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