffrey E. Hoffstein, Jeffry N. Kahn, James E. McClure, Rick L. Smith, Mark Steinberger.

Seventh award, 1980–1981: Robert K. Lazarsfeld, Thomas H. Parker, Robert Sachs.

Eighth award, 1981–1982: Lawrence Man-Hou Ein, Mark Williams.

Ninth award, 1982–1983: Nicholas J. Kuhn.

Tenth award, 1983–1984: Russell David Lyons.

Eleventh award, 1984–1985: Richard Timothy Durrett.

Twelfth award, 1985–1986: R. Michael Beals.

Thirteenth award, 1986–1987: Dinakar Ramakrishnan.

Fourteenth award, 1987–1988: Richard Hain, Bill Jacob.

Fifteenth award, 1988–1989: Steven R. Bell, Don M. Blasius, David Gabai.

Sixteenth award, 1989–1990: Isaac Y. Efrat, John M. Lee, Ralf J. Spatzier.

Seventeenth award, 1990–1991: Michael Anderson, Carolyn Gordon, Steven Mitchell.

Eighteenth award, 1991–1992: Daniel Bump, Kari Vilonen.

Nineteenth award, 1992–1993: Krzysztof Burdzy, William Menasco, David Morrison.

Twentieth award, 1993–1994: Jacques Hurtubise, Andre Scedrov, David Webb.

Twenty-first award, 1994–1995: Patricia E. Bauman, David E. Marker.

Twenty-second award, 1995–1996: Rafael de la Llave, William Gordon McCallum, Kent Edward Orr.

Twenty-third award, 1996–1997: Yi Hu, Robert McCann, Alexander Voronov, Jiaping Wang.

Twenty-fourth award, 1997–1998: Ovidiu Costin, Fred Diamond, Gang Liu, Zhongwei Shen, Stephanie Frank Singer.

Twenty-fifth award, 1998–1999: Mark Andrea A. de Cataldo, Stavros Garoufalidis, Sándor Kovács, Yanguang Li.

Twenty-sixth award, 1999–2000: Charles W. Rezk, Bin Wang, Changyou Wang, Tonghai Yang.

Twenty-seventh award, 2000–2001: Siqi Fu, Christopher Herald, Wei-Dong Ruan, Vasily Strela.

Twenty-eighth award, 2001–2002: Ivan Dimitrov, Ravi Vakil, Jiahong Wu, Meijun Zhu.

Twenty-ninth award, 2002–2003: Albert C. Fannjiang, Wee Teck Gan, Ravi Kumar Ramakrishna.

Thirtieth award, 2003–2004: Henry H. Kim, John E. Meier.

Thirty-first award, 2004–2005: Jinho Baik, Nitu Kitchloo.

Thirty-second award, 2005–2006: Yuan-Pin Lee, Mihnea Popa.

Thirty-third award, 2006–2007: Christopher Hacon, Bryna Kra.

Thirty-fourth award, 2007–2008: Martin Kassabov.

Thirty-fifth award, 2008–2009: Christopher Hoffman.

Thirty-sixth award, 2009–2010: Antonio Montalban.

Thirty-seventh award, 2010–2011: Joel Bellaiche.

Thirty-eighth award, 2011–2012: Andrew S. Toms.

Thirty-ninth award, 2012–2013: Karin Melnick.

Fortieth award, 2013–2014: Xinwen Zhu.

Next award (for 2014–2015 academic year): June 2014.

JPBM Communications Award

This award was established by the Joint Policy Board for Mathematics (JPBM) in 1988 to reward and encourage communicators who, on a sustained basis, bring mathematical ideas and information to nonmathematical audiences. Both mathematicians and nonmathematicians are eligible. Currently, the US$1,000 award is made annually. JPBM is a collaborative effort of the American Mathematical Society, the Mathematical Association of America, the Society for Industrial and Applied Mathematics, and the American Statistical Association.

First award, 1988: To James Gleick for sustained and outstanding contributions in communicating mathematics to the general public.

Second award, 1990: To Hugh Whitemore for contributions to communicating mathematics to the public in his play *Breaking the Code*, which chronicles the brilliant but troubled life of British mathematician Alan Turing.

Third award, 1991: To Ivars Peterson for exceptional skill in communicating mathematics to the general public over the last decade.

Fourth award, 1993: To Joel Schneider for *Square One TV*.

Fifth award, 1994: To Martin Gardner, for authoring numerous books and articles about mathematics, including his long-running *Scientific American* column "Mathematical Games", and his books *Fads and Fallacies in the Name of Science* and *Mathematical Carnival*.

Sixth award, 1996: To Gina Kolata for consistently giving outstanding coverage to many of the most exciting breakthroughs in mathematics and computer science over the past twenty years.

Seventh award, 1997: To Philip J. Davis for being a prolific communicator of mathematics to the general public.

Eighth award, 1998: To Constance Reid for writing about mathematics with grace, knowledge, skill, and clarity.

Ninth award, 1999: To Ian Stewart for communicating the excitement of science and mathematics to millions of people around the world for more than twenty years. Also a "Special Communications Award" to John Lynch and Simon Singh for their exceptional contributions to public understanding of mathematics through their documentary on Andrew Wiles and the Fermat Conjecture, entitled *Fermat's Last Theorem* (shown on *NOVA* as "The Proof").

Tenth award, 2000: To Sylvia Nasar for *A Beautiful Mind*, her biography of John Forbes Nash Jr.

Eleventh award, 2001: To Keith J. Devlin for his many contributions to public understanding of mathematics through great numbers of radio and television appearances; public talks; books; and articles in magazines, newsletters, newspapers, journals, and online.

Twelfth award, 2002: To Helaman and Claire Ferguson for dazzling the mathematical community and a far wider public with exquisite sculptures embodying mathematical ideas, along with artful and accessible essays and lectures elucidating the mathematical concepts.

Thirteenth award, 2003: To Robert Osserman for being an erudite spokesman for mathematics, communicating its charm and excitement to thousands of people from all walks of life.

2004: No award given.

Fourteenth award, 2005: To Barry Cipra for writing about mathematics of every kind—from the most abstract to the most applied—for nearly twenty years. His lucid explanations of complicated ideas at the frontiers of research have appeared in dozens of articles in newspapers, magazines, and books.

Fifteenth award, 2006: To Roger Penrose for the discovery of Penrose tilings, which have captured the public's imagination, and for an extraordinary series of books that brought the subject of consciousness to the public in mathematical terms.

Sixteenth award, 2007: To Steven H. Strogatz for making a consistent effort to reach out to a wider audience. He has made significant contact with the wider scientific community. The style of his book, *Sync: The Emerging Science of Spontaneous Order* (2003), and its sales indicate that it is intended for and has reached an even wider audience. The volume of this work is impressive, but the quality and breadth are spectacular as well.

Seventeenth award, 2008: To Carl Bialik for increasing the public's understanding of mathematical concepts.

Eighteenth award, 2009: To George Csicsery for communicating the beauty and fascination of mathematics and the passion of those who pursue it.

Nineteenth award, 2010: To Marcus du Sautoy for complementing his love of mathematical discovery with a passion for communicating mathematics to a broad public.

Twentieth award, 2011: To Nicolas Falacci and Cheryl Heuton for their positive portrayal of the power and fun of mathematics through their hit TV series, *Numb3rs*.

Twenty-first award, 2012: To Dana Mackenzie for his remarkably broad and deep body of writing for experts and nonexperts alike over the last fifteen years.

Twenty-second award, 2013: To John Allen Paulos because his books, columns, reviews, speeches, and editorials have for more than twenty-five years brought mathematically informed ideas, information, opinion, and humor to a broad nonspecialist audience.

Next award: January 2014

AMS Epsilon Awards for Young Scholars Programs

In 1999 the American Mathematical Society started the Epsilon Fund to help support existing summer programs for mathematically talented high school students. The name for the fund was chosen in remembrance of the late Paul Erdős, who was fond of calling children "epsilons". At its meeting in November 2000, the AMS Board of Trustees approved the Society's engagement in a sustained effort to raise an endowment for the Epsilon Fund. In addition, a Board-designated fund of US$500,000 was created as a start for the endowment. As a start for the program, the AMS used money from its Program Development Fund to award Epsilon grants for activities during summers 2000, 2001, 2002, and 2003. The Epsilon Fund now stands at a level where it can annually provide grants to support ten separate programs that touch approximately 600 talented and highly motivated mathematics students every year. To make a contribution to the Epsilon Fund, see `http://www.ams.org/about-us/support-ams/giving_op/epsilon`. To apply for an Epsilon grant, see `http://www.ams.org/programs/edu-support/epsilon/emp-epsilon`.

First awards, 2000: To All Girls/All Math (University of Nebraska, Lincoln), Hampshire College Summer Studies in Mathematics, Mathcamp, PROMYS (Boston University), Ross Young Scholars Program (Ohio State University), SWT Honors Summer Math Camp (Southwest Texas State University), and the University of Michigan Math Scholars.

Second awards, 2001: To All Girls/All Math (University of Nebraska), Mathcamp (Port Huron, Michigan), Michigan Math & Science Scholars (University of Michigan, Ann

Arbor), Mathematics Scholars Academy (Oklahoma State University), Hampshire College Summer Studies in Mathematics (Hampshire College), PROMYS (Boston University), Young Scholars Program (University of Chicago), and Ross Mathematics Program (The Ohio State University).

Third awards, 2002: To All Girls/All Math (University of Nebraska), Hampshire College Summer Studies in Mathematics (Amherst, Massachusetts), Mathcamp (Mathematics Foundation of America), Michigan Math and Science Scholars (University of Michigan, Ann Arbor), PROMYS (Boston University), Ross Mathematics Program (The Ohio State University), SWT Honors Summer Math Camp (Southwest Texas State University), and University of Chicago Young Scholars Program.

Fourth awards, 2003: To All Girls/All Math (University of Nebraska), Canada/USA Mathcamp (Mathematics Foundation of America), Hampshire College Summer Studies in Mathematics (Amherst, Massachusetts), PROMYS (Boston University), Ross Mathematics Program (The Ohio State University), Stanford University Mathematics Camp (Stanford University), SWT Honors Summer Math Camp (Southwest Texas State University), and University of Chicago Young Scholars Program.

Fifth awards, 2004: To Ross Mathematics Program (The Ohio State University), Texas State University Honors Summer Math Camp, PROMYS (Boston University), Canada/USA Mathcamp (Mathematics Foundation of America), Hampshire College Summer Studies in Mathematics (Amherst, Massachusetts), All Girls/All Math (University of Nebraska), University of Chicago Young Scholars Program, and MathPath (MathPath Foundation).

Sixth awards, 2005: To All Girls/All Math Summer Camp for High School Girls (University of Nebraska, Lincoln), Canada/USA Mathcamp (Reed College, Portland, Oregon), Hampshire College Summer Studies in Mathematics (Hampshire College, Amherst, Massachusetts), MathPath, (Colorado College, Colorado Springs), Michigan Math and Science Scholars Program (University of Michigan, Ann Arbor), PROMYS (Boston University), Ross Mathematics Program (The Ohio State University), Texas State Honors Summer Math Camp (Texas State University, San Marcos), and University of Chicago Young Scholars Program.

Seventh awards, 2006: To All Girls/All Math Summer Camp for High School Girls (University of Nebraska, Lincoln), Canada/USA Mathcamp (University of Puget Sound, Tacoma, Washington), Hampshire College Summer Studies in Mathematics (Hampshire College, Amherst, Massachusetts), MathPath, (University of California, Santa Cruz), Michigan Math and Science Scholars Program (University of Michigan, Ann Arbor), PROMYS (Boston University), Puerto Rico Opportunities for Talented Students in Mathematics (PROTaSM) (University of Puerto Rico, Mayaguez), Ross Mathematics Program (Ohio State University, Columbus), Summer Explorations and Research Collaborations for High School Girls (SEARCH) (Mount Holyoke College, South Hadley, Massachusetts), Texas State Honors Summer Math Camp (Texas State University, San Marcos), Texas Tech University Summer Mathematics Academy (Texas Tech University, Lubbock), and University of Chicago Young Scholars Program (University of Chicago).

Eighth awards, 2007: Hampshire College Summer Studies in Mathematics, Amherst, Massachusetts; Michigan Math and Science Scholars Summer Program, University of Michigan, Ann Arbor; PROMYS, Boston University; Ross Mathematics Program, Ohio State University, Columbus; Summer Explorations and Research Collaborations for High School Girls (SEARCH), Mount Holyoke College, South Hadley, Massachusetts; and Texas State University Honors Summer Math Camp, Texas State University, San Marcos.

Ninth awards, 2008: All Girls/All Math, University of Nebraska, Lincoln; Hampshire College Summer Studies in Mathematics, Amherst, Massachusetts; MathPath, University of Vermont, Burlington; Michigan Math and Science Scholars Summer Program, University of Michigan, Ann Arbor; PROMYS, Boston University; PROTaSM (Puerto Rico Opportunities for Talented Students in Mathematics), University of Puerto Rico, Mayaguez; Ross Mathematics Program, Ohio State University, Columbus; and Texas State University Honors Summer Math Camp, Texas State University, San Marcos.

Tenth awards, 2009: Achievement in Mathematics Program (AMP), Lamar University; All Girls/All Math, University of Nebraska, Lincoln; Hampshire College Summer Studies in Mathematics (HCSSiM), Hampshire College; MathPath, Colorado College, Colorado Springs; Michigan Math and Science Scholars Summer Program, University of Michigan, Ann Arbor; PROMYS (Program in Mathematics for Young Scientists), Boston University; PROTaSM (Puerto Rico Opportunities for Talented Students in Mathematics), University of Puerto Rico, Mayagüez Campus; Research Science Institute, Massachusetts Institute of Technology; Ross Mathematics Program, Ohio State University, Columbus; Texas State University Honors Summer Math Camp, Texas State University, San Marcos.

Eleventh awards, 2010: All Girls/All Math, University of Nebraska, Lincoln; Lamar Achievement in Mathematics Program (LAMP), Lamar University; MathPath, Macalester College; PROMYS (Program in Mathematics for Young Scientists), Boston University; PROTaSM (Puerto Rico Opportunities for Talented Students in Mathematics), University of Puerto Rico, Mayagüez Campus; Research Science Institute, Massachusetts Institute of Technology; Stanford University Mathematics Camp (SUMaC), Stanford University; Stony Brook Mathematics Camp, State University of New York at Stony Brook; Texas State Honors Summer Math Camp, Texas State University; Young Scholars Program, University of Chicago.

Twelfth awards, 2011: All Girls/All Math, University of Nebraska, Lincoln; Canada/USA Mathcamp, Reed College, Portland, Oregon; Lamar Achievement in Mathematics Program (LAMP), Lamar University, Beaumont, Texas; MathPath, Colorado College, Colorado Springs; PROMYS, Boston University; PROTaSM (Puerto Rico Opportunities for Talented Students in Mathematics), University of Puerto Rico, Mayagüez Campus; Research Science Institute, Massachusetts Institute of Technology; Ross Mathematics Program, The Ohio State University; Texas State Honors Summer Math Camp, Texas State University, San Marcos; Young Scholars Program, University of Chicago.

Thirteenth awards, 2012: Canada/USA Mathcamp; Governor's Institutes of Vermont: Mathematical Sciences; Hampshire College Summer Studies in Mathematics (HCSSiM); Lamar Achievement in Mathematics Program (LAMP; MathPath; Mathworks Honors Summer Math Camp; PROMYS; PROTaSM (Puerto Rico Opportunities for Talented Students in Mathematics); Research Science Institute; Ross Mathematics Program; Stanford University Mathematics Camp (SUMaC); Summer Program in Mathematical Problem Solving; Young Scholars Program

Fourteenth awards, 2013: Girls/All Math, University of Nebraska; Camp Euclid, online; Canada/USA Mathcamp, University of Puget Sound, Tacoma, WA; Hampshire College Summer Studies in Mathematics (HCSSiM), Hampshire College, Amherst, MA; LSU Mathcircle Summer Enrichment Program, Louisiana State University; MathPath, Macalester College, Saint Paul, MN; Mathworks Honors Summer Math Camp, Texas State University, San Marcos, TX; Michigan Math and Science Scholars Summer Program, University of Michigan, Ann Arbor; New York Math Circle High School Summer Program, NYU Courant Institute of Mathematical Sciences, New York; PROMYS, Boston University, MA; PROTaSM (Puerto Rico Opportunities for Talented Students in Mathematics), University of Puerto Rico, Mayagüez; Research Science Institute, Massachusetts Institute of Technology, Cambridge, MA; Ross Mathematics Program, The Ohio State University, Columbus, OH; Stanford University Mathematics Camp (SUMaC), Stanford University, CA; Summer Program in Mathematical Problem Solving, Bard College, NY; Young Scholars Program, University of Chicago, IL.

Next awards (for summer 2014): March 2014.

Award for an Exemplary Program or Achievement in a Mathematics Department

This award was established in 2004 to recognize a department which 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. Examples might include a department that runs a notable minority outreach program, a department that has instituted an unusually effective industrial mathematics internship program, a department that has promoted mathematics so successfully that a large fraction of its university's undergraduate population majors in mathematics, or a department that has made some form of innovation in its research support to faculty and/or graduate students or which has created a special and innovative environment for some aspect of mathematics research. Departments of mathematical sciences in North America that offer at least a bachelor's degree in mathematical sciences are eligible. The prize is awarded annually. For the first three awards (2006-2008), the prize amount was US$1,200. The prize was endowed by an anonymous donor in 2008, and, starting with the 2009 prize, the amount is US$5,000.

Nomination process: A letter of nomination may be submitted by one or more individuals. Nomination of the writer's own institution is permitted. The letter should describe the specific program(s) for which the department in being nominated as well as the achievements which make the program(s) an outstanding success and may include any ancillary documents which support the success of the program(s). The letter should not exceed two pages, with supporting documentation not to exceed an additional three pages. Nominations should be submitted to the Office of the Secretary. Nominations received by September 15 will be considered for the award presented the following January.

First award, 2006: Harvey Mudd College.

Second award, 2007: University of California, Los Angeles (UCLA).

Third award, 2008: University of Iowa. See also http://www.ams.org/notices/200805/tx080500599p.pdf.

Fourth award, 2009: University of Nebraska-Lincoln. See also http://www.ams.org/notices/200905/rtx090500622p.pdf.

Fifth award, 2010: North Carolina State University. See also http://www.ams.org/notices/201005/rtx100500653p.pdf.

Sixth award, 2011: University of Arizona. See also http://www.ams.org/notices/201105/rtx110500718p.pdf.

Seventh award, 2012: Department of Mathematics at Bryn Mawr College. See also http://www.ams.org/notices/201205/rtx120500667p.pdf.

Eighth award, 2013: Mathematics Department at the University of Texas at Arlington. See also http://www.ams.org/notices/201305/rnoti-p608.pdf.

Next award: Spring 2014.

Mathematical Art Exhibition Award

This award "for aesthetically pleasing works that combine mathematics and art" was established in 2008 through an endowment provided by an anonymous donor who wishes to acknowledge those whose works demonstrate the beauty and elegance of mathematics expressed in a visual art form. The exhibition takes place every January at the Joint Mathematics Meetings. First (US$500), second (US$300), and third place (US$200) awards are made annually. For further information about this award, email the AMS Public Awareness Office (paoffice@ams.org).

First Awards, 2009: First place award to Goran Konjevod, for his origami work, "Wave (32), 2006"; second place award to Carlo Séquin, for his sculpture, "Figure-8 Knot, 2007"; and third place award to Robert Fathauer, for "Twice Iterated Knot No. 1, 2008".

Second Awards, 2010: First place award to Robert Bosch for "Embrace"; second place award to Harry Benke for "The Vase"; and third place award to Richard Werner for "Meditations on f(x,y) = x2/2 + xy/2 - y4/8".

Third Awards, 2011: First place award to to Margaret Kepner for "Magic Square 25 Study"; second place award to Carlo H. Séquin for "Torus Knot (5,3)"; and third place award to Anne Burns for "Circles on Orthogonal Circles".

Fourth Awards, 2012: First place award to Sylvie Donmoyer for "Still Life with Magic Square" ; second place award to Thomas Hull, Robert Lang, and Ray Schamp for "Pleated Multi-sliced Cone"; and third place award to Carlo H. Séquin for "Lawson's Minimum-Energy Klein Bottle".

Fifth Awards, 2013: Best photograph, painting, or print: Vladimir Bulatov for "Bended Circle Limit III".

Best textile, sculpture, or other medium: Kevin Lee for "Inlaid Wooden Boxes of Makoto Nakamura's Tessellations".

Honorable Mention: Susan Goldstine for "Tessellation Evolution".

Next Award: January 2014.

The Award for Mathematics Programs that Make a Difference

This award was established in 2005 in response to a recommendation from the AMS's Committee on the Profession that the AMS compile and publish a series of profiles of programs that:

1) aim to bring more persons from underrepresented minority 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 are replicable models.

Preference will be given to programs with significant participation by underrepresented minorities. Two programs are highlighted annually.

First award, 2006: Summer Institute in Mathematics for Undergraduates (SIMU), Universidad de Puerto Rico, Humacao; and Graduate Program, Department of Mathematics, University of Iowa.

Second award, 2007: Enhancing Diversity in Graduate Education (EDGE), Bryn Mawr College and Spelman College; and Mathematical Theoretical Biology Institute (MTBI), Arizona State University.

Third award, 2008: Summer Undergraduate Mathematical Science Research Institute (SUMSRI), Miami University (Ohio) and Mathematics Summer Program in Research and Learning (Math SPIRAL), University of Maryland, College Park. See citations and descriptions of programs. See *Notices of the AMS* article.

Fourth award, 2009: Department of Mathematics at the University of Mississippi and the Department of Statistics at North Carolina State University. See citations and description of programs.

Fifth award, 2010: Department of Computational and Applied Mathematics (CAAM) at Rice University and the Summer Program in Quantitative Sciences at the Harvard School of Public Health. See citations and descriptions of programs. See *Notices of the AMS* article, May 2010, p. 650.

Sixth award, 2011: Department of Mathematics at North Carolina State University and the Center for Women in Mathematics and the Center's Post-baccalaureate Program at Smith College. See citations and descriptions of programs. See *Notices of the AMS* article, May 2011, p. 713.

Seventh award, 2012: Mathematical Sciences Research Institute in Berkeley. See citations and descriptions of programs. See *Notices of the AMS* article, May 2012, p. 665.

Eighth award, 2013: The Nebraska Conference for Undergraduate Women in Mathematics. See citations and descriptions of programs. See *Notices of the AMS* article, May 2013, p. 606.

Next award: Spring 2014. For information about the nomination process, please see `www.ams.org/programs/diversity/emp-makeadiff` or contact Dr. Ellen Maycock, AMS Executive Director for Meetings & Professional Services, at `ejm@ams.org` or phone (800-321-4267).

The Karl Menger Memorial Awards

Family members of the late Karl Menger were the major contributors to a fund established at Duke University. The majority of the income from this fund is to be used by the Society for annual awards at the International Science and Engineering Fair.

First award, 1990: Daniel K. Dugger, Joshua Erlich, Joshua B. Fischman, Min-Horng Chen, Matthew Baker, Michael L. Harrison, Virginia A. DiDomizio.

Second award, 1991: Monwhea Jeng, Hans Christian Gromoll, Jesse L. Tseng, Andrew Olstrom Dittmer, Matthew A. Neimark, Rageshree Ramachandran, Jeb E. Willenbring.

Third award, 1992: Mahesh Kalyana Mahanthappa, Harrison Kwei Tsai, Andrew Olstrom Dittmer, Jonobie Dale Baker, Joshua Brody, Yen-Hsiang Li, Robert Jordon Pollack.

Fourth award, 1993: Mahesh Kalyana Mahanthappa, Steve Shaw-Tang Chien, Andrew Olstrom Dittmer, Moon Duchin, Robert Michael Kirby II, Sarah Ann Lord, Anna Ruth Terry.

Fifth award, 1994: Davesh Maulik, Eric Matthew Dennis, Sarah Ann Lord, Timothy Stephen Eller, Rahul Manu Kohli, Fam-ye Lin, Benedek Valko, Mary Kathleen Clavenna, Vinay Kumak Goyal-Singhal, Jan Kristian Haugland, Wes Andres Watters, Ian George Zacharia.

Sixth award, 1995: Davesh Maulik, Benjamin Michael Goetz, Jacob Lurie, Daniel Kalman Biss, Samit Dasgupta, Yueh-Hsing Lin, Claus Mazanti Sorensen, Theodore Haw-Yun Hwa, Samuel Jacob Klein Jr., Katherine Anne Paur, Bridget Helen Penny, Scott Nicholas Sanders.

Seventh award, 1996: Davesh Maulik, Nicholas Karl Eriksson, Logan Joseph Kleinwaks, Eric Jon Landquist, Vanesa Miranda-Diaz, Jason Charles Stone, Lauren Kiyomi Williams, Ryan Thomas Hebert, Kendrick Norris Kay, Scott Nicholas Sanders, Claus Mazanti Sorensen, Yvette Karen Wood.

Eighth award, 1997: Davesh Maulik, Nicholas Eriksson, Jeremy Rahe, Jennifer Pelka, Yen-Jen Chen, Sylvain Halle, Melanie Schechter, Matthew Seligman, Thomas Mack, Susannah Rutherglen, Jy-Ying Janet Chen, Chun-Hsiang Fu, Daniel Ying-Jeh Little.

Ninth award, 1998: Jonathan Adam Kelner, Michael Yanchee Lee, Daniel Yamins, Alexey Evgenjevitch Eroshin, Sarah Flannery, Jeremy Ryan Rahe, Jennifer Rose Walk, Richard Lee Barnes, Matthew Christopher Ong, David Carl Rennard, Anna Welling Salamon, Hui Yu.

Tenth award, 1999: Amit Kumar Sabharwal, Andrew Chi, Jennifer Lynn Pelka, Ching-Tang Chen, C. Andrew McManus, Jennifer Rose Walk, Heidi Lee Williams, Jack Nelson Bewley, Adam Douglas Bryant, Jason A. Loy, John William Pope, Bryce Leitner Roberts.

Eleventh award, 2000: Jayce R. Getz, Aadel Ahmed Chaudhuri, Zachary Howard Cohn, Ching Tang Chen, Elaine Pei-San Gee, Siarhei Markouski, Ilya Malakhovsky, Vassily Vladimirovich Starodubtsev, Daniel Richard Green, Daniyar Z. Kamenov, Craig Allan Schroeder.

Twelfth award, 2001: Abdur Rasheed Sabar, Yuri Georgievich Kudryashov, Serge A. Tishchenko, Jason Wah Lone Chiu, Craig Allen Schroeder, Hasuk Francis Song, Daniel Wichs, Jennifer Shyamala Sayaka Balakrishnan, Christopher Ryan Bruner, Lindsey Jo Cable, Michael Harry Kaleta, Matthew Howard Stemm, Heon Joon Choe, Jesse Scott Trana.

Thirteenth awards, 2002: Jacob Licht, Matthew Aaron Tesch, Andrew Michael Korth, Chun-Chen Yeh, Liang Chen, Ashum Karahanovich Kaibhanov, Amanda Bryce Shaw, Mary Augusta Brazelton, Nikita Rozenblyum, Jonathan Charles Zweig, Boris O. Figovsky, Ronli Phyllis Diakow.

Fourteenth awards, 2003: Andrew Michael Leifer, Raymund Chun-Hung To, David Guillaume Pothier, Alexandr V. Medvedev, Ethan James Street, Hyeyoun Chung, Anatoly Preygel, Lester Wayne Mackey, Evgeniy E. Loharu, Sergey O. Ivanov, Robert Shea Bracco, Brian Todd Rice, Alexey V. Baran, Evgeny A. Amosov, Artem G. Viktorov, Jeremy Takashi Warshauer, Alan Craig Taylor, Hannah Chung.

Fifteenth awards, 2004: Brett Alexander Harrison, Ilya Gurwich, Brian Todd Rice, Sam Jay Lewallen, Brianna Rachel Satinoff, Huan-Chun Yeh, Ning Zhang, Carolos Eduardo Arreche-Aguayo, Tair Assangali, Nurlan Bakitzhanov, Allison Paige Berke, Ginger Beardslee Howell, Nimish P. Ramanlal.

Sixteenth awards, 2005: Scott Duke Kominers, Samuel Mohun Bhagwat, Matthew Ryan Tierney, Elad Oster, John Michael Sillcox, Carlos Manuel Fonseca, Manuel Luis Rivera, Niket Ranjan Pandey, Robert Thomas Cordwell, Paul Francis Jacobs, Valentina N. Dobrovolskaya, Vladimir N. Trubnikov, Oleg V. Mikhaylovsky, Mikhail A. Ptichkin.

Seventeenth awards, 2006: Michael Anthony Viscardi, Daniel Abraham Litt, Brett Alexander Harrison, Anarghya A. Vardhana, Gleb A. Pogudin, Nicholas Michael Wage, Sohan Venkat, Meelap Vijay Shah, Manuel Luis Rivera-Morales, Bakhytzhan Baizhanov.

Eighteenth awards, 2007: Dmitry Vaintrob, Cheng-Tao Chung, Daniel K. Bezdek, Christopher Lopez, Hagai Helman, Albert C. Liu, Nikita M. Savushkin, Lado Meskhishvili, Almas U. Abdulla, Avi W. Levy, Ardit Kroni, Alexey S. Telishev.

Nineteenth awards, 2008: Alexander Lee Churchill, Shravani Mikkilineni, David Alex Rosengarten, Eric Kerner Larson, Alex Hao Chen, Paul Myer Kominers, Matthew Michael Wage, Swara Satya Kopparty, Sana Raoof, Nurlan Taiganov, Artem A. Timoshenko, Sarah Lee Sellers.

Twentieth awards, 2009: Joshua Vekhter, Andrei Triffo, Yale Wang Fan, Almas Abdulla, Sarah Lee Sellers, Sohini Sengupta, Sameer Kirtikumar Deshpande, Jeffrey Chan, Alicia Zhang, Martin Augustine Camacho, Michael Christopher Yurko, Wenhan Cui, Matthew Henry Stoffregen, Nilesh Tripuraneni.

Twenty-first awards, 2010: Yale Wang Fan, Joshua W. Pfeffer, Anirudha Balasubramanian, Kate A. Geschwind, Almas Abdulla, Jacob B. Hurwitz, Evgenia I. Alekseeva, Akhil Mathew, Jonathan F. Li.

Twenty-second awards, 2011: Manosij G. Dastidar, John Tilla Parish IV, Tzu-Hsuan Su, Vasily Sergeevich Bolbachan, Benjamin Jerome Kraft, Anirudh Prabhu, Ryan Thomas Baker, Rebecca Chen, Kate Alexandra Geschwind, Georgiy Vladimirovich Kolyshev, Aaron Lawrence Zweig.

Twenty-third awards, 2012: Fabian Henneke, Xianghui Zhong, Danial Sanusi, Raman A. Birulia, Katherine Leigh Cordwell, Viachaslau I. Murashka, Danila Alexandrovich Baygushev, Sidharth Dhawan, Anirudh Prabhu, Frederik Benzing, Rashad Abdulla, Anita Kummamuri Rao, Lyndon Ji, Youkow Homma, Theresa Lynn McLaughlin, Mark Alan Holmstrom.

Twenty-fourth awards, 2013: Colin Aitken, Stanislav I. Atanasov, Hannah Larson, Asbjorn C. Nordentoft, Simanta Gautam, Ilya Kirillov, Maksim L. Bezrukov and Aliasksandr O. Stadolnik, Rumen R. Dangovski, Yu-Fang Hsu, Sarah Shader, Akhil Nistala, David Pan.

Next awards: June 2014.

Public Policy Award

This award was established in 2007 by the American Mathematical Society (AMS) to recognize a public figure for sustained and exceptional contributions to public policies that foster support for research, education, and innovation. The award will be given annually, starting in 2009.

The Award for Distinguished Public Service

This award was established by the AMS Council in response to a recommendation from their Committee on Science Policy. The US$4,000 award is presented every two years to a research mathematician who has made a distinguished contribution to the mathematics profession during the preceding five years.

First award, 1990: To Kenneth M. Hoffman for his outstanding leadership in establishing channels of communication between the mathematical community and makers of public policy as well as the general public.

Second award, 1992: To Harvey B. Keynes for his multifaceted efforts to revitalize mathematics education, especially for young people.

Third award, 1993: To Isadore M. Singer in recognition of his outstanding contributions to his profession, to science more broadly, and to the public good by bringing the best of mathematics and his own insights to bear on the activities of the National Academy of Sciences; on committees of the National Research Council, including the two so-called David Committees on the health of the mathematical sciences, and the Committee on Science, Engineering, and Public Policy; on the President's Science Advisory Council; on decisions of Congress, through testimony concerning the support of mathematics and mathematical research; and on a host of critical situations over many years in which his wisdom and intervention helped gain a hearing for the problems of his community and the contributions it makes to the nation.

Fourth award, 1995: To Donald J. Lewis for his many contributions to mathematical education, mathematics policy, and mathematical research and administration during a career that has spanned several decades.

Fifth award, 1997: No award made.

Sixth award, 1998: To Kenneth C. Millett for his work devoted to underrepresented minority students in the mathematical sciences. Professor Millett founded the University of California, Santa Barbara, Achievement Program and directed the mathematics component of the Summer Academic Research Internship and the Summer Institute in Mathematics and Science at UCSB.

Seventh award, 2000: To Paul J. Sally Jr. for the quality of his research, for his service to the [American Mathematical]

Society as trustee, but more importantly for his many efforts in improvement of mathematics education for the nation's youth and especially for members of minority and underrepresented groups and for his longitudinal mentoring of students, in particular the mathematics majors at Chicago.

Eighth award, 2002: To Margaret H. Wright for notable contributions to the federal government and the scientific community and for encouraging women and minority students.

Ninth award, 2004: To Richard A. Tapia for inspiring and teaching thousands of people (from elementary school students to senior citizens) to study and appreciate the mathematical sciences.

Tenth award, 2006: To Roger Howe for his multifaceted contributions to mathematics and to mathematics education.

Eleventh award, 2008: To Herbert Clemens for his superb research in complex algebraic geometry, his continuing efforts in education, and his seminal role in the founding and continuation of the Park City/IAS Mathematics Institute.

Twelfth award, 2010: To Carlos Castillo-Chavez for having a major impact with his efforts and activities in improving the representation in the broad mathematical sciences of the nation's traditionally underrepresented and economically disadvantaged students.

Thirteenth award, 2012: To William McCallum for his energetic and effective efforts in promoting improvements to mathematics education.

Next award: January 2014.

Citation for Public Service

To provide encouragement and recognition for contributions to public service activities in support of mathematics, the Council of the Society established the Citation for Public Service. The award is no longer being made.

First award, 1991: Andre Z. Manitius for the contributions he made to the mathematical community while employed in the Division of Mathematical Sciences at the National Science Foundation.

Second award, 1992: Marcia P. Sward for her contributions toward establishing and directing the Mathematical Sciences Education Board from its inception in the fall of 1985 until August 1989.

Third award, 1998: Liang-Shin Hahn and Arnold E. Ross. Liang-Shin Hahn for carrying forward and developing the New Mexico High School Mathematics Contest and for exposition and popularization of mathematics attractive to and suitable for potential candidates for the contest and others with similar intellectual interests. Arnold E. Ross for inspiring generations of young people through the summer mathematics programs he created and has continued to run for nearly 40 years.

AAS-AMS-APS Public Service Award

This award was established in 1999 by the American Mathematical Society (AMS), the American Astronomical Society (AAS), and the American Physical Society (APS) to recognize a public figure for his or her sustained and exceptional contributions to public policies that foster support for research, education, and industrial innovation in the physical sciences and mathematics. As of January 2007, the AMS no longer participates in this award, but instead offers the AMS Public Policy Award.

First award, 2000: To William Frist, Joseph L. Lieberman, and Harold Varmus.

Second award, 2001: To Vernon Ehlers and Neal Lane.

Third award, 2002: To James T. Walsh and Barbara Mikulski.

Fourth award, 2003: To Sherwood L. Boehlert, Alan B. Mollohan, and Pete V. Domenici.

2004: No award made.

2005: No award made.

2006: No award made.

Waldemar J. Trjitzinsky Memorial Awards

The Society received a bequest from the estate of Waldemar J., Barbara G., and Juliet Trjitzinsky, the income from which is used to assist students who have declared a major in mathematics at a college or university that is an institutional member of the AMS. These funds help support students who lack adequate financial resources and who may be in danger of not completing the degree program in mathematics for financial reasons. Each year the Society selects a number of geographically distributed schools who in turn make one-time awards to beginning mathematical students to assist them in pursuit of careers in mathematics. The amount of each scholarship is currently US$3,000, and the number of scholarships awarded each year varies.

First award, 1991: Duke University (Robert Lane Bassett, Linie Yunwen Chang, Kara Lee Lavender), University of Scranton (Thomas A. Shimkus), Montana State University (Melissa Cockerill, Deborah Fagan, Sherry Heis), Howard Payne University (Pamela Jo Chaney).

Second award, 1992: Allegheny College (Julianne Stile), Memphis State University (Cassandra Burns), University of California at Irvine (James Anthony Nunez), University of Puerto Rico (Juan Ramon Romero-Oliveras).

Third award, 1993: University of California at Los Angeles (Michelle L. Lanir), State University of New York at Geneseo (Jodi C. Wright), Eastern New Mexico University (Rebecca K. Moore), University of Virginia (Mikhail Krichman).

Fourth award, 1994: Boise State University (William Hudson and Margaret Norris), Illinois Institute of Technology (Guanghong Xu), Temple University (Coleen Clemetson), University of Maryland at College Park (Mikhail G. Konikov).

Fifth award, 1995: University of Arizona (Mark Robert Moseley), Arkansas State University (Donna J. Shepherd), Mississippi State University (Clayton T. Hester), Montclair State College (James R. Jarrell III).

Sixth award, 1996: Murray State University (Christie M. Safin), Stanford University (Andreea Nicoara), Union College (Allison Pacelli), Western Illinois University (Lorna Renee Sanders).

Seventh award, 1997: Georgetown University (Martin Akguc), Loyola Marymount University (Laura Steiner, Claudia Catalan, Elizabeth Madrigal), New York University

(Emily Press), Southern Illinois University at Carbondale (Laura Wasser).

Eighth award, 1998: Stevens Institute of Technology (Kelly Cornish), Georgia State University (Kevin A. Wilson), Iowa State University (Matthew A. Halverson), University of Nevada at Las Vegas (Dumitru C. Tutuianu).

Ninth award, 1999: City University of New York (Hulya Cebeciouglu), Reed College (Jeremy Copeland), University of Texas at San Antonio (Danielle Lyles), Western Kentucky University (Marcia Jean Mercer).

Tenth award, 2000: California State University at Long Beach (Yen Hai Le), Case Western Reserve University (Alexander Statnikov), Clarkson University (Matthew Bartholomew), University of Houston (Alyssa Burns).

Eleventh award, 2001: Columbia University (Alexander Ivanov Sotirov), Florida Atlantic University (Gregory Nevil Leuchiali Maxwell), Henderson State University (Ann Smith), John Carroll University (Andrea C. Forney), Seattle University (Sinead Pollom), University of Texas at Austin (Virginia Roberts), University of Utah (Paul T. Watkins), Worcester Polytechnic Institute (Yakov Kronrod and Megan Lally).

Twelfth award, 2002: Stephen F. Austin State University (Marcus A. Arreguin), Bates College (Challis Kinnucan), Brigham Young University (Julie Brinton), The College of William and Mary (Suzanne L. Robertson), Furman University (Kevin L. Smith), University of Hartford (Aimee J. Groudas), University of Southern California (Peter Kirkpatrick), University of Texas at Dallas (Kevin R. Pond).

Thirteenth award, 2003: Bryn Mawr College (Thida S. Aye), Minnesota State University at Mankato (Andrew Richard Tackmann), University of Maryland at Baltimore County (Maria Christin Llewellyn), Colorado College (Rahbar Virk), California State University, Hayward (Sarah Deiwert and Angela Martinho), Lehigh University (Timothy P. Lewis), State University of New York at Potsdam (Bishal Thapa).

Fourteenth award, 2004: Beloit College (Laura Wolfram), Lafayette College (Prince Chidyagwai, Ekaterina Jager, Blerta Shtylla), Michigan State University (Antonio Veloz), University of Pennsylvania (Daniel Pomerleano), Portland State University (Kathryn Carr and Cass Bath), Santa Clara University (Olivia Gistand).

Fifteenth award, 2005: Abilene Christian University (Carissa Joy Strawn), Amherst College (Jennifer A. Roberge), Arizona State University (Yukiko Kozakai), University of Missouri, Kansas City (Melanie Marie Meyer), University of North Carolina at Greensboro (Christian Sykes), University of Rhode Island (Christopher Piecuch), Ohio State University (Sophia Leibman and Gabor Revesz).

Sixteenth award, 2006: California State University, San Bernardino (Lorena Pulido and Jennifer Renee Winter), University of Missouri, Rolla (Sean Michael Eagan), University of Central Missouri (Khadijah Shadeed), Boston College (Elizabeth Rini), Eckerd College (Elizabeth R. Morra), University of California, San Diego (John Roosevelt Quinn), Swarthmore College (Adam Joseph Lizzi).

Seventeenth award, 2007: Susan Christine Massey (University of Washington), Amy Streifel (Lewis and Clark College), Rosemary Holguin (SUNY at New Paltz), Emily Jean Ognacevic (Saint Louis University), Betsy Kay Barr (University of Tennessee Knoxville), Kayla Rose Boyle (University of Northern Iowa).

Eighteenth award, 2008: Aaron Peterson (Luther College), Faith L. Buell (Wright State University), Phillip David Lorren (Georgia Southern University), Daksha Shakya (Ithaca College), Joseph Zancocchio (College of Staten Island (CUNY)), Amanda J. Mueller (University of Wisconsin Milwaukee), Hans Parshall (Humboldt State University).

Nineteenth award, 2009: Alison Lynette Ashe (University of Vermont); Kendall Olivia Brown (Truman State University); Zehui Chen (Smith College); Jonathan Jordan Edwards (Kenyon College); David Hassan (University of California, Santa Barbara); Ana-Cristina Cerda Jimenez (California State University, Fresno); Mantatisi S. Walker (Jackson State University).

Twentieth award, 2010: Vianey Carolina Leos Barajas (California State University, Bakersfield); Langston W. Joiner (University of Cincinnati); Michelle Chu (Emory University); Perla Salazar (Kansas State University); Dana C. Haymon (University of Oklahoma); James S. Wratten Jr. (Rochester Institute of Technology); Bebi Z. G. Rajendra (York College).

Twenty-first award, 2011: David Samuel Allen (Colorado State University); Xavier Eduardo Garcia (University of Minnesota Twin Cities); Jeffrey Hart (California State University San Marcos); Amina S. Mendez (Ohio Wesleyan University); Amanda Nicole Rodriguez (Texas A&M University Corpus Christi); Tyler Wippel (Central Michigan University); Maocai Wu (Brooklyn College-CUNY).

Twenty-second award, 2012: Anakaren Santana (University of California, Berkeley); Emily Mavaddat (University of Denver); Abigail Margaret Skelton (Lebanon Valley College), Benjamin Levi Heebner (Pennsylvania State University); Tyler Raven Billingsley (Purdue University Calumet); Matthew Phillip Larson (Hendrix College); Ryan T. Uding (University of Missouri Saint Louis).

Next awards: Fall 2013.

Report of the Executive Director, State of the AMS, 2013

November 2012 marked the beginning of the Society's 125th year. The AMS will observe its milestone anniversary on November 24 this year. I am pleased to report that the AMS remains flexible, robust, financially healthy, and very active in serving the mathematics community, thanks to the efforts of members and a dedicated staff. Several notable events and transitions occurred in 2012.

• Robert Daverman completed fourteen years as secretary of the AMS at the end of January 2013. The job expanded greatly during his tenure. He pursued its demands with boundless energy and dedication, for which the Society owes genuine gratitude.

• The Joint Mathematics Meetings (JMM) in Boston in January 2012 broke records for attendance and for the number of talks and Special Sessions. More than 6,600 participants accounted for an 18 percent increase from the year before!

• The print version of *Mathematical Reviews* published its last issue in December 2012. This was a bittersweet transition whose time had come as the online version, MathSciNet®, continues to be enriched with new features that simply cannot be duplicated in print.

• More than 1,100 Fellows of the AMS were invited in 2012 and formally inducted in January 2013 at the Joint Mathematics Meetings in San Diego.

Photograph by Sandy Huffaker.

Fellows reception, January 2013, San Diego.

Current Issues

The work of the Society is often driven by exogenous issues affecting the mathematics community. In 2012 education policy was at the forefront. In February the President's Council of Advisors on Science and Technology (PCAST) released the report *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*, which has spurred a great deal of activity from the Society's leadership and from the Committee on Education. Some elements of the PCAST report are controversial, but more to the point, it has stimulated new attention to important initiatives in undergraduate mathematics teaching and learning.

Online education was transformed in 2012 by the emerging availability of Massive Open Online Courses (MOOCs), through which a single course can reach tens of thousands of students. MOOCs offer new opportunities and new challenges for higher education. They are potentially revolutionary, and their long-term impact is yet to be determined. The AMS is exploring ways that it might facilitate discovery of and access to online educational resources for mathematics.

The Common Core State Standards for Mathematics have been adopted by forty-five states and are currently being implemented. The development and implementation of the standards has been a priority of the Conference Board of the Mathematical Sciences (CBMS) for several years. In 2012 the AMS (in cooperation with the MAA) and CBMS published *The Mathematical Education of Teachers II.* MET II is a professional development resource for PreK–12 teachers of mathematics. The content of the new edition has been aligned with the Common Core Standards.

The public advocacy role of the Society and of individual members became more important in dealing with distractions that gained far more attention than they ever should have received in mass media. The important outcome here is that members of the mathematics community have written eloquent rebuttals in the press to the politicizing of the Common Core State Standards, to an op-ed column questioning the importance of algebra in basic education, and to the claim by a distinguished biologist that mathematics need not be an important component of the education of a scientist. The AMS will continue efforts to facilitate contributions by the community in presenting the "public face" of mathematics.

Open access continues to be a major issue for scholarly publishing. Briefly, the debate about open access publishing is concerned with different approaches to making research articles freely available to everyone. The AMS started discussions in September 2012 about a proposal for establishing two new open access journals. The discussions culminated in April 2013, when the Council approved an experiment to launch *Proceedings of the American Mathematical Society, Series B,* and *Transactions of the American Mathematical Society, Series B,* to begin publication in 2014.[1] A benefit for the entire mathematics community is that the AMS is able to publish more of the expanding research literature at no cost to libraries or readers.

Highlights of 2012 Activities

The year 2012 was a very busy one for the Society in all of its principal areas of activity. I shall highlight a number of specific accomplishments in publishing, professional programs and services, meetings, and outreach and advocacy for the mathematics community.

[1] *Robert M. Harington, "New journals from AMS",* Notices of the AMS ***60****, no. 8, pp. 1064–65.*

Serving the Community

The Society continued to provide its well-known traditional programs as well as offer new ones for members and mathematicians at all levels. The pilot program for AMS Graduate Student Chapters was introduced, which resulted in several applications to establish chapters. The program is now open to all departments and will provide direct support to help groups of students become engaged in mathematical research. The AMS is pleased to offer the chapters, together with the Graduate Student Travel Grants program and very active AMS Graduate Student Blog, to serve the interests and needs of graduate students in the mathematical sciences.

Each year approximately 300 graduate students receive travel support from the AMS to attend meetings. There were 103 Graduate Student Travel Grant recipients at JMM 2013; they were treated to a brunch where they could meet other students and members of the AMS leadership. In 2012, 187 graduate students accepted travel grants to attend AMS sectional meetings. The student travel grants are supported by one generous anonymous donor.

Grad student brunch in San Diego.

Meetings are thriving: 6,189 mathematicians, including many students, took part in JMM 2013 in San Diego and contributed to seventy-nine Special Sessions. In contrast, the attendance at JMM in San Diego in 2008 was 4,600. The Society also held eight Sectional Meetings in 2012 with total attendance of over 3,000.

The Mathematics Research Communities (MRC) program continues to be highly successful. The 2012 MRC summer conferences at the Snowbird Resort in Utah drew 119 early-career mathematicians. These conferences, funded by the National Science Foundation, are part of this AMS program that also includes special sessions at JMMs, ongoing support from conference organizers, and a continuation of the connections and collaborations via electronic forums and occasional face-to-face meetings. Through 2012, a total of 529 participants have taken part in the MRC program.

> Overall, I enjoyed it immensely; I feel I became stronger as a mathematician, and I got a chance to meet and work with some amazing people. Thank you!—*2012 MRC participant*

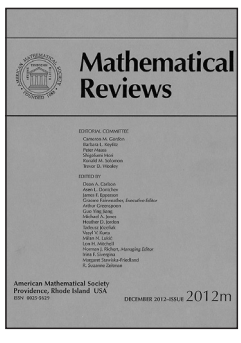
MRC workshop.

One of the major developments in communications was the increased AMS activity on social media. Followers from around the world can find news, comment on topics, initiate and join discussions, and view and comment on videos on AMS Facebook, Twitter, LinkedIn, and YouTube. I welcome AMS members and others to become part of the community on these social networks.

An important improvement to the AMS website in 2012 was the enhancement of the Prizes and Awards area, which now enables browsing of the archive by prize or award, recipient name and/or year; includes upcoming deadlines for nominations; and accepts online nomination submissions. I invite the mathematical community to peruse the list of impressive recipients and to nominate colleagues.

Publications

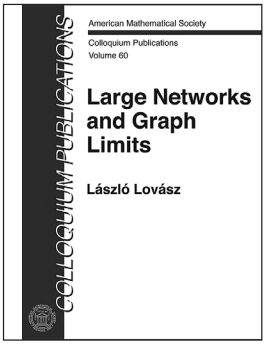
Mathematical Reviews (MR) added almost 125,000 items to the MR database in 2012, including more than 85,000 reviews. The size of the mathematics research literature continues to grow at a rate of about 3.5 percent per year, steadily increasing the workload for MR. Nevertheless, the staff of MR continues to enrich MathSciNet® with features that benefit its users. In 2012 thirty new Reference List Journals were added, Preliminary Data was implemented to accelerate the availability of information about new papers, and mobile pairing was added to facilitate access from mobile devices.



The Contemporary Mathematics series was offered as an electronic subscription product in 2012. At the same time, the backlist of about 550 Contemporary Mathematics volumes was also offered to research libraries as a collection of eBooks. The Society added the Proceedings of Symposia in Applied Mathematics (seventy-one volumes, 1949–2012) and Proceedings of Symposia in Pure Mathematics (eighty-six volumes, 1959–2012) to the eBook collections in 2012. The retrodigitization of other

principal series—Mathematical Surveys and Monographs, Graduate Studies in Mathematics, and Student Mathematical Library—was also initiated.

The AMS also continued to develop its Undergraduate Texts series by publishing several high-quality undergraduate textbooks in various areas of mathematics and making them available to students at prices that are significantly lower than textbook prices from large commercial publishers. The book program also added notable titles to all of the text and research monograph series. Among them were László Lovász, *Large Networks and Graph Limits* (Colloquium Publications); Peter Duren, *Invitation to Classical Analysis* (Pure and Applied Undergraduate Texts); John B. Walsh, *Knowing the Odds: An Introduction to Probability* (Graduate Studies in Mathematics); and David M. Clark, *Euclidean Geometry: A Guided Inquiry Approach* (Mathematical Circles Library).



The four primary research journals published 14,400 pages in 2012. The number of submitted articles continues to increase, and the overall growth of the mathematics literature is steadily increasing. To accommodate the growth, the Society is exploring ways that it can increase the total size of its journals without a commensurate increase in costs to the community. In addition, our creative software groups in Providence and Ann Arbor are improving the delivery of electronic publications. In 2012 enhanced reference lists were added to the abstract pages for the journals, mobile pairing was implemented to simplify delivery of electronic products to mobile devices, and Counter Compliant usage statistics were added to improve information resources for librarians.

Advocacy and Partnerships for Mathematics and Science

The AMS Public Awareness Office continued its support of two popular programs:

The fourth national Who Wants to Be a Mathematician contest for high school students was held at JMM 2013. The national competition is the culmination of qualifying rounds that are open to high school students throughout the U.S. Calvin Deng, a senior from the North Carolina School of Science and Mathematics, won US$5,000 and a TI-Nspire CX for himself and US$5,000 for the math department at his school. Deng was a gold medal winner at the 2012 International Mathematical Olympiad.

AMS posters and Mathematical Moments, a collection of free eye-catching posters on many topics, are the result of collaboration between the AMS Public Awareness Office and graphics arts staff. They are widely distributed and generate many orders and much appreciation from high school teachers and others.

The AMS Washington Office sponsored a congressional briefing in December 2012 to inform members of Congress and congressional staff about the impact of mathematics

Calvin Deng, winner of the 2013 national Who Wants to Be a Mathematician competition.

on important issues of broad interest. James A. Yorke, Distinguished University Professor of Mathematics and Physics at the University of Maryland, presented "Chaos and avalanches in science and socio-political systems". He talked about the science of chaos and how it has completely changed the understanding of physical processes in the last thirty years. His presentation demonstrated how political upheavals have much in common with avalanches and earthquakes.

Long-standing collaboration with other organizations includes the AMS participation in two fellowship programs offered through the American Association for the Advancement of Science (AAAS): Congressional Fellowships and Mass Media Fellowships.

Samuel M. Rankin III, director of the AMS Washington Office, serves as chairman of the Coalition for National Science Funding, a coalition that supports the goal of increasing the national investment in the National Science Foundation's research and education programs. The AMS is one of the participating societies in the Conference Board of the Mathematical Sciences, the International Mathematical Union, and the Joint Policy Board for Mathematics.

Though not without challenges facing all professional societies, the Society continued to fulfill its mission, maintaining excellence in mathematical sciences research, advancing the mathematics profession, supporting mathematics education at all levels, and fostering awareness and appreciation of mathematics.

—Donald McClure
Executive Director

Backlog of Mathematics Research Journals

Journal (Print and Electronic)	Number issues per Year	Approximate Number Pages per Year	2012 Median Time (in Months) from: Submission to Final Acceptance	Acceptance to Print	Acceptance to Electronic Posting	Editor's Current Estimate of Waiting Time between Submission and Publication (in Months) Print	Electronic
Acta Inform.	8	640	4	2	1	6	5
Acta Math.	4	800	10	14	13	24	23
Adv. in Appl. Math.	10	1400	9	3	1	11	9
Adv. Math.	18	9500	13	2	1.3	15	14
Adv. Math. Commun.	4	500	4	5	4	9	8
Algebr. Geom. Topol.	6	3750	8.3	3.6	3.1	11.9	11.4
Algebra Number Theory	10	2560	8.1	13.9	13.4	22	21.5
Algorithmica	12	1500	7	14	8	13	7
Amer. J. Math.	6	1728	NA	NA	NA	16–18	12–14
Anal. PDE	8	2048	8.2	16.7	16.2	24.9	24.4
Ann. Appl. Probab.	6	2615	9.75	12	12	26	26
Ann. Inst. H. Poincare Anal. Lineaire	6	985	8	6	1.4	19	12
Ann. Mat. Pura Appl. (4)	4	960	8.5	11.5	1	20	9
Ann. of Math. (2)	6	2400	17	10	7	12	10
Ann. Probab.	6	2700	7	16.5	16.5	29.5	29.5
Ann. Pure Appl. Logic	12	1959	12	5	1.6	17	16
Ann. Statist.	6	3175	8.5	5.5	5.5	12	12
Appl. Anal.	12	2304	3.5	14.88	1.89	18	5
Appl. Comput. Harmon. Anal.	9	940	10	7	0.6	18	9
Appl. Math. Comput.	24	11531	11	3	1	15	13
Arch. Hist. Exact. Sci.	6	696	3	5	2	5	2
Arch. Math. Logic	8	1040	2	4	1	6	4
Arch. Ration. Mech. Anal.	12	4200	4	6	2	4	1
Ark. Mat.	2	400	9	20	6	24	13
Automatica J. IFAC	12	3193	13	6	4.2	17	16
Balkan J. Geom. Appl.	2	200	5	5	3	8	6
Beitr. Algebra Geom.	2	900	3.5	3	1	6.5	4.5
Bernoulli	4	1460	8	16.5	16.5	26.5	26.5
Bull. Aust. Math. Soc.	6	860	11	15	12	12	11
Bull. Lond. Math. Soc.	6	1344	7.5	7.8	3	13.1	9.9
Bull. Sci. Math.	8	936	1	9	2.5	14	6
Bull. Soc. Math. France	4	600	6	8	6	8	6
C. R. Math. Acad. Sci. Paris	24	850	4	2	0.6	6	4

The Backlog of Research Journals is reported each year in the November issue of the *Notices*. The report covers journals of publishers who have agreed to participate and who continue to provide backlog information. Publishers whose journals are not currently included can request that their journals be added. Such requests should be made in email to Marcia Almeida, `backlogreport@ams.org`. To be eligible for inclusion in the backlog report, a journal must be on the list of journals receiving cover-to-cover treatment in *Mathematical Reviews* (`http://www.ams.org/msnhtml/serials.pdf`).

Once a publisher's journals are accepted for inclusion, the publisher must designate a contact person or persons to supply data about the journals to the AMS. While the AMS makes every effort to obtain the data from the designated contacts, if data about a journal is not supplied, then that journal will not appear in the backlog report.

Journal (Print and Electronic)	Number issues per Year	Approximate Number Pages per Year	2012 Median Time (in Months) from: Submission to Final Acceptance	Acceptance to Print	Acceptance to Electronic Posting	Editor's Current Estimate of Waiting Time between Submission and Publication (in Months) Print	Electronic
Calc. Var. Partial Differential Equations	12	2600	6	10	1.1	16	6
Canad. J. Math.	6	1440	6	15	3	19	8
Canad. Math. Bull.	4	896	4	33	3	10	8
Cent. Eur. J. Math.	12	2320	4.4	3.3	2.8	7.8	7.3
Comm. Math. Phys.	24	7000	6	4.5	1	3.5	1
Commun. Appl. Math. Comput. Sci.	1	200	9.8	4.6	4.1	14.4	13.9
Commun. Pure Appl. Anal.	6	2500	3	5	7	8	7
Complex Var. Elliptic Equ.	12	1392	4.75	19.32	5.4	23	9.5
Compos. Math.	12	2208	7	10	6.3	14.4	11
Comput. Aided Geom. Design	9	805	7	4	1.6	20	15
Comput. Math. Appl.	24	5000	7	5	1	11	7
Comput. Methods Funct. Theory	4*	720	NA	NA	NA	NA	NA
Computing	12	960	8	NA	12	8	12
Constr. Approx.	6	1000	9	12	3	13	10
Des. Codes Cryptogr.	12	1300	6	14	7	13	7
Differential Geom. Appl.	6	744	9	3	0.4	10	3
Discrete Appl. Math	18	2600	12	5	0.9	17	14
Discrete Comput. Geom.	8	2000	8	4	1	12	9
Discrete Contin. Dyn. Syst.	12	5000	3	6	5	9	8
Discrete Contin. Dyn. Syst. Ser. B	8	3000	4	6	5	10	9
Discrete Math.	24	3260	12	3	0.8	14	12
Discrete Optim.	4	300	15	3	1	23	21
Duke Math. J.	15	3000	12	9	9	11	11
Dyn. Syst.	4	537	8.1	4.6	1.14	18	15
European J. Combin.	8	2257	10	4	2.1	13	12
Expo. Math.	4	416	9	7	2.7	21	17
Finite Fields Appl.	6	1359	8	4	0.5	8	7
Found. Comput. Math.	6	800	14	5.5	1.5	18	12
Geom. Dedicata	6	2270	10	10	10	20	20
Geom. Topol.	5	3125	13.3	5.2	4.7	17.7	17.2
Graphs Combin.	6	900	16.5	30	1	12	12
Historia Math.	4	365	7	4	1.3	16	13
Homology Homotopy Appl.	2	700–800	5.8	6.7	5	10	7
Houston J. Math.	4	1400	8	27	24	30	27
Illinois J. Math.	4	1500	6	14	12	18	16
Indag. Math. (N.S.)	4	1467	7	5	1.2	11	8
Infor. Process. Lett.	24	963	9	2	0.8	11	10
Invent. Math.	12	3000	7	6	1.2	13.4	8.7
Inverse Probl. Imaging	4	800	6	6	5	12	11
Involve	5	600	6.8	9.8	9.3	16.6	16.1
Israel J. Math.	8	4000	6	21	11	20	12
J. Algebra	24	7949	10	2	0.9	12	11
J. Algebraic Geom.	4	800	10	18	2	20	10
J. Amer. Math. Soc.	4	1200	9.6	5.6	1.1	22.4	18.9
J. Anal. Math.	3	1200	5	12	12	18	18
J. Appl. Log.	4	444	10	7	3.9	11	7
J. Approx. Theory	12	1700	9	2	0.9	12	11
J. Aust. Math. Soc.	6	860	11	15	12	13	11

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J. Combin. Theory Ser. A	8	2000	10	2	1.5	11	10
J. Combin. Theory Ser. B	6	800	25	4	0.7	23	20
J. Complexity	6	597	7	5	1.4	13	10
J. Comput. Appl. Math.	18	5253	11	3	0.8	14	10
J. Comput. System Sci.	8	1841	19	6	0.9	21	18
J. Convex Anal.	4	1200	7.5	10.1	0.5	15	6
J. Difference Equ. Appl.	12	2115	5.11	18.71	3.07	22	5
J. Differential Equations	24	9000	8	2	0.5	9	8
J. Differential Geom.	9	1700	6	9	6	6	6
J. Discrete Algorithms	6	1087	11	6	1	13	9
J. Eur. Math. Soc. (JEMS)	6	2038	6	12	11	18	17
J. Funct. Anal.	24	9097	8	2	0.6	10	9
J. Geom. Anal.	4	1235	7.63	17.10	1.48	12	6
J. Geom. Phys.	12	2250	5	3.5	1.5	10	9
J. Ind. Manag. Optim.	4	1100	6	5	4	11	10
J. Integral Equations Appl.	4	600	8	27	25	20	18
J. Lie Theory	4	1200	8	8	1	15	7
J. Log. Algebr. Program.	8	954	11	5	1.8	19	17
J. Lond. Math. Soc. (2)	6	1920	9	9.2	4.9	15.4	11
J. Math. Anal. Appl.	24	10000	7	2	0.7	10	8
J. Math. Biol.	14	3000	8.8	8.5	1.4	17	10.5
J. Math. Ecom.	6	457	11	3	1.2	15	13
J. Math. Phys.	12	9133	4.3	1.6	1.1	5.9	4.9
J. Math. Pures Appl. (9)	12	1492	7	8	2.5	15	10
J. Mod. Dyn.	4	600	4	3	2	7	6
J. Multivariate Anal.	10	2831	8	8	1.1	16	13
J. Number Theory	12	3800	11	4	2.3	15	14
J. Operator Theory	4	1200	7	27	24	24	16
J. Pure Appl. Algebra	12	3083	9	4	1	14	11
J. Statist. Plann. Inference	12	3112	13	3	0.8	16	14
J. Symbolic Comput.	12	2157	7	9	5.3	12	8
J. Symbolic Logic	4	1320	22	9	8	17	16
J. Topol.	4	1024	10.3	5.2	2.7	22.8	13
Kyoto J. Math.	4	900	5	10	10	16	17
Linear Algebra Appl.	24	8233	7	5	1.5	12	8
Linear Multilinear Algebra	12	1456	4.5	9.3	2.1	14	5
Lobachevskii J. Math.	4	450	4	4	4	8	6
Manuscripta Math.	12	1900	6	6	1.5	12	7.5
Math. Ann.	12	4800	10	12	1.5	NR	NR
Math. Comp.	4	2400	9.3	13.7	7	26.1	19.6
Math. Control Signals Systems	4	500	10.5	3	0.6	14	7
Math. Oper. Res.	4	800	17.4	3.3	1.8	15	13
Math. Program.	4	400	7	12	1.5	NR	NR
Math. Res. Lett.	6	1300	7	9	9	9	9
Math. Social Sci.	6	615	11	6	1.3	18	15
Math. Z.	12	3600	10	12	1.5	20	12
Mathematika	2	512	4.5	6.5	3.6	10.5	8.1
Mem. Amer. Math. Soc.	6	3200	9.5	16.1	9	30.9	23.5
Methods Appl. Anal.	4	500	5	4	4	6	6

Journal (Print and Electronic)	Number issues per Year	Approximate Number Pages per Year	2012 Median Time (in Months) from: Submission to Final Acceptance	Acceptance to Print	Acceptance to Electronic Posting	Editor's Current Estimate of Waiting Time between Submission and Publication (in Months) Print	Electronic
Michigan Math. J.	4	896	5	14	13	9	7
Monatsh. Math.	16	1920	3	2	1	5	4
Multiscale Model. Simul.	4	1525	7.3	6	3.4	12.7	10.7
Nonlinear Anal.	18	5494	5	3	0.9	7	5
Nonlinear Anal. Hybrid Syst.	4	340	10	4	0.9	10	7
Nonlinear Anal. Real World Appl.	6	3161	7	3	1.1	9	7
Notre Dame J. Form. Log.	4	600	5	11	11	11	11
Numer. Math.	12	2400	15	11	1	NR	NR
Pacific J. Math.	12	3072	6.9	6.5	6	13.4	12.9
Probab. Theory Related Fields	12	2400	8.5	10	1.2	18.5	9.5
Proc. Amer. Math. Soc.	12	4200	5.1	14.7	7.3	23.5	16.7
Proc. Lond. Math. Soc. (3)	12	2880	9	9.3	4	18.2	12.3
Publ. Math. Inst. Hautes Etudes Sci.	2	700	12	4	1.4	16	13.5
Quart. Appl. Math.	4	800	0.7	17.6	12.6	22.2	16.2
Rocky Mountain J. Math.	6	2100	8	24	22	28	16
Semigroup Forum	6	1200	10	4	1	15	12
SIAM J. Appl. Math.	6	1950	8	4.8	2.8	12.8	10.8
SIAM J. Comput.	6	1800	15.4	4.5	2.7	20.1	18.1
SIAM J. Control Optim.	6	3375	13.5	4.9	3.1	18.6	16.6
SIAM J. Discrete Math.	4	1820	12	5	3	17	15
SIAM J. Math. Anal.	6	4380	8.3	4	3	12.3	11.3
SIAM J. Matrix Anal. Appl.	4	1420	9.6	5.4	3	14.6	12.6
SIAM J. Numer. Anal.	6	3400	11.1	4.1	3.1	15.2	14.2
SIAM J. Optim.	4	1685	11.7	5.8	2.9	16.6	14.6
SIAM J. Sci. Comput.	6	4300	14.7	4	3	18.7	17.7
SIAM Rev.	4	800	13.5	12.6	11.6	26.1	25.1
Stochastic Process. Appl.	12	3938	10	3	1.2	13	11
Theoret. Comput. Sci.	48	5786	13	4	0.9	17	16
Theory Comput. Syst.	8	1000	7	12	8	11	7
Topology Appl.	18	3654	8	4	2.2	10	8
Trans. Amer. Math. Soc.	12	6600	7.4	20.1	16.2	26.5	21.3

Journal (Electronic)	Number of Articles Posted in 2011	2012 Median Time (in days) from: Submission to Final Acceptance	Acceptance to Posting	Format(s)
Abstr. Appl. Anal. www.hindawi.com/journals/aaa	820	63	31	html, pdf, ePUB
Acta Math. Acad. Paedagog. Nyházi. (N.S.) www.emis.de/journals/AMAPN/	21	210	180	pdf, ps
Adv. Difference Equ. www.advancesindifferenceequations.com/content	232	65	0**	html, pdf
Appl. Math. E-Notes www.math.nthu.edu.tw/~sscheng/	29	250	100	pdf
Bound. Value Probl. www.boundaryvalueproblems.com/content	153	130	0**	html, pdf

Journal (Electronic)	Number of Articles Posted in 2011	2012 Median Time (in days) from: Submission to Final Acceptance	2012 Median Time (in days) from: Acceptance to Posting	Format(s)
Conform. Geom. Dyn. www.ams.org/publications/journals/journalsframework/ecgd	14	60	87	pdf
Differ. Geom. Dyn. Syst. www.mathem.pub.ro/dgds/	13	100	180	pdf
Discrete Math. Theor. Comput. Sci. www.dmtcs.org	31	376	19	pdf, ps
Electron. Commun. Probab. ecp.ejpecp.org	63	139	7	pdf, tex
Electron. J. Combin. www.combinatorics.org/	236	179	13	pdf
Electron. J. Differential Equations ejde.math.txstate.edu	240	105	9	html, pdf, tex
Electron. J. Qual. Theory Differ. Equ. www.math.u-szeged.hu/ejqtde/	117	150	10	pdf
Electron. Res. Announc. Math. Sci. eramath.s3-website-us-east-1.amazonaws.com/	11	30	30	pdf
Electron. Trans. Numer. Anal. etna.mcs.kent.edu	26	265	62	html, pdf
ESAIM Control Optim. Calc. Var. www.esaim-cocv.org	53	240	340	pdf, ps, tex
ESAIM Math. Model. Numer. Anal. www.esaim-m2an.org	64	180	140	pdf, ps, tex
ESAIM Probab. Stat. www.esaim-ps.org	22	340	160	pdf, ps, tex
Fixed Point Theory Appl. www.fixedpointtheoryandapplications.com/content	234	155	0**	html, pdf
Int. J. Math. Math. Sci. www.hindawi.com/journals/ijmms	181	108	31	html, pdf, ePUB
Int. J. Stoch. Anal. www.hindawi.com/journals/ijsa	24	90	31	html, pdf, ePUB
Integers www.integers-ejcnt.org	99	240	14	pdf
J. Appl. Math. www.hindawi.com/journals/jam	828	75	31	html, pdf, ePUB
J. Inequal. Appl. www.journalofinequalitiesandapplications.com/content	310	100	0**	html, pdf
J. Integer Seq. cs.uwaterloo.ca/journals/JIS/	72	98	7	html, pdf, ps, tex
LMS J. Comput. Math. www.lms.ac.uk/publications/jcm	28	272	143	pdf, other ***
Math. Biosci. Eng. www.aimsciences.org/journals/home.jsp?journalID=8	46	120	120	pdf
Netw. Heterog. Media www.aimsciences.org/journals/home.jsp?journalID=9	53	120	150	pdf
Reliab. Comput. interval.louisiana.edu/reliable-computing-journal/RC.html	25	243	2	pdf
Represent. Theory www.ams.org/publications/journals/journals-framework/ert	17	324	162	pdf
Sém. Lothar. Combin. www.mat.univie.ac.at/~slc/	8	159	42	pdf, ps, dvi, tex

Journal (Electronic)	Number of Articles Posted in 2011	2012 Median Time (in days) from: Submission to Final Acceptance	2012 Median Time (in days) from: Acceptance to Posting	Format(s)
SIAM J. Appl. Dyn. Syst. epubs.siam.org/siads/	62	207	90	pdf, BibTeX
SIAM J. Financial Math. epubs.siam.org/sifin	28	408	93	pdf, BibTeX
SIAM J. Imaging Sci. epubs.siam.org/siims	46	291	102	pdf, BibTeX
Theory Appl. Categ. www.tac.mta.ca/tac/	40	213	5	pdf, ps, dvi
Theory Comput. theoryofcomputing.org	27	356	99	html†, pdf, ps, tex

NR means no response received. NA means not available or not applicable.
*First issue processed in 2013, no data available.
**Journal publishes provisional PDF directly after acceptance
*** "Add-ons" (appendixes, computer programs, graphics, animations, etc.) are provided as appropriate with no restriction on the format.
†Applies to abstract, bibliography, author information, but not to full article.

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Mathematics Calendar

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

November 2013

* 4–5 **DIMACS Workshop on Systems and Analytics of Big Data**, DIMACS Center, CoRE Building, Rutgers University, Piscataway, New Jersey, 08854-8018

Description: Tremendous progress has been made in systems and analytics of big data, e.g. Hadoop/MapReduce, STORM. However, modern data analytics faces a confluence of growing challenges. First, the increasing data deluge in social networks, online retails, web pages, mobile data, etc. creates the need to scale out across hundreds of thousands of commodity machines. Second, the complexity of data analytics has also grown to include sophisticated machine learning algorithm with data dependencies. Third, many systems process streaming data and have real time requirements. We believe that this emerging field will benefit from close interaction among researchers and industry practitioners. To this end, we are planning to organize a DIMACS workshop where we bring together academics and practitioners in computer systems, databases, networking, machine learning, and algorithms to share their research accomplishments and identify core problems on big data.

Organizers: Li Erran Li, Bell Labs, erranlli@gmail.com; Kathleen R. McKeown, Columbia University, kathy@cs.columbia.edu. Presented under the auspices of the Special Focus on Information Sharing and Dynamic Data Analysis.

Local Arrangements: Workshop Coordinator, DIMACS Center, workshop@dimacs.rutgers.edu, 732-445-5928; http://dimacs.rutgers.edu/Workshops/Analytics/index.html.

* 7–8 **DIMACS Workshop on Statistical Analysis of Network Dynamics and Interactions**, DIMACS Center, CoRE Building, Rutgers University, Piscataway, New Jersey, 08854-8018

Description: The analysis and modeling of large and complex real-world networks has become indispensable across the diverse set of social, technological, and natural worlds. While the field remains heterogeneous and diverse, we have seen emerging signs of convergence. There has been growing computer science and statistical literature expounding on topics of analyzing and visualizing time-varying networks, a subject popularized earlier within the physics community. Social media researchers are beginning to use problem-specific structure to infer between social influence, homophile, and external forces – areas historically of intense interest amongst statisticians and social scientists. Highly complex application domains, such as brain and financial networks, are coming into the scope of the field. The primary goal of the workshop is to actively promote a concerted effort to address theoretical, methodological and computational issues that arise when modeling and analyzing dynamic networks, stochastic processes on networks, and collection of interactions. To this end, we aim at bringing together researchers from applied disciplines such as sociology, economics, medicine and biology, together with researchers from more theoretical disciplines such as mathematics, statistics, physics and computer science. All these communities have a long-standing interest in modeling large scale networks, and we would like to foster cross-disciplinary collaborations and exchanges in order to identify directions that can provide theoretical and computational foundations to push forward this extremely important field.

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

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

In general, announcements of meetings and conferences carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. If there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the *Notices* in care of the American Mathematical Society in Providence or electronically to notices@ams.org or mathcal@ams.org.

In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **eight months** prior to the scheduled date of the meeting.

The complete listing of the Mathematics Calendar will be published only in the September issue of the *Notices*. The March, June/July, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through the AMS website on the World Wide Web. To access the AMS website, use the URL: http://www.ams.org/.

Organizers: Edo Airoldi, Harvard University; Andrea Collevecchio, University Ca' Foscari- Venice and Monash University; Xiaodong Lin, Rutgers University, lin@business.rutgers.edu. Presented under the auspices of the DIMACS Special Focus on Information Sharing and Dynamic Data Analysis
Local Arrangements: Workshop Coordinator, DIMACS Center, workshop@dimacs.rutgers.edu, 732-445-5928; http://dimacs.rutgers.edu/Workshops/DynamicNetwork/.

* 9 **Algebra, Geometry and Combinatorics Day (AlGeCom)**, Loyola University Chicago, Chicago, Illinois.
Description: A one-day informal meeting of mathematicians from the University of Illinois, Purdue University, IUPUI, and nearby universities, with interests in algebra, geometry and combinatorics (widely interpreted).
Invited Speakers: Ryan Kinser (Northeastern), Greg Musiker (Minnesota), Steven Sam (Berkeley), David Speyer (Michigan).
Funding: There is limited funding for graduate student attendance, made possible by NSF support.
Local organizers: Peter Tingley (email: ptingley@luc.edu), Aaron Lauve (email: alauve@luc.edu).
Information: http://sites.google.com/site/algecomday/algecom9/.

* 12–16 **GeoLMI 2013—Conference on Geometry and Algebra of Linear Matrix Inequalities**, Centre International de Rencontres Mathématiques (CIRM), Luminy, Marseille, France.
Description: This is a conference organized by Didier Henrion and Monique Laurent, jointly with the 3rd official meeting of the GeoLMI project funded by the French National Research Agency. The conference aims at bringing together various researchers in pure and applied mathematics (real algebraic geometry, commutative algebra, functional analysis, continuous and discrete optimization) interested in linear matrix inequalities and their application areas (operations research, system control, performance analysis of dynamical systems).
Information: http://homepages.laas.fr/henrion/geolmi13/.

* 18–22 **Discrete Curvature: Theory and Applications**, Centre International de Rencontres Mathématiques (CIRM), Luminy, Marseille, France.
Description: The aim of this summer school is to bring together researchers from diverse backgrounds on the common problem of discrete curvature and make an update on the many achievements of the last decade. In recent years, new concepts have emerged in different areas of mathematics and computer science, all related to the notion of discrete curvature. The notion of discrete curvature being not uniquely defined, unlike in the case of differential geometry, it is still an open subject of investigation. We believe it is crucial for all contributors in these various fields to meet one another, discuss their views and share their knowledge. The target audience includes both senior researchers who will find a new point of view on issues they know and/or put into perspective their contributions, as well as young researchers and Ph.D. students interested in this growing domain. The speakers will come from academic research, applied research and private companies.
Information: http://www.laurentnajman.org/curvature/.

December 2013

* 13–15 **International Conference on Special Functions & their Applications (ICSFA 2013) and symposium on "Applications in Diverse Fields of Engineering and Technology"**, Department of Mathematics. Malviya National Institute of Technology, J.L.N. Marg, Jaipur-302017, Rajasthan, India.
Description: The three days conference aims to bring together the researchers working in the area of Special Functions and their Applications for interaction and exchange of ideas. In addition, it will inspire young researchers to pursue research in this important branch of Mathematical sciences. The Academic program of the conference will consist of Plenary sessions, Invited Talks and Paper Presentations covering a wide range of topics including Special Functions, Ramanujan.s Mathematics, Fractional calculus, q-series and continued fractions, complex function theory, Applications of special functions to Statistics, Physical sciences and Engineering. The R. P. Agarwal Memorial Lecture shall be delivered on the first day of the conference by an eminent mathematician. In previous years it is been delivered by Prof. George Andrews (Pennsylvania), Prof. Bruce Berndt (Illinois), Prof. H.L. Manocha (NY).
Information: http://www.ssfaindia.webs.com/conf.htm.

January 2014

* 25–30 **From Random Walks to Lévy Processes**, Australian National University, Kioloa, Australia.
Location: The conference will be held at the Kioloa campus on the NSW coast.
Description: The aim of the conference is to provide a unique opportunity for Australian researchers, practitioners, and students to hear, meet, and mingle with some of the most prominent international and Australian researchers currently working on random walks, Lévy processes, or closely related areas. The ANU Kioloa Campus on the NSW coast provides a sequestered gathering place in a beautifully located environment with full accommodation and conference facilities permitting close networking and interaction among participants.
Information: http://maths.anu.edu.au/events/kioloa-conference-random-walks-levy-processes.

February 2014

* 17–21 **Hot Topics: Perfectoid Spaces and their Applications**, Mathematical Sciences Research Institute, Berkeley, California.
Description: Since their introduction just two years ago, perfectoid spaces have played a crucial role in a number of striking advances in arithmetic algebraic geometry: The proof of Deligne's weight-monodromy conjecture for complete intersections in toric varieties; the development of p-adic Hodge theory for rigid analytic spaces; a p-adic analogue of Riemann's classification of abelian varieties over the complex numbers; and the construction of Galois representations for torsion classes in the cohomology of many locally symmetric spaces (for instance arithmetic hyperbolic 3-manifolds). We will start the week with an exposition of the foundations of the theory of perfectoid spaces, with the aim of teaching novices to work with them. Then we will discuss their current and potential applications.
Information: http://www.msri.org/workshops/731.

March 2014

* 14–28 **Representation Theory and Geometry of Reductive Groups**, Kloster Heiligkreuztal, a Monastary in Germany, Altheim, Germany.
Description: A 10-day spring school followed by a 3-day conference organized by Bernhard Krötz and Eric M. Opdam. The lecturers are: Michel Brion, Dan Ciubotaru, Friedrich Knop, Mark Reeder and Henrik Schlichtkrull.
Information: http://www2.math.uni-paderborn.de/konferenzen/conferencespring-school.html.

* 28–30 **38th Annual SIAM Southeastern Atlantic Section (SEAS) Conference**, Florida Institute of Technology, Melbourne, Florida.
Description: Conference web page is http://my.fit.edu/abdulla/SIAMSEAS-2014. The meeting will contain plenary lectures, minisymposia, contributed, and poster sessions.
Plenary speakers: Louis Block, University of Florida; Emmanuele DiBenedetto, Vanderbilt University; Joel Smoller, University of Michigan; and Gunther Uhlmann, University of Washington and University of Helsinki. The minisymposium Proposal Submission deadline is January 10, 2014. We look forward to meeting you all in Melbourne, Florida next year. Regards, Ugur G. Abdulla (abdulla@fit.edu).

Information: http://my.fit.edu/~abdulla/SIAMSEAS-2014.

April 2014

* 3–4 **13th New Mexico Analysis Seminar**, University of New Mexico, Albuquerque, New Mexico.
Description: The New Mexico Analysis Seminar is organized by analysts at New Mexico State University and The University of New Mexico. The goal of the conference is to provide an opportunity for scientific exchange and cooperation among broadly defined analysts. This year the center piece of the seminar is a minicourse given by the keynote speaker Sasha Volberg from Michigan State University on "Harmonic Analysis and Spectral Theory".
Information: http://www.math.unm.edu/conferences/13thAnalysis/.

* 4 **An Afternoon in Honor to Cora Sadosky**, University of New Mexico, Albuquerque, New Mexico.
Description: Cora Sadosky (1940-2010) was an expert in harmonic analysis and operator theory, a student of Alberto Calderón and Antony Zygmund. She was a strong advocate for women in mathematics as well as active in promoting the greater participation of African-Americans in mathematics. She was president of the Association for Women in Mathematics (AWM) from 1993 to 1995, among other public offices she held during her life. This afternoon will be devoted to current results in harmonic analysis, operator theory and PDEs related to the mathematics of Cora Sadosky.
Invited speakers: Svitlana Mayboroda (University of Minnesota and first recipient of the AWM-Sadosky Award), Jill Pipher (Brown University), Sergei Treil (Brown University), Sasha Volberg (Michigan State University).
Information: http://www.math.unm.edu/conferences/13thAnalysis/.

May 2014

* 1–30 **Self-normalized Asymptotic Theory in Probability, Statistics and Econometrics**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: This program will provide the probabilists, statisticians and econometricians a unique platform to discuss interesting fundamental problems and results and explore possible solutions related to asymptotic theory. It is also intended to bring young researchers to the frontier of this fascinating area. Research and Informal Discussions: May 5–9, 2014 and May 26–30, 2014. Tutorial on Introduction to Self-normalized Limit Theory: May 13–16, 2014. Tutorial on Introductory Econometrics: May 13–16, 2014. Workshop on Self-normalized Asymptotic Theory in Probability, Statistics and Econometrics: May 19–23, May 2014.
Information: http://www2.ims.nus.edu.sg/Programs/014self/index.php.

* 5–9 **AIM Workshop: Projective modules and A1-homotopy theory**, American Institute of Mathematics, Palo Alto, California.
Description: This workshop, sponsored by AIM and the NSF, will be devoted to studying recent interactions between the classical theory of projective modules and A1-homotopy theory.
Information: http://www.aimath.org/ARCC/workshops/projectiveA1.html.

* 19 **Bers 100 celebration**, City University of New York, Graduate Center New York, New York.
Description: This one day informal event to celebrate the mathematics and life of Lipman Bers, on the 100th anniversary of his birth, is currently in the planning stage. There will be two speakers: Dennis Sullivan and Yair Minsky and a social calendar. Contact Irwin Kra for more information.
Information: http://fsw01.bcc.cuny.edu/zhe.wang/IB.html.

* 20–22 **Sixth Iberoamerican congress on geometry**, City University of New York, Graduate Center New York, New York.
Description: There will be nine plenary speakers and five special sessions. For more information contact Ara Basmajian.
Information: http://fsw01.bcc.cuny.edu/zhe.wang/IB.html.

* 27–30 **International Conference on Nonlinear Differential and Difference Equations: Recent Developments and Applications**, Side, Antalya, Turkey.
Description: The main aim of the conference is to promote, encourage, and bring together researchers in the fields of ordinary differential equations, functional differential equations, difference equations, impulsive differential equations, fractional differential equations and applications.
Information: http://icndde.ankara.edu.tr.

June 2014

* 2–6 **Computational Nonlinear Algebra**, Institute for Computational and Experimental Research in Mathematics, (ICERM), Brown University, Providence, Rhode Island.
Description: Over the last two decades, algebraic and numerical techniques for nonlinear problems have begun a steady and relentless transition from mostly academic constructions, to widely used tools across the mathematical sciences, engineering and industrial applications. The workshop will bring together participants from many diverse fields including computer vision, cryptography, optimization and control, partial differential equations, robotics, and quantum computation, with the common interest in nonlinear algebraic computations. The main goal is to assess the state of the art, to stimulate further progress, and to accelerate developments by bringing together these diverse communities and have them share computational challenges and successes.
Information: http://icerm.brown.edu/tw-14-3-cna.

* 10–13 **Geometry of Banach Spaces - A conference in honor of Stanimir Troyanski**, Albacete, Spain.
Description: The conference will be held in Albacete (Spain) on June 10-13, 2014, on the occasion of the 70th birthday of Professor Troyanski. We hope the conference to be a meeting point of researchers interested in Banach space theory. Main speakers who already accepted our invitation are: S. Argyros, J. Castillo, S. Dilworth, M. Fabian, V. Fonf, G. Godefroy, P. Hajek, R. Haydon, F. Hernandez, P. Kenderov, P. Koszmider, D. Kutzarova, A. Molto, T. Schlumprecht, R. Smith, A. Suarez Granero. Participants will have the opportunity to deliver a short talk.
Organizers: A. Aviles, S. Lajara, J.P. Moreno, J. Rodriguez.
Information: email: geometry.banach.spaces.2014@gmail.com; http://sites.google.com/site/geometryofbanachspaces/.

* 15–20 **4th European Seminar on Computing (ESCO 2014)**, Pilsen, Czech Republic.
Description: ESCO 2014 is the 4th event in a successful series of interdisciplineary international conferences. It promotes modern technologies and practices in scientific computing and visualization, and strengthens the interaction between researchers and practitioners in various areas of computational engineering and sciences. Thematic areas of ESCO 2014: Multiphysics coupled problems, higher-order computational methods, GPU computing and cloud computing, computing with Python and Octave, open source projects in scientific computing.
Invited keynote speakers: Oszkar Biro (Institut für Grundlagen und Theorie der Elektrotechnik, Graz, Austria), Herbert Edelsbrunner (Institute of Science and Technology, Vienna, Austria), Jean-Frédéric Gerbeau (INRIA, Paris-Rocquencourt, France), Stanley Osher (UCLA, Los Angeles, USA-pending), Ulrich Rüde (University Erlangen-Nuremberg, Erlangen, Germany).

Information: http://esco2014.femhub.com.

* 16–27 **Summer Graduate School: Dispersive Partial Differential Equations**, Mathematical Sciences Research Institute, Berkeley, California.
Description: The purpose of the workshop is to introduce graduate students to the recent developments in the area of dispersive partial differential equations (PDE). Dispersive equations have received a great deal of attention from mathematicians because of their applications to nonlinear optics, water wave theory and plasma physics. We will outline the basic tools of the theory that were developed with the help of multi-linear Harmonic Analysis techniques. The exposition will be as self-contained as possible.
Information: http://www.msri.org/summer_schools/713.

* 21–August 3 **MSRI-UP 2014: Arithmetic Aspects of Elementary Functions**, Mathematical Sciences Research Institute, Berkeley, California.
Description: The MSRI Undergraduate Program (MSRI–UP) is a comprehensive summer program designed for undergraduate students who have completed two years of university-level mathematics courses and would like to conduct research in the mathematical sciences. The main objective of the MSRI-UP is to identify talented students, especially those from underrepresented groups, who are interested in mathematics and make available to them meaningful research opportunities, the necessary skills and knowledge to participate in successful collaborations, and a community of academic peers and mentors who can advise, encourage and support them through a successful graduate program. The academic and research portion of the 2014 MSRI-UP will be led by Professor Victor Moll from Tulane University.
Information: http://www.msri.org/msri_ups/735.

* 23–27 **Boltzmann, Vlasov and related equations: Last results and open problems**, University of Cartagena, Cartagena, Colombia.
Description: The kinetic theory is one of the areas of active scientific research today, theoretical wealth and the many applications in various areas of science and technology as well as important phenomena unifying power microscopic and macroscopic world. Studying of Boltzmann and Vlasov equations play a central role in the kinetic theory. For this reason, June 23–27, 2014, will be celebrating in the city of Cartagena de Indias, Colombia, an International Conference, about Boltzmann, Vlasov and related equations, which will address recent results by leading international experts and current open problems. We invite mathematicians, physicists, chemists, biologists, engineers and young scientists to this beautiful city.
Information: http://matematicas.unicartagena.edu.co.

July 2014

* 7–18 **Summer Graduate School: Stochastic Partial Differential Equations**, Mathematical Sciences Research Institute, Berkeley, California.
Description: Stochastic Partial Differential Equations (SPDEs) serve as fundamental models of physical systems subject to random inputs, interactions or environments. It is a particular challenge to develop tools to construct solutions, prove robustness of approximation schemes, and study properties like ergodicity and fluctuation statistics for a wide variety of SPDEs. The purpose of this two week workshop is to educate graduate students on the state-of-the-art methods and results in SPDEs. The three courses which will be run simultaneously will highlight different (though related) aspects of this area including (1) Fluctuation theory of PDEs with random coefficients (2) Ergodic theory of SPDEs and (3) Exact solvability of SPDEs.
Information: http://www.msri.org/summer_schools/714.

* 7–August 29 **The Geometry, Topology and Physics of Moduli Spaces of Higgs Bundles**, Institute for Mathematical Sciences, National University of Singapore, Singapore.
Description: The goals of the program are: Bring together experts who study the geometry, topology and physics of Higgs bundles. Invite leading researchers to give talks on recent results and the latest developments in the field. Have experts give mini-courses explaining the background to their fields. Encourage collaborative work. Introduce graduate students and young researchers to the latest research and open problems in the field.
Information: http://www2.ims.nus.edu.sg/Programs/014geometry/index.php.

* 28–August 8 **Summer Graduate School: Geometry and Analysis**, Mathematical Sciences Research Institute, Berkeley, California.
Description: Geometric and complex analysis is the application of tools from analysis to study questions from geometry and topology. This two week summer course will provide graduate students with the necessary background to begin studies in the area. The first week will consist of introductory courses on geometric analysis, complex analysis, and Riemann surfaces. The second week will consist of more advanced courses on the regularity theory of Einstein manifolds, Kahler-Einstein manifolds, and the analysis of Riemann surfaces.
Information: http://www.msri.org/summer_schools/712.

September 2014

* 1–December 19 **Trimester Program on Non-commutative Geometry and its Applications**, Hausdorff Research Institute for Mathematics, Bonn, Germany.
Description: There will be four workshops during the trimester, a series of lecture courses aimed at postgraduate students and postdoctoral level researchers, and also a weekly seminar series on current research topics and a working seminar within that part of the program aimed at junior researchers.
Information: http://www.him.uni-bonn.de/programs/future-programs/future-trimester-programs/non-commutative-geometry-2014/description/.

The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.

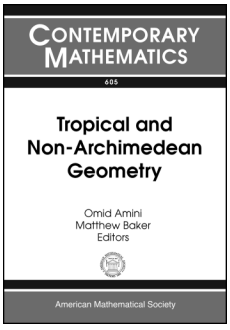
May 2015

* 17–21 **SIAM Conference on Applications of Dynamical Systems (DS15)**, Snowbird Ski and Summer Resort, Snowbird, Utah.
Description: The application of dynamical systems theory to areas outside of mathematics continues to be a vibrant, exciting and fruitful endeavor. These application areas are diverse and multidisciplinary, ranging over all areas of applied science and engineering, including biology, chemistry, physics, finance, and industrial applied mathematics. This conference strives to achieve a blend of application-oriented material and the mathematics that informs and supports it. The goals of the meeting are a cross-fertilization of ideas from different application areas, and increased communication between the mathematicians who develop dynamical systems techniques and applied scientists who use them.
Information: http://www.siam.org/meetings/ds15/|.

New Publications Offered by the AMS

To subscribe to email notification of new AMS publications, please go to http://www.ams.org/bookstore-email.

Algebra and Algebraic Geometry



Tropical and Non-Archimedean Geometry

Omid Amini, *École Normale Supérieure, Paris, France*, **Matthew Baker**, *Georgia Institute of Technology, Atlanta, GA*, and **Xander Faber**, *University of Hawaii at Manoa, Honolulu, HI*, Editors

Over the past decade, it has become apparent that tropical geometry and non-Archimedean geometry should be studied in tandem; each subject has a great deal to say about the other.

This volume is a collection of articles dedicated to one or both of these disciplines. Some of the articles are based, at least in part, on the authors' lectures at the 2011 Bellairs Workshop in Number Theory, held from May 6–13, 2011, at the Bellairs Research Institute, Holetown, Barbados.

Lecture topics covered in this volume include polyhedral structures on tropical varieties, the structure theory of non-Archimedean curves (algebraic, analytic, tropical, and formal), uniformization theory for non-Archimedean curves and abelian varieties, and applications to Diophantine geometry. Additional articles selected for inclusion in this volume represent other facets of current research and illuminate connections between tropical geometry, non-Archimedean geometry, toric geometry, algebraic graph theory, and algorithmic aspects of systems of polynomial equations.

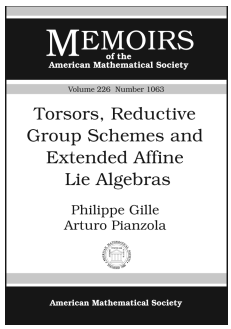
This item will also be of interest to those working in number theory.

This book is co-published with the Centre de Recherches Mathématiques.

Contents: **D. Maclagan**, Polyhedral structures on tropical varieties; **B. Osserman** and **J. Rabinoff**, Lifting nonproper tropical intersections; **K. Phillipson** and **J. M. Rojas**, Fewnomial systems with many roots, and an adelic Tau conjecture; **M. Nisse** and **F. Sottile**, Non-Archimedean coamoebae; **M. Baker**, **S. Payne**, and **J. Rabinoff**, On the structure of non-Archimedean analytic curves; **M. Papikian**, Non-Archimedean uniformization and monodromy pairing; **A. Chambert-Loir**, Diophantine geometry and analytic spaces; **F. Viviani**, Tropicalizing vs. compactifying the Torelli morphism; **D. Perkinson**, **J. Perlman**, and **J. Wilmes**, Primer for the algebraic geometry of sandpiles.

Contemporary Mathematics, Volume 605

January 2014, approximately 264 pages, Softcover, ISBN: 978-1-4704-1021-6, 2010 *Mathematics Subject Classification:* 14T05, 14G22, **AMS members US$71.20**, List US$89, Order code CONM/605



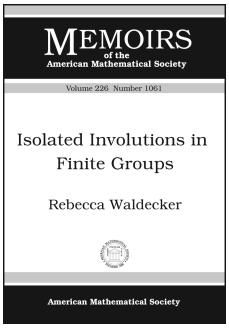
Torsors, Reductive Group Schemes and Extended Affine Lie Algebras

Philippe Gille, *Ecole Normale Supérieure, Paris, France*, and **Arturo Pianzola**, *University of Alberta, Edmonton, Canada*

Contents: Introduction; Generalities on the algebraic fundamental group, torsors, and reductive group schemes; Loop, finite and toral torsors; Semilinear considerations; Maximal tori of group schemes over the punctured line; Internal characterization of loop torsors and applications; Isotropy of loop torsors; Acyclicity; Small dimensions; The case of orthogonal groups; Groups of type G_2; Case of groups of type F_4, E_8 and simply connected E_7 in nullity 3; The case of $\mathbf{PGL}_d$; Invariants attached to EALAs and multiloop algebras; Appendix 1: Pseudo-parabolic subgroup schemes; Appendix 2: Global automorphisms of G–torsors over the projective line; Bibliography.

Memoirs of the American Mathematical Society, Volume 226, Number 1063

October 2013, 112 pages, Softcover, ISBN: 978-0-8218-8774-5, LC 2013025512, 2010 *Mathematics Subject Classification:* 17B67, 11E72, 14L30, 14E20, **Individual member US$43.80**, List US$73, Institutional member US$58.40, Order code MEMO/226/1063



Isolated Involutions in Finite Groups

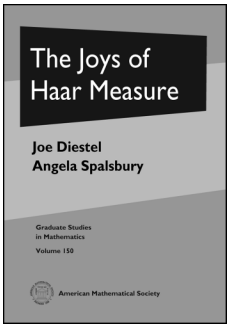
Rebecca Waldecker, *Martin-Luther-Universität Halle-Wittenberg, Germany*

Contents: Introduction; Preliminaries; Isolated involutions; A minimal counter-example to Glauberman's Z*-theorem; Balance and signalizer functors; Preparatory results for the local analysis; Maximal subgroups containing C; The 2-rank of $O_{2'}{}_{,2}(C)$; Components of $\overline{C}$ and the Soluble Z*-theorem; Unbalanced components; The 2-rank of G; The F*-structure theorem; More involutions; The endgame; The final contradiction and the Z*-theorem for $\mathcal{K}_2$-Groups; Bibliography; Index.

Memoirs of the American Mathematical Society, Volume 226, Number 1061

October 2013, 150 pages, Softcover, ISBN: 978-0-8218-8803-2, LC 2013025509, 2010 *Mathematics Subject Classification:* 20E25, 20E34, **Individual member US$49.80**, List US$83, Institutional member US$66.40, Order code MEMO/226/1061

Analysis



The Joys of Haar Measure

Joe Diestel, *Kent State University, OH*, and **Angela Spalsbury**, *Youngstown State University, OH*

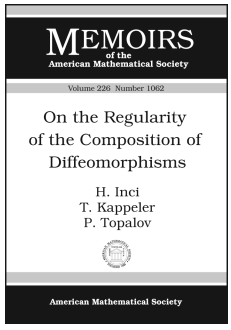
From the earliest days of measure theory, invariant measures have held the interests of geometers and analysts alike, with the Haar measure playing an especially delightful role. The aim of this book is to present invariant measures on topological groups, progressing from special cases to the more general. Presenting existence proofs in special cases, such as compact metrizable groups, highlights how the added assumptions give insight into just what the Haar measure is like; tools from different aspects of analysis and/or combinatorics demonstrate the diverse views afforded the subject. After presenting the compact case, applications indicate how these tools can find use. The generalization to locally compact groups is then presented and applied to show relations between metric and measure theoretic invariance. Steinlage's approach to the general problem of homogeneous action in the locally compact setting shows how Banach's approach and that of Cartan and Weil can be unified with good effect. Finally, the situation of a nonlocally compact Polish group is discussed briefly with the surprisingly unsettling consequences indicated.

The book is accessible to graduate and advanced undergraduate students who have been exposed to a basic course in real variables, although the authors do review the development of the Lebesgue measure. It will be a stimulating reference for students and professors who use the Haar measure in their studies and research.

Contents: Lebesgue measure in Euclidean space; Measures on metric spaces; Introduction to topological groups; Banach and measure; Compact groups have a Haar measure; Applications; Haar measure on locally compact groups; Metric invariance and Haar measure; Steinlage on Haar measure; Oxtoby's view of Haar measure; Appendix A; Appendix B; Bibliography; Author index; Subject index.

Graduate Studies in Mathematics, Volume 150

January 2014, approximately 327 pages, Hardcover, ISBN: 978-1-4704-0935-7, LC 2013027434, 2010 *Mathematics Subject Classification:* 28-XX, **AMS members US$52**, List US$65, Order code GSM/150



On the Regularity of the Composition of Diffeomorphisms

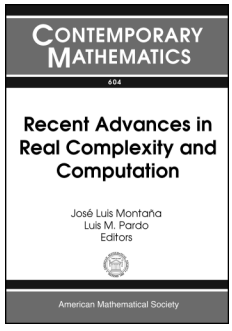
H. Inci and **T. Kappeler**, *University of Zurich, Switzerland*, and **P. Topalov**, *Northeastern University, Boston, MA*

Contents: Introduction; Groups of diffeomorphisms on $\mathbb{R}^n$; Diffeomorphisms of a closed manifold; Differentiable structure of $H^s(M, N)$; Appendix A; Appendix B; Bibliography.

Memoirs of the American Mathematical Society, Volume 226, Number 1062

October 2013, 60 pages, Softcover, ISBN: 978-0-8218-8741-7, LC 2013025511, 2010 *Mathematics Subject Classification:* 58D17, 35Q31, 76N10, **Individual member US$37.20**, List US$62, Institutional member US$49.60, Order code MEMO/226/1062

Applications



Recent Advances in Real Complexity and Computation

José Luis Montaña and **Luis M. Pardo**, *Universidad de Cantabria, Santander, Spain*, Editors

This volume is composed of six contributions derived from the lectures given during the UIMP-RSME Lluís Santaló Summer School on "Recent Advances in Real Complexity and Computation", held July 16–20, 2012, in Santander, Spain.

The goal of this Summer School was to present some of the recent advances on Smale's 17th Problem: "Can a zero of n complex polynomial equations in n unknowns be found approximately, on the average, in polynomial time with a uniform algorithm?"

These papers cover several aspects of this problem: from numerical to symbolic methods in polynomial equation solving, computational complexity aspects (both worse and average cases and both upper and lower complexity bounds) as well as aspects of the underlying

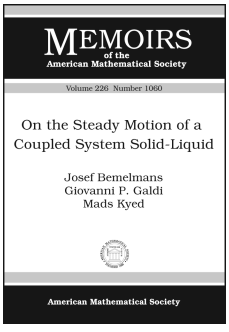
geometry of the problem. Some of the contributions also deal with either real or multiple solutions solving.

Contents: **M. Baartse** and **K. Meer**, Topics in real and complex number complexity theory; **B. Bank**, **M. Giusti**, and **J. Heintz**, Polar, bipolar and copolar varieties: Real solving and algebraic varieties with intrinsic complexity; **C. Beltrán** and **M. Shub**, The complexity and geometry of numerically solving polynomial systems; **M. Giusti** and **J.-C. Yakoubsohn**, Multiplicity hunting and approximating multiple roots of polynomials systems; **J. Heintz**, **B. Kuijpers**, and **A. R. Paredes**, On the intrinsic complexity of elimination problems in effective algebraic geometry; **G. Malajovich**, Newton iteration, conditioning and zero counting.

Contemporary Mathematics, Volume 604

January 2014, 185 pages, Softcover, ISBN: 978-0-8218-9150-6, LC 2013022512, 2010 *Mathematics Subject Classification:* 03D15, 14Qxx, 14Q20, 65-XX, 65H20, **AMS members US$60.80**, List US$76, Order code CONM/604

Differential Equations



On the Steady Motion of a Coupled System Solid-Liquid

Josef Bemelmans, *Rheinisch-Westf Technische Hochschule-Aachen, Germany*, **Giovanni P. Galdi**, *University of Pittsburgh, PA*, and **Mads Kyed**, *Technische Universität Darmstadt, Germany*

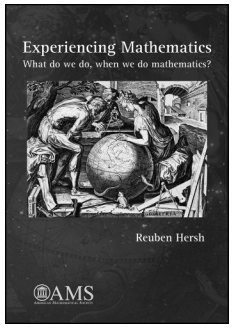
This item will also be of interest to those working in mathematical physics.

Contents: Introduction; Notation and preliminaries; Steady free motion: Definition and formulation of the problem; Main result; Approximating problem in bounded domains; Proof of main theorem; Bodies with symmetry; Appendix A. Isolated orientation; Bibliography.

Memoirs of the American Mathematical Society, Volume 226, Number 1060

October 2013, 89 pages, Softcover, ISBN: 978-0-8218-8773-8, LC 2013025510, 2010 *Mathematics Subject Classification:* 35Q30, 76D05, 74B20, 74F10, 35R35, **Individual member US$43.20**, List US$72, Institutional member US$57.60, Order code MEMO/226/1060

General Interest



Experiencing Mathematics

What do we do, when we do mathematics?

Reuben Hersh, *University of New Mexico, Albuquerque, NM*

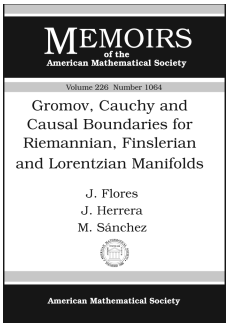
Most mathematicians, when asked about the nature and meaning of mathematics, vacillate between the two unrealistic poles of Platonism and formalism. By looking carefully at what mathematicians really do when they are doing mathematics, Reuben Hersh offers an escape from this trap. This book of selected articles and essays provides an honest, coherent, and clearly understandable account of mathematicians' proof as it really is, and of the existence and reality of mathematical entities. It follows in the footsteps of Poincaré, Hadamard, and Polya. The pragmatism of John Dewey is a better fit for mathematical practice than the dominant "analytic philosophy". Dialogue, satire, and fantasy enliven the philosophical and methodological analysis.

Reuben Hersh has written extensively on mathematics, often from the point of view of a philosopher of science. His book with Philip Davis, *The Mathematical Experience*, won the National Book Award in science. Hersh is emeritus professor of mathematics at the University of New Mexico.

Contents: Overture; The ideal mathematician; Manifesto; Self-introduction; Mathematics has a front and a back; Chronology; References; *Mostly for the right hand:* Introduction to part 1; True facts about imaginary objects; Mathematical intuition (Poincaré, Polya, Dewey); To establish new mathematics, we use our mental models and build on established mathematics; How mathematicians convince each other or "The kingdom of math is within you"; On the interdisciplinary study of mathematical practice, with a real live case study; Wings, not foundations!; Inner vision, outer truth; Mathematical practice as a scientific problem; Proving is convincing and explaining; Fresh breezes in the philosophy of mathematics; Definition of mathematics; Introduction to "18 unconventional essays on the nature of mathematics"; *Mostly for the left hand:* Introduction to part 2; Rhetoric and mathematics; Math lingo vs. plain English: Double entendre; Independent thinking; The "origin" of geometry; The wedding; Mathematics and ethics; Ethics for mathematicians; Under-represented, then over-represented: A memoir of Jews in American mathematics; Paul Cohen and forcing in 1963; *Selected book reviews:* Introduction to part 3; Review of *Not exactly ... in praise of vagueness* by Kees van Deemter; Review of *How mathematicians think* by William Byers; Review of *The mathematician's brain* by David Ruelle; Review of *Perfect rigor* by Marsha Gessen; Review of *Letters to a young mathematician* by Ian Stewart; Review of *Number and numbers* by Alain Badiou; An amusing elementary example; Annotated research bibliography; Curriculum vitae; List of articles; Acknowledgments.

February 2014, approximately 257 pages, Softcover, ISBN: 978-0-8218-9420-0, LC 2013025483, 2010 *Mathematics Subject Classification:* 00A30, 00A35, 00B10, **AMS members US$31.20**, List US$39, Order code MBK/83

Geometry and Topology



Gromov, Cauchy and Causal Boundaries for Riemannian, Finslerian and Lorentzian Manifolds

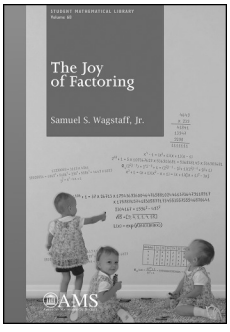
J. L. Flores and **J. Herrera**, *University of Malaga, Spain*, and **M. Sánchez**, *University of Granada, Spain*

Contents: Introduction; Preliminaries; Cauchy completion of a generalized metric space; Riemannian Gromov and Busemann completions; Finslerian completions; C-boundary of standard stationary spacetimes; Bibliography.

Memoirs of the American Mathematical Society, Volume 226, Number 1064

October 2013, 76 pages, Softcover, ISBN: 978-0-8218-8775-2, LC 2013025504, 2010 *Mathematics Subject Classification:* 53C23, 53C50, 53C60, 83C75, **Individual member US$41.40**, List US$69, Institutional member US$55.20, Order code MEMO/226/1064

Number Theory



The Joy of Factoring

Samuel S. Wagstaff, Jr., *Purdue University, West Lafayette, IN*

This book is about the theory and practice of integer factorization presented in a historic perspective. It describes about twenty algorithms for factoring and a dozen other number theory algorithms that support the factoring algorithms. Most algorithms are described both in words and in pseudocode to satisfy both number theorists and computer scientists. Each of the ten chapters begins with a concise summary of its contents.

The book starts with a general explanation of why factoring integers is important. The next two chapters present number theory results that are relevant to factoring. Further on there is a chapter discussing, in particular, mechanical and electronic devices for factoring, as well as factoring using quantum physics and DNA molecules. Another chapter applies factoring to breaking certain cryptographic algorithms. Yet another chapter is devoted to practical vs. theoretical aspects of factoring. The book contains more than 100 examples illustrating various algorithms and theorems. It also contains more than 100 interesting exercises to test the reader's understanding. Hints or answers are given for about a third of the exercises. The book concludes with a dozen suggestions of possible new methods for factoring integers.

This book is written for readers who want to learn more about the best methods of factoring integers, many reasons for factoring, and some history of this fascinating subject. It can be read by anyone who has taken a first course in number theory.

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

Contents: Why factor integers?; Number theory review; Number theory relevant to factoring; How are factors used?; Simple factoring algorithms; Continued fractions; Ellliptic curves; Sieve algorithms; Factoring devices; Theoretical and practical factoring; Answers and hints for exercises; Bibliography; Index.

Student Mathematical Library, Volume 68

November 2013, 293 pages, Softcover, ISBN: 978-1-4704-1048-3, LC 2013026680, 2010 *Mathematics Subject Classification:* 11A51, 11Y05, 11Y11, 11Y16; 11A25, 11A55, 11B68, 11N35, **AMS members US$39.20**, List US$49, Order code STML/68

Classified Advertisements

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

ALABAMA

UNIVERSITY OF ALABAMA AT BIRMINGHAM
Department of Mathematics
Assistant Professor

The Department of Mathematics at the University of Alabama at Birmingham (UAB) is soliciting applications for a tenure-track assistant professor position beginning August 15, 2014. Applicants whose research is compatible with the department's strengths in differential equations, differential geometry, dynamical systems, mathematical physics, and probability, including computational aspects of these areas, are encouraged to apply. Those with expertise in applications, e.g., in mathematical biology, mathematical finance, or mathematical modeling are of particular interest in this search. Applicants may be interested to collaborate with one of the University Wide Interdisciplinary Research Centers (UWIRC) on UAB campus, see http://www.uab.edu/institutionaleffectiveness/uwircs. For additional information about the department please visit http://www.uab.edu/mathematics/.

Applicants should have demonstrated the potential to excel in one of the research areas mentioned and in teaching at all levels of instruction. They should also be committed to professional service including departmental service. Postdoc experience is preferred.

Applications should include a curriculum vita with a publication list, a statement of future research plans, a statement on teaching experience and philosophy, and minimally three letters of reference with at least one letter addressing teaching experience and ability. We prefer applications and all other materials be submitted electronically at http://www.mathjobs.org, although applicants may submit an application including an AMS cover sheet to:

Math Faculty Search
Department of Mathematics
The University of Alabama at Birmingham
Birmingham, AL 35294-1170

UAB is an Equal Opportunity/Affirmative Action Employer committed to fostering a diverse, equitable and family-friendly environment in which all faculty and staff can excel and achieve work/life balance irrespective of ethnicity, gender, faith, gender identity and expression as well as sexual orientation. UAB also encourages applications from individuals with disabilities and veterans. A pre-employment background investigation is performed on candidates selected for employment.

000052

CALIFORNIA

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Harry Bateman Research Instructorships in Mathematics

Description: Appointments are for two years with one-year terminal extension expected. The academic year runs from approximately October 1 to June 1. Instructors typically are expected to teach one course per quarter for the full academic year and to devote the rest of their time to research. During the summer months there are no duties except research.

Eligibility: Open to persons who have recently received their doctorates in mathematics.

Deadline: January 1, 2014.

Application information: Please apply online at http://mathjobs.org. You can also find information about this position at www.math.caltech.edu/positions.html. To avoid duplication of paperwork, your application may also be considered for an Olga Taussky and John Todd Instructorship. Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

000054

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Olga Taussky and John Todd Instructorships in Mathematics

Description: Appointments are for three years. There are three terms in the Caltech academic year, and instructors typically are expected to teach one course in all but two terms of the total appointment. These two terms will be devoted to research. During the summer months there are no duties except research.

Eligibility: Offered to persons within three years of having received the Ph.D. who show strong research promise in one

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 2012 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: December 2013 issue–September 30, 2013; January 2014 issue–October 29, 2013; February 2014 issue–December 2, 2013; March 2014 issue–January 2, 2014; April 2014 issue–January 30, 2014; May 2014 issue–March 3, 2014.

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

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

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940; or via fax: 401-331-3842; or send email to classads@ams.org. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 20904. Advertisers will be billed upon publication.

of the areas in which Caltech's mathematics faculty is currently active.

Deadline: January 1, 2014.

Application information: Please apply online at http://mathjobs.org. You can also find information about this position at www.math.caltech.edu/positions.html. To avoid duplication of paperwork, your application may also be considered for a Harry Bateman Research Instructorship. Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

000049

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Scott Russell Johnson Senior Postdoctoral Scholar in Mathematics

Description: There are three terms in the Caltech academic year. The fellow is typically expected to teach one course in two terms each year, and is expected to be in residence even during terms when not teaching. The initial appointment is for three years with an additional three-year terminal extension expected.

Eligibility: Offered to a candidate within six years of having received the Ph.D. who shows strong research promise in one of the areas in which Caltech's mathematics faculty is currently active.

Deadline: January 1, 2014.

Application information: Please apply online at http://mathjobs.org. You can also find information about this position at www.math.caltech.edu/positions.html. To avoid duplication of paperwork, your application may also be considered for an Olga Taussky and John Todd Instructorship. Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

000050

CALIFORNIA STATE UNIVERSITY
Department of Mathematics

Department of Mathematics at California State University, San Bernardino, invites applications for a tenure-track faculty position at the level of Assistant Professor to begin September 2014. Applicants are required to hold a Ph.D. in mathematics or a Ph.D. in mathematics education with a master's in mathematics. The terminal degree is required at the time of appointment. Submit vita, three letters of reference, and a letter of application that includes a statement of teaching philosophy and strategies, and research/professional accomplishments and goals. Also submit the names, telephone and fax numbers, and email addresses of the three references along with an official copy of most recent transcripts. Send these materials to: Recruiting Committee, Department of Mathematics, California State University, San Bernardino, 5500 University Parkway, San Bernardino, CA 92407. Applications received after December 2, 2013, cannot be guaranteed full consideration.

000064

CALIFORNIA STATE UNIVERSITY SAN DIEGO
Department of Mathematics and Statistics
Tenure-Track Assistant Professor Position in Mathematics

The Department of Mathematics and Statistics at San Diego State University invites applications for a position as tenure-track Assistant Professor of Mathematics, beginning in August 2014. The department seeks a harmonic analyst with a strong background in core mathematics, and a research program that includes applied or interdisciplinary work.

Candidates must have a doctorate, or equivalent degree, in mathematics or applied mathematics, and demonstrate outstanding research potential. The new faculty member will contribute to the department's program in the Mathematics of Communications Systems, and is encouraged to participate in the SDSU Computational Science Research Center. Preference may be given to candidates who would augment or interact with existing research programs in the department or with key university programs. Candidates must demonstrate enthusiasm and ability to teach undergraduate and graduate level courses in pure and applied mathematics.

Applications should include: a cover letter, curriculum vita, a description of research program, a statement of teaching philosophy, and three letters of recommendation sent directly to the search committee. Applications should be addressed to

Professor Peter Blomgren
Chair, Search Committee
Department of Mathematics and Statistics
San Diego State University
San Diego, CA 92182-7720

Review of applications will begin on October 15, 2013, and continue until the position is filled.

SDSU is an Equal Opportunity Employer and does not discriminate against persons on the basis of race, religion, national origin, sexual orientation, gender, gender identity and expression, marital status, age, disability, pregnancy, medical condition, or covered veteran status.

The person holding this position is considered a "mandated reporter" under the California Child Abuse and Neglect Reporting Act and is required to comply with the requirements set forth in CSU Executive Order 1083 as a condition of employment.

000059

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Tenured/Tenure-Track positions

The Department of Mathematics invites applications for tenure-track/tenure faculty positions. Salary is commensurate with the level of experience. Job Tracking #1010-1415-05.

For fullest consideration, all application materials should be submitted on or before December 1, 2013. A Ph.D. is required for all positions.

We also plan to make temporary and visiting appointments in the categories 1-4 below. Depending on the level, candidates must give evidence of potential or demonstrated distinction in scholarship and teaching.

Temporary Positions:

(1) E.R. Hedrick Assistant Professorships. Salary is $64,300 and appointments are for three years. The teaching load is four one-quarter courses per year. Job Tracking #1010-1415-01.

(2) Computational and Applied Mathematics (CAM) Assistant Professorships. Salary is $64,300, and appointments are for three years. The teaching load is normally reduced by research funding to two quarter courses per year. Job Tracking #1010-1415-02.

(3) Program in Computing (PIC) Assistant Adjunct Professorships. Salary is $66,800. Applicants for these positions must show very strong promise in teaching and research in an area related to computing. The teaching load is four one-quarter programming courses each year and one additional course every two years. Initial appointments are for one year and possibly longer, up to a maximum service of four years. Job Tracking #1010-1415-03.

(4) Assistant Adjunct Professorships and Research Postdocs. Normally appointments are for one year, with the possibility of renewal. Strong research and teaching background required. The salary range is $54,300-$60,700. The teaching load for adjuncts is six one-quarter courses per year. Job Tracking #1010-1415-04.

Applications and supporting documentation must be submitted electronically via www.mathjobs.org. All letters of evaluation are subject to UCLA campus policies on confidentiality. Refer potential reviewers to the UCLA Statement of Confidentiality at http://www.math.ucla.edu/people/confidentiality.pdf.

For fullest consideration, all application materials should be submitted on or before December 6, 2013. A Ph.D. is required for all positions.

The university is an Equal Opportunity/Affirmative Action Employer. UCLA and the Department of Mathematics have a

strong commitment to the achievement of excellence in teaching and research and diversity among its faculty and staff. The University of California asks that applicants complete the Equal Opportunity Employer survey for Letters and Science at the following URL: http://cis.ucla.edu/facultysurvey. Please use Job Tracking numbers listed above.

000045

UNIVERSITY OF CALIFORNIA, SAN DIEGO
Mathematics Department Faculty Positions

The Department of Mathematics, within the Division of Physical Sciences at the University of California, San Diego (http://www.math.ucsd.edu), invites applications for one tenured mid-level position and one tenure-track junior position. The tenured mid-level position is expected to be filled in topology and/or geometry and the tenure-track position is open to applicants from all areas of pure and applied mathematics.

The University is committed to an excellent and diverse faculty and student body. Successful candidates will be evaluated on research and teaching accomplishments, as well as on potential for leadership in areas contributing to diversity, equity and inclusion. Candidates must receive their Ph.D. prior to their first quarter of teaching. Salary is commensurate with qualifications and based on UC pay scales. The starting date for the positions, pending funding approval, will be July 1, 2014. To receive full consideration, applications should be submitted online through http://apptrkr.com/377267 by November 1, 2013.

In compliance with the Immigration Reform and Control Act of 1986, individuals offered employment by the University of California are required to show documentation proving identity and authorization to work in the United States. For applicants interested in spousal/partner employment, please visit the UCSD Partner Opportunities Program at: http://academicaffairs.ucsd.edu/offices/partneropp/.

000068

ILLINOIS

UNIVERSITY OF CHICAGO
Department of Mathematics

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

1. L.E. Dickson Instructor: This is open to mathematicians who have recently completed or will soon complete a doctorate in mathematics or a closely related field, and whose work shows remarkable promise in mathematical research. The appointment typically is for two years, with the possibility of renewal for a third year. The teaching obligation is up to four one-quarter courses per year.

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

Applicants will be considered for any of the positions above which seem appropriate. Complete applications consist of (a) a cover letter, (b) a curriculum vitae, (c) three or more letters of reference, at least one of which addresses teaching ability, and (d) a description of previous research and plans for future mathematical research. Applicants are strongly encouraged to include information related to their teaching experience, such as a teaching statement or evaluations from courses previously taught, as well as an AMS cover sheet. If you have applied for an NSF Mathematical Sciences Postdoctoral Fellowship, please include that information in your application, and let us know how you plan to use it if awarded. Applications must be submitted online through www.mathjobs.org. Questions may be directed to apptsec@math.uchicago.edu. We will begin screening applications on November 1, 2013. Screening will continue until all available positions are filled.

The University of Chicago is an Affirmative Action/Equal Opportunity Employer.

000031

MARYLAND

JOHNS HOPKINS UNIVERSITY
Department of Mathematics
J. J. Sylvester Assistant Professor

The Department of Mathematics invites applications for 2-year and 3-year nontenure-track Assistant Professor positions beginning fall 2014. The J.J. Sylvester Assistant Professorship is offered to Ph.D. recipients who are beginning their research career and have outstanding research potential. Candidates in all areas of pure mathematics are encouraged to apply. The teaching load is three courses per academic year. To submit your application, go to http://www.mathjobs.org/jobs/jhu. Submit the AMS cover sheet, your curriculum vitae, and research and teaching statements, and ensure that at least four letters of recommendation, one of which addresses teaching, are submitted by the reference writers. If you are unable to apply online, you may send application materials to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. If you have questions concerning this position, please write to cpoole@jhu.edu. Preference will be given to applications received by December 1, 2013. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply.

000022

JOHNS HOPKINS UNIVERSITY
Department of Mathematics
Tenure-Track Assistant Professor

The Department of Mathematics invites applications for two positions at the tenure-track Assistant Professor level beginning July 1, 2014. A Ph.D. degree or its equivalent and demonstrated promise in research and commitment to teaching are required. Candidates in all areas of pure mathematics are encouraged to apply. To submit your application, go to http://www.mathjobs.org/jobs/jhu. Submit the AMS cover sheet, your curriculum vitae, list of publications, and research and teaching statements, and ensure that at least four letters of recommendation, one of which addresses teaching, are submitted by the reference writers. If you are unable to apply online, you may send application materials to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. If you have questions concerning this position, please write to cpoole@jhu.edu. Preference will be given to applications received by October 15, 2013. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply.

000023

JOHNS HOPKINS UNIVERSITY
Department of Mathematics

The Department of Mathematics invites applications for tenured positions at the Associate and Full Professor level beginning fall 2014 or later. The department is seeking candidates in areas of pure mathematics that fit in with the existing areas of the department, with an emphasis on analysis and geometry. Applications may be submitted online at http://www.mathjobs.org/jobs/jhu or mailed to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. Submit the AMS cover sheet, a curriculum vitae, a list of publications, and the names and addresses of suggested references. The department will assume the responsibility of soliciting letters of evaluation and will provide evaluators with a summary of policies on confidentiality of letters of evaluation. If you have questions concerning this position, please write to

cpoole@jhu.edu. Applications received by October 15, 2013, will be given priority. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply.

000024

MASSACHUSETTS

BOSTON COLLEGE
Department of Mathematics
Tenure-Track Position

The Department of Mathematics at Boston College invites applications for a tenure-track position at the level of Assistant Professor beginning in September 2014. Our preference is to hire in Algebraic Geometry, but candidates in Geometry, Topology, Number Theory, Representation Theory, and related fields are also encouraged to apply. In exceptional cases, a higher level appointment may be considered. The teaching load is three semester courses per year.

Requirements include a Ph.D. or equivalent in mathematics awarded in 2012 or earlier, a record of very strong research combined with outstanding research potential, and demonstrated excellence in teaching mathematics.

A completed application should contain a cover letter, a description of research plans, a statement of teaching philosophy, a curriculum vitae, and at least four letters of recommendation. One or more of the letters of recommendation should directly comment on the candidate's teaching credentials.

Applications completed no later than December 1, 2013, will be assured our fullest consideration. Please submit all application materials through http://MathJobs.org.

Applicants may learn more about the department, its faculty and its programs, and about Boston College at http://www.bc.edu/math. Electronic inquiries concerning this position may be directed to math-search@bc.edu. Boston College is an Affirmative Action/Equal Opportunity Employer. Applications from women, minorities, and individuals with disabilities are encouraged.

000063

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics

The Mathematics Department at MIT is seeking to fill positions in Pure and Applied Mathematics, and Statistics at the level of Instructor, Assistant Professor, or higher beginning September 2014. The department also seeks candidates for the Schramm Postdoctoral Fellowship. Appointments are based primarily on exceptional research qualifications. Appointees will be expected to fulfill teaching duties and to pursue their own research program. Ph.D. required by employment start date.

For more information and to apply, please visit http://www.mathjobs.org. To receive full consideration, submit applications by December 1, 2013. MIT is an Equal Opportunity, Affirmative Action Employer.

000046

WILLIAMS COLLEGE
Department of Mathematics and Statistics

The Williams College Department of Mathematics and Statistics invites applications for two tenure-track positions in mathematics, beginning fall 2014, at the rank of assistant professor (in an exceptional case, a more advanced appointment may be considered). We are seeking highly qualified candidates who have demonstrated excellence in teaching, who will establish an active and successful research program, and who will have a Ph.D. by the time of appointment. Williams College is a private, coeducational, residential, highly selective liberal arts college with an undergraduate enrollment of approximately 2,000 students. The teaching load is two courses per 12-week semester and a winter term course every other January.

Applicants are encouraged to apply electronically at http://mathjobs.org or send a vita and have three letters of recommendation on teaching and research sent to Susan Loepp, Chair of the Hiring Committee, Department of Mathematics and Statistics, Williams College, 18 Hoxsey Street, Williamstown, MA 01267. Teaching and research statements are also welcome. Evaluation of applications will begin on or after November 15 and will continue until the position is filled. All offers of employment are contingent upon completion of a background check. Further information is available upon request. For more information on the Department of Mathematics and Statistics, visit http://math.williams.edu.

Williams College is a coeducational liberal arts institution located in the Berkshire Hills of western Massachusetts with easy access to the culturally rich cities of Albany, Boston, and New York City. The college is committed to building and supporting a diverse population of students, and to fostering an inclusive faculty, staff, and curriculum. Williams has built its reputation on outstanding teaching and scholarship and on the academic excellence of its students. Please visit the Williams College website http://www.williams.edu/. Beyond meeting fully its legal obligations for non-discrimination, Williams College is committed to building a diverse and inclusive community where members from all backgrounds can live, learn, and thrive.

000032

NEW HAMPSHIRE

DARTMOUTH COLLEGE
Department of Mathematics
John Wesley Young Research Instructorships

2-3 years, new or recent Ph.D. graduates whose research overlaps a department member's. Teach 3 ten-week courses spread over 3 terms. Appointment for 26 months, with possible 12 month renewal; monthly salary of $5,100, including two-month research stipend for Instructors in residence during 2 of 3 summer months; if not in residence, salary adjusted accordingly. To initiate an application go to http://www.mathjobs.org. Position ID: JWY #4928. You can also access the application through a link at http://www.math.dartmouth.edu/activities/recruiting/. General inquiries can be directed to Tracy Moloney, Administrator, Department of Mathematics, tfmoloney@math.dartmouth.edu. Applications completed by January 5, 2014, considered first. Dartmouth College is committed to diversity and strongly encourages applications from women and minorities.

000053

NEW JERSEY

INSTITUTE FOR ADVANCED STUDY
School of Mathematics
Princeton, NJ

During the 2014-15 academic year, the School of Mathematics at the Institute for Advanced Study has a limited number of one- and two-year memberships with financial support for research in mathematics and computer science.

The school frequently sponsors special programs. However, these programs comprise no more than one-third of the membership so that each year a wide range of mathematics is supported. During the 2014-15 academic year, Claire Voisin, Institut de Mathématiques de Jussieu, will be the school's Distinguished Visiting Professor. Professor Voisin will lead a special program on "The Topology of Algebraic Varieties". For more information about the special program for the year, please see the school's homepage.

Several years ago the school established the von Neumann Fellowships. Up to eight of these fellowships will be available for each academic year. To be eligible for the von Neumann Fellowships, applicants should be at least five, but no more than fifteen, years following the receipt of their Ph.D.

The Veblen Research Instructorship is a three-year position which was established

in partnership with the Department of Mathematics at Princeton University in 1998. Three-year instructorships will be offered each year to candidates in pure and applied mathematics who have received their Ph.D. within the last three years. Usually the first and third year of the instructorship is spent at Princeton University and will carry regular teaching responsibilities. The second year is spent at the Institute and dedicated to independent research of the instructor's choice.

Candidates must have given evidence of ability in research comparable at least with that expected for the Ph.D. degree. Application materials may be requested from Applications, School of Mathematics, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540; applications@}\break{\tt math.ias.edu}. Postdoctoral computer science and discrete mathematics applicants may be interested in applying for a joint (2-year) position with one of the following: The Department of Computer Science at Princeton University, http://www.cs.princeton.edu; DIMACS at Rutgers, The State University of New Jersey, http://www.dimacs.rutgers.edu; or the Intractability Center, http://intractability.princeton.edu. For a joint appointment, applicants should apply to the School of Mathematics as well as to the above noting their interest in a joint appointment.

Applications may be found online at: https://applications.ias.edu. The deadline for all applications is December 1, 2013. The Institute for Advanced Study is committed to diversity and strongly encourages applications from women and minorities.

000027

PRINCETON UNIVERSITY
Department of Mathematics
Postdoctoral Research Associate 2013-2014

The Program in Applied and Computational Mathematics invites applications for Postdoctoral Research Associates to join in research efforts of interest to its faculty. Domains of interest include nonlinear partial differential equations, computational fluid dynamics and material science, dynamical systems, numerical analysis, stochastic problems and stochastic analysis, graph theory and applications, mathematical biology, financial mathematics and mathematical approaches to signal analysis, information theory, and structural biology and image processing. Appointments are possible for up to three years, renewable yearly, if funding is available and performance is satisfactory. For details on specific faculty members and their research interests, please go to http://www.pacm.princeton.edu. Princeton University is an Equal Opportunity Employer and complies with applicable EEO and affirmative action regulations. Applicants should submit a cover letter, CV, bibliography/publications list, statement of research and three letters of recommendation. Please apply directly to Mathjobs.org, http://www.mathjobs.org/jobs/jobs/4934. Applicants should have a recently completed or soon-to-be completed doctorate.

000055

RUTGERS UNIVERSITY-NEW BRUNSWICK
Department of Mathematics

The Mathematics Department of Rutgers University-New Brunswick invites applications for the following positions which may be available September 2014.

TENURED ASSOCIATE/FULL PROFESSORSHIP: Subject to availability of funding, the department expects an opening at the level of tenured Associate Professor or tenured Full Professor in Numerical Analysis/Scientific Computation. Candidates must have the Ph.D. and show a strong record of research accomplishments, and have a concern for teaching. The normal annual teaching load for research-active faculty is 2-1, that is, two courses for one semester, plus one course for the other semester. Review of applications begins immediately.

TENURE-TRACK ASSISTANT PROFESSORSHIP: Subject to availability of funding, the department expects an opening at the level of Tenure-Track Assistant Professor. In exceptional cases, there may be the possibility of appointment at a higher level. Candidates must have the Ph.D. and show a strong record of research accomplishments in pure or applied mathematics, and have a concern for teaching. The department has a hiring priority in Algebra (including Algebraic Geometry, Number Theory, and intersections with Geometry and Topology), but outstanding candidates in any field of pure or applied mathematics will be considered. The normal annual teaching load for research-active faculty is 2-1, that is, two courses for one semester, plus one course for the other semester. Review of applications begins immediately.

HILL ASSISTANT PROFESSORSHIPS and NON-TENURE-TRACK ASSISTANT PROFESSORSHIPS: These are both three-year nonrenewable positions. Subject to availability of funding, the department expects several open positions of these types. The Hill Assistant Professorship carries a reduced teaching load of 2-1 for research; candidates for it should have received the Ph.D., show outstanding promise of research ability in pure or applied mathematics, and have concern for teaching. The Non-Tenure-Track Assistant Professorship carries a teaching load of 2-2; candidates for it should have received the Ph.D., show evidence of superior teaching accomplishments, and promise of research ability. Review of applications begins January 1, 2014.

Applicants for the above position(s) should submit a curriculum vitae (including a publication list) and arrange for four letters of reference to be submitted, one of which evaluates teaching. Applicants should first go to the website http://www.mathjobs.org/jobs and fill out the AMS Cover Sheet electronically. It is essential to fill out the cover sheet completely, including naming the positions being applied for (TAP, TTAP, HILL, NTTAP, respectively) giving the AMS Subject Classification number(s) of area(s) of specialization, and answering the question about how materials are being submitted. The strongly preferred way to submit the CV, references, and any other application materials is online at: http://www.mathjobs.org/jobs. If necessary, however, application materials may instead be mailed to: Search Committee, Dept. of Math., Hill Center, Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. Review of applications will begin on the dates indicated above, and will continue until openings are filled. Updates on these positions will appear on the Rutgers Mathematics Department webpage at: http://www.math.rutgers.edu. Rutgers is an Affirmative Action/Equal Opportunity Employer.

000051

NORTH CAROLINA

NORTH CAROLINA STATE UNIVERSITY
Department of Mathematics

Invites applications for tenure-track positions beginning Fall 2014, depending on the availability of funding. We are seeking exceptionally well-qualified individuals with research interests compatible with those in the department, and in particular in areas of numerical linear algebra, or control; operations research; Personalized Medicine/Mathematical modeling and health system analysis. For position requirements please see listings on mathjobs.org. The Department of Mathematics has strong researchprograms in applied and pure mathematics. Information about the department is available at http://www.math.ncsu.edu. Submit your application materials at http://www.mathjobs.org/jobs/ncsu. You will then receive instructions to complete a faculty profile at http://jobs.ncsu.edu using the link in the posting. AA/EOE. NC State welcomes all persons without regard to sexual orientation. The College of Sciences welcomes the opportunity to work with candidates to identify suitable employment opportunities for spouses or partners. Priority will be given to applications received by November 15, 2013.

000066

PENNSYLVANIA

UNIVERSITY OF PENNSYLVANIA
School of Arts and Sciences

The School of Arts and Sciences at the University of Pennsylvania seeks to add to the faculty of our newly formed Evolution Cluster. We invite applicants for a tenure-track assistant professor appointment in evolution, broadly interpreted. We are interested in exceptional scientists who will establish a research program to empirically study the evolution of dynamical processes using field or laboratory experiments or the construction and analysis of massive data sets. Areas of interest include, but are not limited to: the evolution of neural, social, ecological or linguistic dynamics and networks; evolution of early life or exobiology; biochemical, neuronal, or cooperative interactions and exchange of information at the molecular, cellular, human, or ecosystems scales; directed evolution of organisms or processes; analyzing extant structures and networks, from molecules to populations, along with their evolutionary trajectories, including the development of new modalities to extract data from the geologic, genetic, or linguistic historical records. The successful candidate's primary appointment will be in a single department in the natural sciences: Biology, Chemistry, Earth and Environmental Science, Linguistics, Mathematics, Physics and Astronomy, or Psychology. Secondary appointments in other departments can be arranged, as appropriate. The successful candidate will have a strong interest in building a program that generates interaction with researchers from other disciplines who are working within the overarching theme of evolution and will teach courses in his or her home department and participate in the development of curricula pertinent to the Evolution Cluster (See http://evolutioncluster.sas.upenn.edu for more information). The University of Pennsylvania is an Affirmative Action/Equal Opportunity Employer and is strongly committed to establishing a diverse faculty: www.upenn.edu/almanac/volumes/v58/n02/diversityplan.html.

Applications should be submitted online at http://facultysearches.provost.upenn.edu/postings/23 and include a curriculum vitae, a research statement that includes the candidate's perspective on how she or he fits into one of the core departments, links to no more than three journal publications, and the contact information for three individuals who will provide letters of recommendation. Review of applications will begin November 1, 2013, and will continue until the position is filled.

000056

UTAH

UNIVERSITY OF UTAH
Department of Mathematics

The Department of Mathematics at the University of Utah invites applications for the following faculty positions:

· Full-time tenure-track or tenured appointments at the level of Assistant, Associate, or Full Professor in all areas of mathematics and statistics.

· Three-year Wylie and Burgess Assistant Professor Lecturer positions.

· Three-year RTG postdoctoral fellows in Algebraic Geometry and Topology (http://www.math.utah.edu/agtrtg/postdoc_fellowship.html).

· Three-year RTG postdoctoral fellows in Mathematical Biology (http://www.math.utah.edu/research/mathbio/rtg/rtg_postdoc.html).

Applications for all positions must be completed through the website www.mathjobs.org/jobs/Utah, and will be accepted until the position(s) have been filled. All applications will be reviewed when they are complete.

In accordance with University of Utah policy, this offer of appointment is contingent upon final approval of the President and Board of Trustees of the University of Utah. Utah state law requires the university to perform a background check on new employees. This offer of employment is conditioned upon your successfully passing a pre-employment criminal background check and a verification of your education.

The University of Utah is an Equal Opportunity/Affirmative Action Employer and Educator. Minorities, women, and persons with disabilities are strongly encouraged to apply. Veteran's preference. Reasonable accommodations provided. For additional information: www.regulations.utah.edu/humanResources/5-106.html. The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and possess a strong commitment to improving access to higher education for historically underrepresented students.

The department is one of 25 Group I Mathematics Departments in public institutions nationwide, and its faculty have received many honors including Clay, Guggenheim, Packard, and Sloan Fellowships. For more information see http://www.math.utah.edu or hiring@math.utah.edu.

000062

VIRGINIA

UNIVERSITY OF VIRGINIA
Department of Mathematics
Whyburn Instructor of Mathematics

The Department of Mathematics at the University of Virginia invites applications for a Whyburn Instructorship beginning August 25, 2014. This position carries a three-year appointment. Preference will be given to candidates who have received their Ph.D. within the last three years. Candidates must have an outstanding research record, and demonstrated teaching success. Applicants must be on track to receive a Ph.D. in the relevant field by May 2014 and must hold a Ph.D. at the time of appointment. Information about the department may be found at http://artsandsciences.virginia.edu/mathematics/index.html.

Review of applications will begin on November 15, 2013; however, the position will remain open until filled.

To apply candidates must submit a Candidate Profile through Jobs@UVa (https://jobs.virginia.edu), search on posting number 0612682 and electronically attach the following: a cover letter of interest describing research agenda and teaching experience, a curriculum vitae, andcontact information for four references.

In addition, please submit the following required documents electronically through www.MathJobs.org: A cover letter, an AMS Standard Cover Sheet, a curriculum vitae, a publication list, a description of research, and a statement about teaching interests and experience. The applicant must also have at least four letters of recommendation submitted, of which one must support the applicant's effectiveness as a teacher.

Questions regarding the application process in JOBS@UVa should be directed to: Zvezdana Kish, zk4g@virginia.edu; 434-924-9437.

For additional information about the position contact: mathematics-hiring@Virginia.EDU.

The university will perform background checks on all new faculty hires prior to making a final offer of employment.

The College of A&S and the University of Virginia welcome applications from women, minorities, veterans, and persons with disabilities; we seek to build a culturally diverse, intellectual environment and are committed to a policy of equal employment opportunity and to the principles of affirmative action in accordance with state and federal laws.

000060

VIRGINIA COMMONWEALTH UNIVERSITY
Department of Mathematics

Invites applications for the position of Chair of the Department of Mathematics and Applied Mathematics. We are looking for an accomplished mathematician who wants to make a difference. The successful candidate must demonstrate the vision and skills necessary to lead the department as it expands and strengthens its Ph.D. program, contributes to the university's goal of becoming a leading research university, and continues in its strong commitment to excellence in its undergraduate and graduate programs. The successful candidate is required to have a well-developed scholarly/research portfolio with evidence of multi-disciplinary applications and external funding appropriate to complement and expand existing expertise in the department. VCU takes pride in its diverse community and the successful candidate must demonstrate a strong commitment to fostering and enhancing our diversity. Evaluation of the applications will begin on December 1, 2013, and continue until the position is filled.

Complete information on the position and how to apply can be found at https://www.mathjobs.org/jobs/jobs/4286.

Virginia Commonwealth University is an Equal Opportunity/Affirmative Action Employer. Women, minorities and persons with disabilities are encouraged to apply.

000067

CANADA

UNIVERSITY OF TORONTO MISSISSAUGA (UTM)
The Department of Mathematical and Computational Sciences
and
UNIVERSITY OF TORONTO (ST. GEORGE CAMPUS)
Department of Mathematics

Invite applications for two tenure-stream appointments in the area of Applied Mathematics at the rank of Assistant Professor. The expected start date of the appointments is July 1, 2014. All qualified candidates are invited to apply by the following link https://www.mathjobs.org/jobs/jobs/4921. To receive full consideration, applications should be received by November 15, 2013.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

000057

UNIVERSITY OF TORONTO MISSISSAUGA
The Department of Mathematical and Computational Sciences

Invites applications for a tenure-stream appointment in the area of Algebra or Number Theory at the rank of Assistant Professor. The expected start date of the appointment is July 1, 2014. All qualified candidates are invited to apply by the following link http://www.mathjobs.org/jobs/jobs/4922. To receive full consideration, applications should be received by November 15, 2013.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applicants from visible minority group members, women, Aboriginals, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

000058

KOREA

INSTITUTE FOR BASIC SCIENCE (IBS)
Center for Geometry and Physics

The IBS Center for Geometry and Physics (IBS-CGP) invites applications for several tenure-track and postdoctoral research fellowship positions. IBS-CGP is working to bring the world's leading scientists in mathematics together with young researchers to collaborate on research projects with passion and commitment. To this end, IBS recruits based on scientific excellence and creative ideas, rather than pre-determined goals or demonstrated practical outcomes. IBS provides an open and autonomous research environment. The existing members of IBS-CGP are working in symplectic geometry and topology, dynamical systems, mirror symmetry, algebraic geometry, and mathematical aspects of quantum field and string theory.

Postdoctoral research fellowship positions. Successful candidates will be new or recent Ph.D.'s with outstanding research potential. These non-tenure-track appointments are for three years, and the salary range is KRW 57,000,000–66,000,000 (approximately USD 50,800–58,800).

Tenure-track positions. Successful candidates must have exceptional research qualifications. Starting salary with three years of experience beyond Ph.D. is KRW 92,880,000 (may vary by experience). Relocation expenses and housing allowance for up to 2 years may be provided for qualified overseas candidates.

IBS-CGP offers annual travel funds of KRW 8,000,000 for postdoctoral position and KRW 15,000,000 for tenure-track position in addition to basic research equipment and comprehensive benefits including medical and travel insurance and retirement funds.

A complete application packet should include a cover letter, a curriculum vitae which includes a publication list, a research statement, and at least three letters of recommendation for postdoctoral positions and four for tenure-track positions. For full consideration, application packets must be submitted electronically to cgp@ibs.re.kr by December 15, 2013. IBS encourages applications from individuals of diverse backgrounds. IBS-CGP website: http://cgp.ibs.re.kr.

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LEBANON

THE AMERICAN UNIVERSITY OF BEIRUT
Assistant Professor Positions in Mathematics

The Department of Mathematics at the American University of Beirut (AUB) invites applications for positions in Mathematics at the Assistant Professor level. Employment will begin September 1, 2014.

Only applicants holding a Ph.D. in Mathematics, Statistics, or Applied Mathematics and showing a strong commitment to teaching and research will be considered. Anticipated vacancies are in any of the following areas: (1) Analysis, (2) Partial Differential Equations and Differential Geometry, (3) Numerical Analysis and Computing, (4) Statistics and Probability. Strong candidates in other areas of mathematics may be considered.

All interested applicants should send a letter of application with a current CV, research and teaching statements, and arrange for three letters of reference to be directly sent to:

Patrick McGreevy
Dean, Faculty of Arts and Sciences
American University of Beirut
c/o New York Office
3 Dag Hammarskjold Plaza, 8th Floor
New York, NY 10017-2303
USA
Or
Patrick McGreevy
Dean, Faculty of Arts and Sciences
American University of Beirut
P.O. Box 11-0236, Riad El-Solh
Beirut 1107 2020, Lebanon

Electronic submissions may be sent by e-mail to: as_dean@aub.edu.lb, or can be sent through the Mathjobs website at https://www.mathjobs.org.

Applicants should indicate whether they are planning to attend the AMS.MAA

Joint Mathematics Meetings on January 15–18, 2014, in Baltimore, Maryland.

All applications and letters of reference should arrive by December 1, 2013. Applications will continue to be received after the deadline, but may not receive full consideration.

For more information, please visit the Faculty of Arts and Sciences' website at http://www.aub.edu.lb/fas or the Mathematics Department's website at http://www.aub.edu.lb/fas/math.

The American University of Beirut is an Equal Opportunity Employer.

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PUERTO RICO

UNIVERSITY OF PUERTO RICO
Mayagüez Campus
Assistant Professor

The Department of Mathematical Sciences at the University of Puerto Rico in Mayagüez anticipates offering at least one tenure-track faculty position in Computer Science, Applied Mathematics, or Statistics, starting July 1, 2014. Applicants should have a strong research potental and commitment to teaching; and should demonstrate a good publication record in quality journals. Duties include undergraduate and graduate teaching and independent research. Initiative and leadership is expected.

Requirements:

Minimum qualifications include having completed a doctoral degree in Mathematics, Statistics, Computer Science or a related area, or the expectation of its completion before the start of the appointment, July 1, 2014. A Ph.D. in Computer Sciences, with specialty in Computer Architecture, Parallel Computing or Software Engineering is preferred. Applicants should submit a plan which outlines their short and long term research goals. In addition, this research plan should outline how the applicant expects to bring in external funding.

How to Apply: Send an application letter, research plan, current Curriculum Vitae, three (3) letters of recommendation, Graduate School transcripts, AMS cover sheet, teaching and research philosophy no later than November 14, 2013. However, applications will continue to be accepted until the position is filled.

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SINGAPORE

NATIONAL UNIVERSITY OF SINGAPORE (NUS)
Department of Mathematics

The Department of Mathematics at the National University of Singapore (NUS) invites applications for tenured, tenure-track and visiting positions at all levels, beginning in August 2014.

NUS is a research intensive university that provides quality undergraduate and graduate education. The Department of Mathematics has about 65 faculty members and teaching staff whose expertise cover major areas of contemporary mathematical research.

We seek promising scholars and established mathematicians with outstanding track records in any field of pure and applied mathematics. The department, housed in a newly renovated building equipped with state-of-the-art facilities, offers internationally competitive salary with start-up research grants, as well as an environment conducive to active research, with ample opportunities for career development. The teaching load for junior faculty is kept especially light.

The department is particularly interested in, but not restricted to, considering applicants specializing in any of the following areas:

- Ergodic Theory and Dynamical Systems
- Partial Differential Equations and Applied Analysis
- Computational Science, Imaging and Data Science
- Operations Research and Financial Mathematics
- Probability and Stochastic Processes

Application materials should be sent to the Search Committee via email (as PDF files): search@math.nus.edu.sg.

Please include the following supporting documentation in the application:

1. An American Mathematical Society Standard Cover Sheet;
2. A detailed CV including publications list;
3. A statement (max. of 3 pages) of research accomplishments and plan.
4. A statement (max. of 2 pages) of teaching philosophy and methodology. Please attach evaluation on teaching from faculty members or students of your current institution, where applicable.
5. At least three letters of recommendation including one which indicates the candidate's effectiveness and commitment in teaching.

Please ask your referees to send their letters directly to search@math.nus.edu.sg.

Enquiries may also be sent to this email address. Review process will begin on 15 October, and will continue until positions are filled.

For further information about the department, please visit http://www.math.nus.edu.sg.

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TAIWAN

NATIONAL CENTRAL UNIVERSITY
Department of Mathematics

The Department of Mathematics invites applications for the following positions: regular positions at all levels and visiting positions (for a period of up to two years) at the level of assistant professor. All application materials should be sent to department via email (as pdf files) to: ncu5100@ncu.edu.tw or mail to: Chair, Department of Mathematics National Central University No. 300, Jhongda Rd., Jhongli City, Taoyuan County 32001 Taiwan (R. O. C.) Please include the following supporting documentation in the application:

1. Cover letter;
2. Curriculum Vitae;
3. Publication List;
4. Three recommendation letters (submitted directly by writers).

In order to ensure full consideration, applications should be received by December 20, 2013. For more information, visit: http://www.math.ncu.edu.tw.

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POSITION AVAILABLE

CONSULTANT/COLLABORATOR WANTED

To look over unorthodox approach to $3x + 1$ Problem. Must have insight, imagination and the ability to objectively evaluate new ideas. I will be glad to pay any reasonable consulting fee, and to offer shared-authorship for a significant contribution toward preparing a paper for publication. Contact Peter at peteschorer@gmail.com or 510-548-3827.

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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 `http://www.ams.org/meetings/`. Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL and in an electronic issue of the *Notices* as noted below for each meeting.

St. Louis, Missouri

Washington University

October 18–20, 2013
Friday – Sunday

Meeting #1094
Central Section
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: August 2013
Program first available on AMS website: September 5, 2013
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 34, Issue 4

Deadlines

For organizers: Expired
For abstracts: Expired

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

Invited Addresses

Ronny Hadani, University of Texas at Austin, *Representation theoretic patterns in three-dimensional cryo-electron microscopy*.

Efstratia Kalfagianni, Michigan State University, *Geometric structures and knot invariants*.

Jon Kleinberg, Cornell University, *Bursts, cascades, and hot spots: A glimpse of some on-line social phenomena at global scales*.

Vladimir Sverak, University of Minnesota, *PDE analysis of incompressible flows - old problems and recent develpments*.

Special Sessions

Advances in Difference, Differential, and Dynamic Equations with Applications, **Elvan Akin**, Missouri S&T University, **Youssef Raffoul**, University of Dayton, and **Agacik Zafer**, American University of the Middle East.

Advances in Mathematical Methods for Disease Modeling, **Jimin Ding**, Washington University in St. Louis, **Necibe Tuncer**, University of Tulsa, and **Naveen K. Vaidya**, University of Missouri-Kansas City.

Algebraic Cycles and Coherent Sheaves, **Roya Beheshti**, **Matt Kerr**, and **N. Mohan Kumar**, Washington University in St. Louis.

Algebraic and Combinatorial Invariants of Knots, **Heather Dye**, McKendree University, **Allison Henrich**, Seattle University, **Aaron Kaestner**, North Park University, and **Louis Kauffman**, University of Illinois.

Automorphic Forms and Representation Theory, **Dubravka Ban** and **Joe Hundley**, Southern Illinois University, and **Shuichiro Takeda**, University of Missouri, Columbia.

Commutative Algebra, **Lianna Sega**, University of Missouri, Kansas City, and **Hema Srinivasan**, University of Missouri, Columbia.

Computability Across Mathematics, **Wesley Calvert**, Southern Illinois University, and **Johanna Franklin**, University of Connecticut.

Convex Geometry and its Applications, **Susanna Dann**, **Alexander Koldobsky**, and **Peter Pivovarov**, University of Missouri.

Geometric Aspects of 3-Manifold Invariants, **Oliver Dasbach**, Louisiana State University, and **Effie Kalfagianni**, Michigan State University.

Geometric Topology in Low Dimensions, **William H. Kazez**, University of Georgia, and **Rachel Roberts**, Washington University in St. Louis.

Groupoids in Analysis and Geometry, **Alex Kumjian**, University of Nevada at Reno, **Markus Pflaum**, University of Colorado, and **Xiang Tang**, Washington University in St. Louis.

Interactions between Geometric and Harmonic Analysis, **Leonid Kovalev**, Syracuse University, and **Jeremy Tyson**, University of Illinois, Urbana-Champaign.

Linear and Non-linear Geometry of Banach Spaces, **Daniel Freeman** and **Nirina Lovasoa Randrianarivony**, St. Louis University.

Noncommutative Rings and Modules, **Greg Marks** and **Ashish Srivastava**, St. Louis University.

Operator Theory, **John McCarthy**, Washington University in St. Louis.

PDEs of Fluid Mechanics, **Roman Shvydkoy**, University of Illinois Chicago, and **Vladimir Sverak**, University of Minnesota.

Spectral, Index, and Symplectic Geometry, **Álvaro Pelayo** and **Xiang Tang**, Washington University in St. Louis.

Statistical Properties of Dynamical Systems, **Timothy Chumley** and **Renato Feres**, Washington University in St. Louis, and **Hongkun Zhang**, University of Massachusetts, Amherst.

Topological Combinatorics, **John Shareshian**, Washington University in St. Louis, and **Russ Woodroofe**, Mississippi State University.

Wavelets, Frames, and Related Expansions, **Marcin Bownik**, University of Oregon, **Darrin Speegle**, Saint Louis University, and **Guido Weiss**, Washington University in St. Louis.

p-local Group Theory, Fusion Systems, and Representation Theory, **Justin Lynd**, Rutgers University, and **Julianne Rainbolt**, Saint Louis University.

Riverside, California

University of California, Riverside

November 2–3, 2013

Saturday – Sunday

Meeting #1095

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2013
Program first available on AMS website: September 19, 2013
Program issue of electronic *Notices*: November 2013
Issue of *Abstracts*: Volume 34, Issue 4

Deadlines

For organizers: Expired
For abstracts: Expired

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

Invited Addresses

Michael Christ, University of California, Berkeley, *Title to be announced.*

Mark Gross, University of California, San Diego, *Title to be announced.*

Matilde Marcolli, California Institute of Technology, *Feynman integrals and motives.*

Paul Vojta, University of California, Berkeley, *Title to be announced.*

Special Sessions

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

Analysis and Geometry of Metric Spaces, **Asuman G. Aksoy**, Claremont McKenna College, and **Zair Ibragimov**, California State University, Fullerton.

Categorification in Representation Theory, **Aaron Lauda** and **David Rose**, University of Southern California.

Commutative Algebra and its Interaction with Algebraic Geometry and Combinatorics, **Kuei-Nuan Lin** and **Paolo Mantero**, University of California, Riverside.

Computational Problems on Large Graphs and Applications, **Kevin Costello** and **Laurent Thomas**, University of California, Riverside.

Computer, Mathematics, Imaging, Technology, Network, Health, Big Data, and Statistics, **Subir Ghosh**, University of California, Riverside.

Developments in Markov Chain Theory and Methodology, **James Flegal**, University of California, Riverside, and **Mark Huber**, Claremont McKenna College.

Diophantine Geometry and Nevanlinna Theory, **Aaron Levin**, Michigan State University, **David McKinnon**, University of Waterloo, and **Paul Vojta**, University of California, Berkeley.

Dynamical Systems, **Nicolai Haydn**, University of Southern California, and **Huyi Hu**, Michigan State University.

Fluids and Boundaries, **James P. Kelliher**, **Juhi Jang**, and **Gung-Min Gie**, University of California, Riverside.

Fractal Geometry, Dynamical Systems, and Mathematical Physics, **Michel L. Lapidus**, University of California, Riverside, **Erin P. J. Pearse**, California State Polytechnic University, San Luis Obispo, and **John A. Rock**, California State Polytechnic University, Pomona.

From Harmonic Analysis to Partial Differential Equations: In Memory of Victor Shapiro, **Alfonso Castro**, Harvey Mudd College, **Michel L. Lapidus**, University of California, Riverside, and **Adolfo J. Rumbos**, Pomona College.

Geometric Analysis, **Zhiqin Lu**, University of California, Irvine, **Bogdan D. Suceava**, California State University, Fullerton, and **Fred Wilhelm**, University of California, Riverside.

Geometric and Combinatorial Aspects of Representation Theory, **Wee Liang Gan** and **Jacob Greenstein**, University of California, Riverside.

Geometry of Algebraic Varieties, **Karl Fredrickson**, University of California, Riverside, **Mark Gross**, University of California, San Diego, and **Ziv Ran**, University of California, Riverside.

Heights, Diophantine Problems, and Lattices, **Lenny Fukshansky**, Claremont McKenna College, and **David Krumm**, University of Georgia and Claremont McKenna College.

Homotopy Theory and K-Theory, **Julie Bergner**, University of California, Riverside, and **Christian Haesemeyer**, University of California, Los Angeles.

Teaching ODEs: Best Practices from CODEE (Community of Ordinary Differential Equations Educators), **Nishu Lal**,

Pomona College and Pitzer College, and **Ami Radunskaya**, Pomona College.

The Mathematics of Planet Earth, **John Baez**, University of California, Riverside.

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel

January 15–18, 2014

Wednesday – Saturday

Meeting #1096

Joint Mathematics Meetings, including the 120th Annual Meeting of the AMS, 97th 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 for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: October 2013
Program first available on AMS website: November 1, 2013
Program issue of electronic *Notices*: January 2013
Issue of *Abstracts*: Volume 35, Issue 1

Deadlines

For organizers: Expired
For abstracts: Expired

MAA Program Updates

The SIGMAA on the History of Mathematics guest lecture will be given by **V. Frederick Rickey**, USMA, *The Notebooks of George Washington on Arithmetic, Geometry, Trigonometry, Logarithms and Surveying*, on Wednesday at 6:30 p.m.

SIAM Program Updates

Additional minisymposia include *Applied and Computational Geometry,* **Kathryn Leonard**, California State University Channel Islands, and **Erin Wolf Chambers**, St. Louis University.

New Developments with Entropic Solutions to Nonlinear Conservation Laws, *Pierre*-**Emmanuel Jabin**, **Eitan Tadmor**, and **Konstantina Trivisa**, University of Maryland.

Frontiers in Geomathematics, **Willi Freeden**, University of Kaiserslaute, and **Zuhair Nashed**, University of Central Florida.

Recent Advances in Financial Mathematics, **Maxim Bichuch**,Worcester Polytechnic Institute, **Ronnie Sircar**, Princeton University, and **Stephan Sturm**, Worcester Polytechnic Institute.

Recent Advances in Partial Differential Equations Modeling Physical Systems, **Edriss S. Titi**, University of California Irvine and the Weizmann Institute of Science.

Recent Mathematical Developments in Imaging, **Weihong Guo**, Case Western Reserve University, and **Luminita Vese**, University of California Los Angeles.

Turbulence and Mixing in Fluids: Analysis and Applications, **Animikh Biswas**, University of Maryland Baltimore County, and **Evelyn Lunasin**, U.S. Naval Academy.

Knoxville, Tennessee

University of Tennessee, Knoxville

March 21–23, 2014

Friday – Sunday

Meeting #1097

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: January 2014
Program first available on AMS website: February 6, 2014
Program issue of electronic *Notices*: March 2014
Issue of *Abstracts*: Volume 35, Issue 2

Deadlines

For organizers: Expired
For abstracts: January 28, 2014

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

Invited Addresses

Maria Chudnovsky, Columbia University, *Title to be announced* (Erdős Memorial Lecture).

Ilse Ipsen, North Carolina State University, *Title to be announced.*

Daniel Krashen, University of Georgia, *Title to be announced.*

Suresh Venapally, Emory University, *Title to be announced.*

Special Sessions

Algebraic Methods in Graph Theory and Combinatorics (Code: SS 7A), **Felix Lazebnik**, University of Delaware, **Andrew Woldar**, Villanova University, and **Bangteng Xu**, Eastern Kentucky University.

Arithmetic of Algebraic Curves (Code: SS 9A), **Lubjana Beshaj**, Oakland University, **Caleb Shor**, Western New England University, and **Andreas Malmendier**, Colby College.

Commutative Ring Theory (in honor of the retirement of David E. Dobbs) (Code: SS 1A), **David Anderson**, University of Tennessee, Knoxville, and **Jay Shapiro**, George Mason University.

Completely Integrable Systems and Dispersive Nonlinear Equations (Code: SS 12A), **Robert Buckingham**, University of Cincinnati, and **Peter Perry**, University of Kentucky.

Complex Analysis, Probability, and Metric Geometry (Code: SS 11A), **Matthew Badger**, Stony Brook University, **Jim Gill**, St. Louis University, and **Joan Lind**, University of Tennessee, Knoxville.

Discontinuous Galerkin Finite Element Methods for Partial Differential Equations (Code: SS 18A), **Xiaobing Feng** and **Ohannes Karakashian**, University of Tennessee, Knoxville, and **Yulong Xing**, University of Tennessee, Knoxville, and Oak Ridge National Laboratory.

Diversity of Modeling and Optimal Control: A Celebration of Suzanne Lenhart's 60th Birthday (Code: SS 3A), **Wandi Ding**, Middle Tennessee State University, and **Renee Fister**, Murrray State University.

Fractal Geometry and Ergodic Theory (Code: SS 2A), **Mrinal Kanti Roychowdhury**, University of Texas Pan American.

Geometric Topology (Code: SS 21A), **Craig Guilbault**, University of Wisconsin-Milwaukee, and **Steve Ferry**, Rutgers University.

Geometric and Algebraic Combinatorics (Code: SS 16A), **Benjamin Braun** and **Carl Lee**, University of Kentucky.

Geometric and Combinatorial Methods in Lie Theory (Code: SS 15A), **Amber Russell** and **William Graham**, University of Georgia.

Graph Theory (Code: SS 8A), **Chris Stevens**, **Dong Ye**, and **Xiaoya Zha**, Middle Tennessee State University.

Harmonic Analysis and Nonlinear Partial Differential Equations (Code: SS 5A), **J. Denzler**, **M. Frazier**, **Tuoc Phan**, and **T. Todorova**, University of Tennessee, Knoxville.

Invariant Subspaces of Function Spaces (Code: SS 6A), **Catherine Beneteau**, University of South Florida, **Alberto A. Condori**, Florida Gulf Coast University, **Constanze Liaw**, Baylor University, and **Bill Ross**, University of Richmond.

Mathematical Physics and Spectral Theory (Code: SS 10A), **Roger Nichols**, The University of Tennessee at Chattanooga, and **Günter Stolz**, University of Alabama at Burmingham.

Nonlinear Partial Differential Equations in the Applied Sciences (Code: SS 19A), **Lorena Bociu**, North Carolina State University, **Ciprian Gal**, Florida International University, and **Daniel Toundykov**, University of Nebraska-Lincoln.

Randomized Numerical Linear Algebra (Code: SS 4A), **Ilse Ipsen**, North Carolina State University.

Recent Development on Hyperbolic Conservation Laws (Code: SS 20A), **Geng Chen**, Georgia Tech, and **Ronghua Pan** and **Weizhe Zhang**, Georgia Tech.

Scientific Computing, Numerical Analysis, and Mathematical Modeling (Code: SS 17A), **Vasilios Alexiades**, **Xiaobing Feng**, and **Steven Wise**, University of Tennessee, Knoxville.

Singularities and Physics (Code: SS 13A), **Mboyo Esole**, Harvard University, and **Paolo Aluffi**, Florida State University.

Stochastic Processes and Related Topics (Code: SS 14A), **Jan Rosinski** and **Jie Xiong**, University of Tennessee, Knoxville.

Baltimore, Maryland

University of Maryland, Baltimore County

March 29–30, 2014

Saturday – Sunday

Meeting #1098

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2014
Program first available on AMS website: February 26, 2014
Program issue of electronic *Notices*: March 2014
Issue of *Abstracts*: Volume 35, Issue 2

Deadlines

For organizers: Expired
For abstracts: January 28, 2014

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

Invited Addresses

Maria Gordina, University of Connecticut, *Title to be announced.*

L. Mahadevan, Harvard University, *Title to be announced.*

Nimish Shah, Ohio State University, *Title to be announced.*

Dani Wise, McGill University, *Title to be announced.*

Special Sessions

Difference Equations and Applications (Code: SS 8A), **Michael Radin**, Rochester Polytechnic Institute.

Harmonic Analysis and Its Applications (Code: SS 10A), **Susanna Dann**, University of Missouri, **Azita Mayeli**, Queensborough College, City University of New York, and **Gestur Olafsson**, Louisana State University.

Invariants in Low-Dimensional Topology (Code: SS 1A), **Jennifer Hom**, Columbia University, and **Tye Lidman**, University of Texas at Austin.

Knots and Applications (Code: SS 3A), **Louis Kauffman**, University of Illinois at Chicago, **Samuel Lomonaco**, University of Maryland, Baltimore County, and **Jozef Przytycki**, George Washington University.

Mathematical Biology (Code: SS 6A), **Jonathan Bell** and **Brad Peercy**, University of Maryland Baltimore County.

Mathematical Finance (Code: SS 2A), **Agostino Capponi**, John Hopkins University.

Mechanics and Control (Code: SS 9A), **Jinglai Shen**, University of Maryland Baltimore County, and **Dmitry Zenkov**, North Carolina State University.

Novel Developments in Tomography and Applications (Code: SS 4A), **Alexander Katsevich**, **Alexandru Tamasan**, and **Alexander Tovbis**, University of Central Florida.

Open Problems in Stochastic Analysis and Related Fields (Code: SS 7A), **Masha Gordina**, University of Connecticut, and **Tai Melcher**, University of Virginia.

Theory and Applications of Differential Equations on Graphs (Code: SS 5A), **Jonathan Bell**, University of Maryland Baltimore County, and **Sergei Avdonin**, University of Alaska Fairbanks.

Albuquerque, New Mexico

University of New Mexico

April 5–6, 2014

Saturday – Sunday

Meeting #1099

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: January 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: April 2014
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For abstracts: February 11, 2014

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

Invited Addresses

Anton Gorodetski, University of California, Irvine, *To be announced.*

Fan Chung Graham, University of California, San Diego, *Some problems and results in spectral graph theory.*

Adrian Ioana, University of California, San Diego, *To be announced.*

Karen Smith, University of Michigan, Ann Harbor, *To be announced.*

Special Sessions

Analysis and Topology in Special Geometries (Code: SS 14A), **Charles Boyer**, **Daniele Grandini**, and **Dimiter Vassilev**, University of New Mexico.

Commutative Algebra (Code: SS 7A), **Daniel J. Hernandez**, University of Utah, **Karen E. Smith**, University of Michigan, and **Emily E. Witt**, University of Minnesota.

Descriptive Set Theory and its Applications (Code: SS 6A), **Alexander Kechris**, California Institute of Technology, and **Christian Rosendal**, University of Illinois, Chicago.

Flat Dynamics (Code: SS 8A), **Jayadev Athreya**, University of Illinois, Urbana-Champaign, **Robert Niemeyer**, University of New Mexico, Albuquerque, **Richard E. Schwartz**, Brown University, and **Sergei Tabachnikov**, The Pennsylvania State University.

Harmonic Analysis and Dispersive Equations (Code: SS 11A), **Matthew Blair**, University of New Mexico, and **Jason Metcalfe**, University of North Carolina.

Interactions in Commutative Algebra (Code: SS 4A), **Louiza Fouli** and **Bruce Olberding**, New Mexico State University, and **Janet Vassilev**, University of New Mexico.

Partial Differential Equations in Materials Science (Code: SS 10A), **Lia Bronsard**, McMaster University, and **Tiziana Giorgi**, New Mexico State University.

Physical Knots, honoring the retirement of Jonathan K. Simon (Code: SS 13A), **Greg Buck**, St. Anselm College, and **Eric Rawdon**, University of St. Thomas.

Progress in Noncommutative Analysis (Code: SS 2A), **Anna Skripka**, University of New Mexico, and **Tao Mei**, Wayne State University.

Spectral Theory (Code: SS 12A), **Milivoje Lukic**, Rice University, and **Maxim Zinchenko**, University of New Mexico.

Stochastics and PDEs (Code: SS 5A), **Juraj Földes**, Institute for Mathematics and Its Applications, **Nathan Glatt-Holtz**, Institute for Mathematics and Its Applications and Virginia Tech, and **Geordie Richards**, Institute for Mathematics and Its Applications and University of Rochester.

The Inverse Problem and Other Mathematical Methods Applied in Physics and Related Sciences (Code: SS 1A), **Hanna Makaruk**, Los Alamos National Laboratory, and **Robert Owczarek**, University of New Mexico and Enfitek, Inc.

Topics in Spectral Geometry and Global Analysis (Code: SS 3A), **Ivan Avramidi**, New Mexico Institute of Mining and Technology, and **Klaus Kirsten**, Baylor University.

Weighted Norm Inequalities and Related Topics (Code: SS 9A), **Oleksandra Beznosova**, Baylor University, **David Cruz-Uribe**, Trinity College, and **Cristina Pereyra**, University of New Mexico.

Lubbock, Texas

Texas Tech University

April 11–13, 2014

Friday – Sunday

Meeting #1100

Central Section
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: February 2014
Program first available on AMS website: February 27, 2014
Program issue of electronic *Notices*: April 2014
Issue of *Abstracts*: Volume 35, Issue 2

Deadlines

For organizers: Expired
For abstracts: February 10, 2014

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

Invited Addresses

Nir Avni, Northwestern University, *To be announced.*

Alessio Figalli, University of Texas, *To be announced.*

Jean-Luc Thiffeault, University of Wisconsin-Madison, *To be announced.*

Rachel Ward, University of Texas at Austin, *To be announced.*

Special Sessions

Algebraic Geometry (Code: SS 9A), **David Weinberg**, Texas Tech University.

Analysis and Applications of Dynamic Equations on Time Scales (Code: SS 2A), **Heidi Berger**, Simpson College, and **Raegan Higgins**, Texas Tech University.

Applications of Special Functions in Combinatorics and Analysis (Code: SS 12A), **Atul Dixit**, Tulane University, and **Timothy Huber**, University of Texas Pan American.

Complex Function Theory and Special Functions (Code: SS 7A), **Roger W. Barnard** and **Kent Pearce**, Texas Tech University, **Kendall Richards**, Southwestern University, and **Alex Solynin** and **Brock Williams**, Texas Tech University.

Fractal Geometry and Dynamical Systems (Code: SS 3A), **Mrinal Kanti Roychowdhury**, The University of Texas-Pan American.

Homological Methods in Algebra (Code: SS 8A), **Lars W. Christensen**, Texas Tech University, **Hamid Rahmati**, Miami University, and **Janet Striuli**, Fairfield University.

Interactions between Commutative Algebra and Algebraic Geometry (Code: SS 11A), **Brian Harbourne** and **Alexandra Seceleanu**, University of Nebraska-Lincoln.

Issues Regarding the Recruitment and Retention of Women and Minorities in Mathematics (Code: SS 5A), **James Valles, Jr.** and **Doug Scheib**, Saint Mary-of-the-Woods College.

Lie Groups (Code: SS 13A), **Benjamin Harris**, **Hongyu He**, and **Gestur Ólafsson**, Louisiana State University.

Navier-Stokes Equations and Fluid Dynamics (Code: SS 14A), **Radu Dascaliuc**, Oregon State University, and **Luan Hoang**, Texas Tech University.

Noncommutative Algebra, Deformations, and Hochschild Cohomology (Code: SS 10A), **Anne Shepler**, University of North Texas, and **Sarah Witherspoon**, Texas A&M University.

Qualitative Theory for Non-linear Parabolic and Elliptic Equations (Code: SS 6A), **Akif Ibragimov**, Texas Tech University, and **Peter Polacik**, University of Minnesota.

Recent Advancements in Differential Geometry and Integrable PDEs, and Their Applications to Cell Biology and Mechanical Systems (Code: SS 4A), **Giorgio Bornia**, **Akif Ibragimov**, and **Magdalena Toda**, Texas Tech University.

Recent Advances in the Applications of Nonstandard Finite Difference Schemes (Code: SS 15A), **Ronald E. Mickens**, Clark Atlanta University, and **Lih-Ing W. Roeger**, Texas Tech University.

Topology and Physics (Code: SS 1A), **Razvan Gelca** and **Alastair Hamilton**, Texas Tech University.

Tel Aviv, Israel

Bar-Ilan University, Ramat-Gan and Tel-Aviv University, Ramat-Aviv

June 16–19, 2014

Monday – Thursday

Meeting #1101

The Second Joint International Meeting between the AMS and the Israel Mathematical Union.
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: January 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For abstracts: To be announced

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

Special Sessions

Mirror Symmetry and Representation Theory, **David Kazhdan**, Hebrew University, and **Roman Bezrukavnikov**, Massachusetts Institute of Technology.

Nonlinear Analysis and Optimization, **Boris Mordukhovich**, Wayne State University, and **Simeon Reich** and **Alexander Zaslavski**, The Technion-Israel Institute of Technology.

Qualitative and Analytic Theory of ODE's, **Yosef Yomdin**, Weizmann Institute.

Eau Claire, Wisconsin

University of Wisconsin-Eau Claire

September 20–21, 2014

Saturday – Sunday

Meeting #1102

Central Section
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: June 2014
Program first available on AMS website: August 7, 2014
Program issue of electronic *Notices*: September 2014
Issue of *Abstracts*: Volume 35, Issue 3

Deadlines

For organizers: March 20, 2014
For abstracts: July 29, 2014

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

Invited Addresses

Matthew Kahle, Ohio State University, *To be announced.*

Markus Keel, University of Minnesota, *To be announced.*

Svitlana Mayboroda, University of Minnesota, *To be announced.*

Dylan Thurston, Indiana University, *To be announced.*

Special Sessions

Directions in Commutative Algebra: Past, Present and Future (Code: SS 1A), **Joseph P. Brennan**, University of Central Florida, and **Robert M. Fossum**, University of Illinois at Urbana-Champaign.

Halifax, Canada

Dalhousie University

October 18–19, 2014

Saturday – Sunday

Meeting #1103

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 5, 2014
Program issue of electronic *Notices*: October 2014
Issue of *Abstracts*: Volume 35, Issue 3

Deadlines

For organizers: March 18, 2014
For abstracts: August 19, 2014

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

Invited Addresses

François Bergeron, Université du Québec à Montréal, *Title to be announced.*

Sourav Chatterjee, New York University, *Title to be announced.*

William M. Goldman, University of Maryland, *Title to be announced.*

Sujatha Ramdorai, University of British Columbia, *Title to be announced.*

Special Sessions

p-adic Methods in Arithmetic. (Code: SS 1A), **Henri Darmon**, McGill University, **Adrian Iovita**, Concordia University, and **Sujatha Ramdorai**, University of British Columbia.

San Francisco, California

San Francisco State University

October 25–26, 2014

Saturday – Sunday

Meeting #1104

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 11, 2014
Program issue of electronic *Notices*: October 2014
Issue of *Abstracts*: Volume 35, Issue 4

Deadlines

For organizers: March 25, 2014
For abstracts: September 3, 2014

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

Invited Addresses

Kai Behrend, University of British Columbia, Vancouver, Canada, *Title to be announced.*

Kiran S. Kedlaya, University of California, San Diego, *Title to be announced.*

Julia Pevtsova, University of Washington, Seattle, *Title to be announced.*

Burt Totaro, University of California, Los Angeles, *Title to be announced.*

Special Sessions

Algebraic Geometry (Code: SS 1A), **Renzo Cavalieri**, Colorado State University, **Noah Giansiracusa**, University of California, Berkeley, and **Burt Totaro**, University of California, Los Angeles.

Geometry of Submanifolds (Code: SS 3A), **Yun Myung Oh**, Andrews University, **Bogdan D. Suceava**, California State University, Fullerton, and **Mihaela B. Vajiac**, Chapman University.

Polyhedral Number Theory (Code: SS 2A), **Matthias Beck**, San Francisco State University, and **Martin Henk**, Universität Magdeburg.

Greensboro, North Carolina

University of North Carolina, Greensboro

November 8–9, 2014
Saturday – Sunday

Meeting #1105
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 25, 2014
Program issue of electronic *Notices*: November 2014
Issue of *Abstracts*: Volume 35, Issue 4

Deadlines
For organizers: April 8, 2014
For abstracts: September 16, 2014

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

Invited Addresses

Susanne Brenner, Louisiana State Unviersity, *Title to be announced*.

Skip Garibaldi, Emory University, *Title to be announced*.

Stavros Garoufaldis, Georgia Institute of Technology, *Title to be announced*.

James Sneyd, University of Auckland, *Title to be announced* (AMS-NZMS Maclaurin Lecture).

San Antonio, Texas

Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio

January 10–13, 2015
Saturday – Tuesday

Meeting #1106
Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th 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 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2015
Issue of *Abstracts*: Volume 36, Issue 1

Deadlines
For organizers: April 1, 2014
For abstracts: To be announced

Washington, District of Columbia

Georgetown University

March 7–8, 2015
Saturday – Sunday
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: August 7, 2014
For abstracts: To be announced

Huntsville, Alabama

University of Alabama in Huntsville

March 27–29, 2015
Friday – Sunday
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: August 20, 2014
For abstracts: To be announced

Las Vegas, Nevada

University of Nevada, Las Vegas

April 18–19, 2015
Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: September 18, 2014
For abstracts: To be announced

Mathematical Sciences Center

Tsinghua University, Beijing, China

Positions:
Distinguished Professorship; Professorship;
Associate Professorship;
Assistant Professorship (tenure-track).

The MSC invites applications for the above positions in the full spectrum of mathematical sciences: ranging from pure mathematics, applied PDE, computational mathematics to statistics. The current annual salary range is between 0.15-1.0 million RMB. Salary will be determined by applicants' qualification. Strong promise/track record in research and teaching are required. Completed applications must be electronically submitted, and must contain curriculum vitae, research statement, teaching statement, selected reprints and /or preprints, three reference letters on academic research and one reference letter on teaching, sent electronically to msc-recruitment@math.tsinghua.edu.cn

The review process starts in December 2013, and closes by April 30, 2014. Applicants are encouraged to submit their applications before February 28, 2014.

****

Positions: post-doctorate fellowship

Mathematical Sciences Center (MSC) will hire a substantial number of post-doctorate fellows in the full spectrum of mathematical sciences. New and recent PhDs are encouraged for this position.

A typical appointment for post-doctorate fellowship of MSC is for three-years.Salary and compensation package are determined by qualification, accomplishment, and experience. MSC offers very competitive packages.

Completed applications must contain curriculum vitae, research statement, teaching statement, selected reprints and /or preprints, three reference letters, sent electronically to msc-recruitment@math.tsinghua.edu.cn

The review process starts in December 2013, and closes by April 30, 2014. Applicants are encouraged to submit their applications before February 28, 2014.

Porto, Portugal

University of Porto

June 11–14, 2015
Thursday – Sunday
First Joint International Meeting involving the American Mathematical Societry (AMS), the European Mathematical Society (EMS), and the Sociedade de Portuguesa Matematica (SPM).
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Not applicable

Deadlines
For organizers: To be announced
For abstracts: To be announced

Chicago, Illinois

Loyola University Chicago

October 3–4, 2015
Saturday – Sunday
Central Section
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2015
Issue of *Abstracts*: To be announced

Deadlines
For organizers: March 10, 2015
For abstracts: To be announced

Fullerton, California

California State University, Fullerton

October 24–25, 2015
Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2015
Issue of *Abstracts*: To be announced

Deadlines
For organizers: March 27, 2015
For abstracts: To be announced

2014 Joint Mathematics Meetings Advance Registration/Housing Form

JOINT MATHEMATICS MEETINGS
BALTIMORE • JAN 15-18, 2014
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

Name _____
(please write name as you would like it to appear on your badge)

Mailing Address _____

_____

Telephone _____ Fax: _____

In case of emergency (for you) at the meeting, call: Day #_____ Evening #:_____

Email Address _____ Additional email address for receipt_____

Acknowledgment of this registration and any hotel reservations will be sent to the email address(s) given here. **Check this box for a copy in U.S. Mail:** ☐

Affiliation for badge _____ Nonmathematician guest badge name: _____
(company/university) (Note fee of US$15)

☐ **I DO NOT want my program and badge to be mailed to me on 12/13/13. (Materials will be mailed to the address listed above unless you check this box.)**

Registration Fees

Membership please ✓ that apply. First row is eligible to register as a JMM member.
☐ AMS ☐ MAA ☐ ASL ☐ CMS ☐ SIAM
☐ ASA ☐ AWM ☐ NAM ☐ YMN

Joint Meetings	**by Dec 24**	**at mtg**	**Subtotal**
☐ Member AMS, MAA, ASL, CMS, SIAM	US$240	US$ 315	
☐ Nonmember	US$374	US$ 486	
☐ Graduate Student (Mem. of AMS or MAA)	US$ 53	US$ 63	
☐ Graduate Student (Nonmember)	US$ 82	US$ 93	
☐ Undergraduate Student	US$ 53	US$ 63	
☐ High School Student	US$ 5	US$ 10	
☐ Unemployed	US$ 53	US$ 63	
☐ Temporarily Employed	US$195	US$ 224	
☐ Developing Countries Special Rate	US$ 53	US$ 63	
☐ Emeritus Member of AMS or MAA	US$ 53	US$ 63	
☐ High School Teacher	US$ 53	US$ 63	
☐ Librarian	US$ 53	US$ 63	
☐ Press	US$ 0	US$ 0	
☐ Nonmathematician Guest	US$ 15	US$ 15	
			$ _____

AMS Short Course: *Geometry and Topology in Statistical Inference (1/13–1/14)*

☐ Member of AMS or MAA	US$106	US$ 140	
☐ Nonmember	US$155	US$ 185	
☐ Student, Unemployed, Emeritus	US$ 54	US$ 75	
			$ _____

MAA Short Course: *Reading, Writing and Doing the History of Mathematics: Learning the Methods of Historical Research (1/13–1/14)*

☐ Member of MAA or AMS	US$ 159	US$ 169	
☐ Nonmember	US$ 234	US$ 244	
☐ Student, Unemployed, Emeritus	US$ 81	US$ 91	
			$ _____

MAA Minicourses (see listing in text)
I would like to attend: ☐ One Minicourse ☐ Two Minicourses
Please enroll me in MAA Minicourse(s) #_____ and/or #_____
In order of preference, my alternatives are: #_____ and/or #_____
Price: US$80 for each minicourse.
(For more than 2 minicourses, call or email the MMSB.) $ _____

Graduate School Fair
☐ Graduate Program Table US$ 75 US$ 75
(includes table, posterboard & electricity) $ _____

MAA Workshops
☐ Introductory Proposal Writing Workshop for Grant Applications to the NSF Div. of Undergraduate Education (1/16) (no charge)
☐ Advanced Proposal Writing Workshop for Grant Applications to the NSF Div. of Undergraduate Education (1/17) (no charge)

Receptions & Banquets
☐ Graduate Student/First Time Attendee Reception (1/15) (no charge)
☐ NAM Banquet (1/17) US$ 62 #___Chicken #___Fish
#___Kosher #___Vegan
☐ AMS Dinner (1/18) US$ 62
(Additional fees may apply for Kosher meals.) $ _____

Total for Registrations and Events $ _____

Registration for the Joint Meetings is not required for the short courses but it is required for the minicourses and the Employment Center. To register for the Employment Center, go to www.ams.org/profession/employment-services/employment-center.

Payment

Registration & Event Total (total from column on left) $ _____

Hotel Deposit (only if paying by check) $ _____

Total Amount To Be Paid **$** _____

(Note: A US$5 processing fee will be charged for each returned check or invalid credit card. Debit cards cannot be accepted.)

Method of Payment

☐ **Check**. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates. For all check payments, please keep a copy of this form for your records.

☐ **Credit Card**. All major credit cards accepted. For your security, we do not accept credit card numbers by postal mail, email or fax. If the MMSB receives your registration form by fax or postal mail, it will contact you at the phone number provided on this form. For questions, contact the MMSB at mmsb@ams.org.

Signature: _____

☐ **Purchase Order #**_____ (please enclose copy)

Other Information

Mathematical Reviews field of interest #_____

How did you hear about this meeting? Check one:
☐ Colleague(s) ☐ Internet ☐ *Notices* ☐ *Focus* ☐ Other_____

☐ This is my first Joint Mathematics Meetings.
☐ I am a mathematics department chair.
☐ For planning purposes for the MAA Two-year College Reception, please check if you are a faculty member at a two-year college.
☐ I would like to receive promotions for future JMM meetings.
☐ Please do not include my name on any promotional mailing lists.
☐ Please do not include my name on any list of participants distributed or displayed at any time.
☐ Please ✓ this box if you have a disability requiring special services.

Mailing Address/Contact:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887 **Fax**: 401-455-4004; **Email:** mmsb@ams.org
Telephone: 401-455-4144 or 1-800-321-4267 x4144 or x4137

Deadlines

To be eligible for the complimentary room drawing:	**Nov. 4, 2013**
For receiving badges/programs in the mail:	**Nov. 19, 2013**
For housing changes/cancellations through MMSB:	**Dec. 13, 2013**
For advance registration for the Joint Meetings, short courses, minicourses, and tickets:	**Dec. 24, 2013**
For 50% refund on banquets, cancel by:	**Jan. 7, 2014***
For 50% refund on advance registration, minicourses & short courses, cancel by:	**Jan. 10, 2014***

***no refunds issued after this date**

2014 Joint Mathematics Meetings Hotel Reservations – Baltimore, Maryland

(Please see the hotel page in the announcement or on the web for detailed information on each hotel.) To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc. in the column on the left and by circling the requested bed confirguration. If your requested hotel and room type is no longer available, you will be assigned a room at the next available comparable rate. Please call the MMSB for details on suite configurations, sizes, availability, etc. All reservations, including suite reservations, must be made through the MMSB to receive the JMM rates. Reservations made directly with the hotels before **December 13, 2013** may be changed to a higher rate. All rates are subject to a 15.5% sales/occupancy tax. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

☐ **Deposit enclosed (see front of form**)

☐ **Hold with my credit card**. **For your security, we do not accept credit card numbers by postal mail, email or fax.** If the MMSB receives your registration form by postal mail or fax, we will contact you at the phone number provided on the reverse of this form.

Date and Time of Arrival _____ **Date and Time of Departure**_____ **Number of adult guests in room** _____

Name of Other Adult Room Occupant _____ **Arrival Date**_____ **Departure Date**_____

Name of Other Adult Room Occupant _____ **Arrival Date**_____ **Departure Date** _____

Name of Other Adult Room Occupant _____ **Arrival Date**_____ **Departure Date** _____

Housing Requests:.(example: rollaway cot, crib, nonsmoking room, low floor) _____

☐ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are: _____

☐ I am a member of a hotel frequent-travel club and would like to receive appropriate credit. The hotel chain and card number are: _____

☐ I am not reserving a room. I am sharing with_____ , who is making the reservation.

Order of choice	Hotel	Bed configuration (please circle preference)	Single/Double Rate	Additional Adult (More than 2 adults; Max: 4)	Rollaway Cot Fee (add to special requests)
	Hilton Baltimore (htqrs)	King bed or 2 double beds	US$ 159	US$ 20 per person	US$ 25.00 (one time)
	Student Rate	King bed or 2 double beds	US$ 127	US$ 20 per person	US$ 25.00 (one time)
	Baltimore Marriott Inner Harbor (htqrs)	King bed or 2 double beds	US$ 149	US$ 20 per person	No charge
	Student Rate	King bed or 2 double beds	US$ 115	US$ 20 per person	No charge
	Sheraton Inner Harbor	King bed or 2 double beds	US$ 149	US$ 20 per person	US$ 20.00 (per day)
	Student Rate	King bed or 2 double beds	US$ 139	US$ 20 per person	US$ 20.00 (per day)
	Hyatt Regency Baltimore	King, Queen or 2 double beds	US$ 145	US$ 25 per person	US$ 25.00 (one time)
	Student Rate	King, Queen or 2 double beds	US$ 135	US$ 25 per person	US$ 25.00 (one time)
	Renaissance Baltimore Harborplace	King, Queen or 2 double beds	US$ 135	US$ 20 per person	US$ 20.00 (per day)
	Student Rate	King, Queen or 2 double beds	US$ 115	US$ 20 per person	US$ 20.00 (per day)
	Baltimore Marriott Waterfront	King bed or 2 double beds	US$ 135	US$ 20 per person	No charge
	Student Rate	King bed or 2 double beds	US$ 115	US$ 20 per person	No charge
	Royal Sonesta Harbor Court	King bed or 2 double beds	US$ 125	US$ 20 per person	US$ 25.00 (per day, king bed room only)
	Student Rate	King bed or 2 double beds	US$ 99	US$ 20 per person	US$ 25.00 (per day, king bed room only)
	Days Inn Baltimore Inner Harbor	King, Queen or 2 double beds	US$ 119	No charge	US$ 10.00 (per day, king bed room only)
	Student Rate	King, Queen or 2 double beds	US$ 109	No charge	US$ 10.00 (per day, king bed room only)
	Holiday Inn Inner Harbor	King, Queen or 2 double beds	US$ 119	No charge	US$ 15.00 (per day, king bed room only)
	Student Rate	King, Queen or 2 double beds	US$ 99	No charge	US$ 15.00 (per day, king bed room only)
	Hotel Monaco	King, 2 Queens or 2 double beds	US$ 119	US$ 20 per person	US$ 25.00 (per day, king bed room only)
	Student Rate	King, 2 Queens or 2 double beds	US$ 109	US$ 20 per person	US$ 25.00 (per day, king bed room only)

People interested in suites should contact the MMSB directly at mmsb@ams.org or call 800-321-4267, ext. 4137 or 4144 (401-455-4137 or 401-455-4144)

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Central Section: **Georgia Benkart**, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388; e-mail: benkart@math.wisc.edu; telephone: 608-263-4283.

Eastern Section: **Steven H. Weintraub**, Department of Mathematics, Lehigh University, Bethlehem, PA 18105-3174; e-mail: steve.weintraub@lehigh.edu; telephone: 610-758-3717.

Southeastern Section: **Brian D. Boe,** Department of Mathematics, University of Georgia, 220 D W Brooks Drive, Athens, GA 30602-7403, e-mail: brian@math.uga.edu; telephone: 706-542-2547.

Western Section: Michel L. Lapidus, Department of Mathematics, University of California, Surge Bldg., Riverside, CA 92521-0135; e-mail: lapidus@math.ucr.edu; telephone: 951-827-5910.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information can be found at** www.ams.org/meetings/.

Meetings:

2013

October 18–20	St. Louis, Missouri	p. 1412
November 2–3	Riverside, California	p. 1413

2014

January 15–18	Baltimore, Maryland Annual Meeting	p. 1414
March 21–23	Knoxville, Tennessee	p. 1414
March 29–30	Baltimore, Maryland	p. 1415
April 5–6	Albuquerque, New Mexico	p. 1416
April 11–13	Lubbock, Texas	p. 1416
June 16–19	Tel Aviv, Israel	p. 1417
September 20–21	Eau Claire, Wisconsin	p. 1417
October 18–19	Halifax, Canada	p. 1418
October 25–26	San Francisco, California	p. 1418
November 8–9	Greensboro, North Carolina	p. 1419

2015

January 10–13	San Antonio, Texas Annual Meeting	p. 1419
March 7–8	Washington, DC	p. 1419
March 20–22	Huntsville, Alabama	p. 1419
April 18–19	Las Vegas, Nevada	p. 1419
June 11–14	Porto, Portugal	p. 1420
October 3–4	Chicago, Illinois	p. 1420
October 24–25	Fullerton, California	p. 1420

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 274 in the the February 2013 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 http://www.ams.org/cgi-bin/abstracts/abstract.pl. Questions about abstracts may be sent to abs-info@ams.org. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences in Cooperation with the AMS: (see http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

November 1–3, 2013: Sixth International Conference on Science and Mathematics Education in Developing Countries, Mandalay, Myanmar.

CAMBRIDGE

E-books Available for most titles!

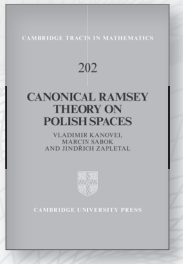
NEW TITLES IN MATHEMATICS *from* CAMBRIDGE UNIVERSITY PRESS!

Canonical Ramsey Theory on Polish Spaces

Vladimir Kanovei, Marcin Sabok, *and* Jindřich Zapletal

Cambridge Tracts in Mathematics

$80.00: Hardback: 978-1-107-02685-8: 278 pp.

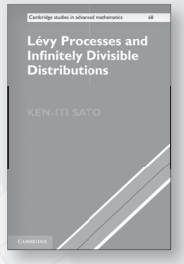


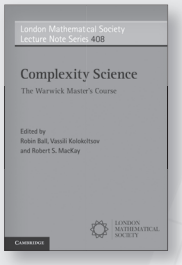
Lévy Processes and Infinitely Divisible Distributions

Ken-iti Sato

Cambridge Studies in Advanced Mathematics

$80.00: Paperback: 978-1-107-65649-9: 536 pp.





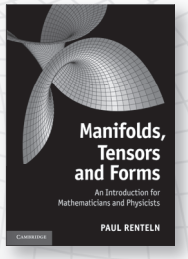
Complexity Science

The Warwick Master's Course

Edited by Robin Ball, Vassili Kolokoltsov, *and* Robert S. MacKay

London Mathematical Society Lecture Note Series

$70.00: Paperback: 978-1-107-64056-6: 450 pp.



Manifolds, Tensors, and Forms

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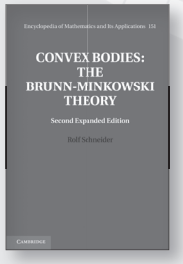

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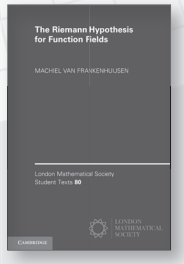

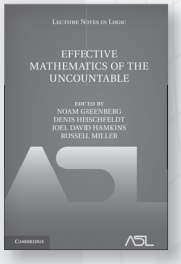

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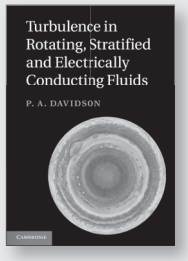

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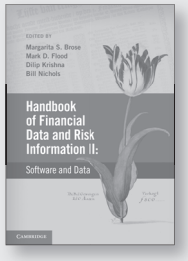

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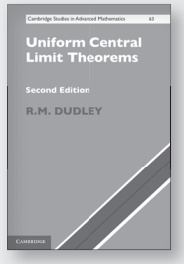

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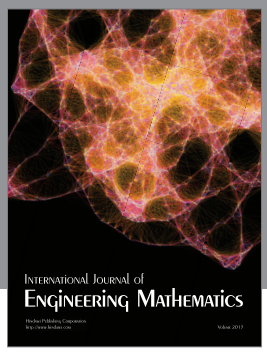

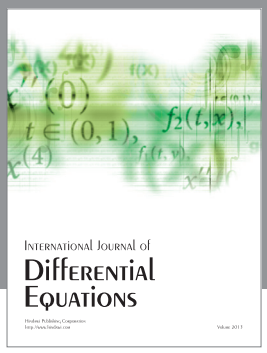

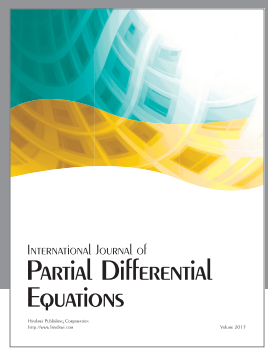

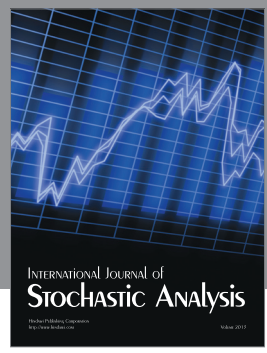

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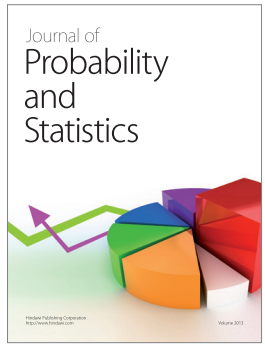

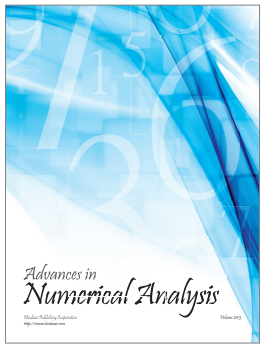

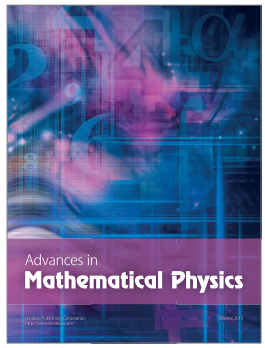

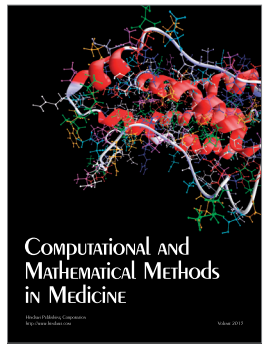

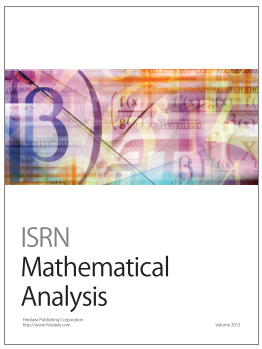

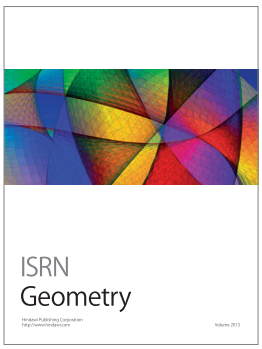

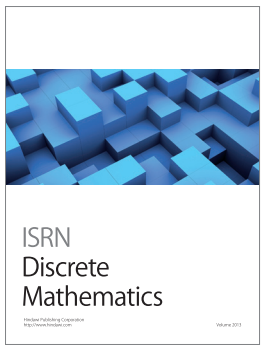

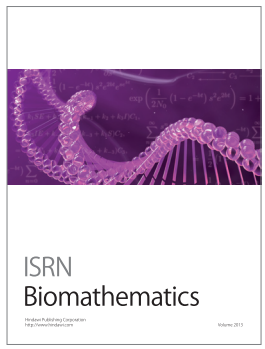

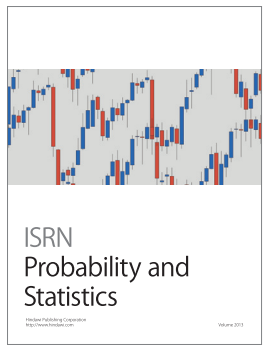

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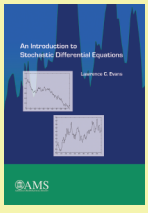

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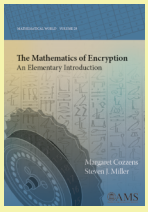

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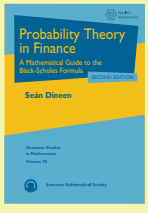

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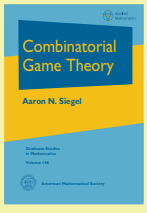

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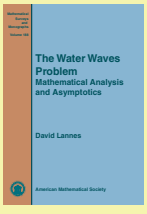

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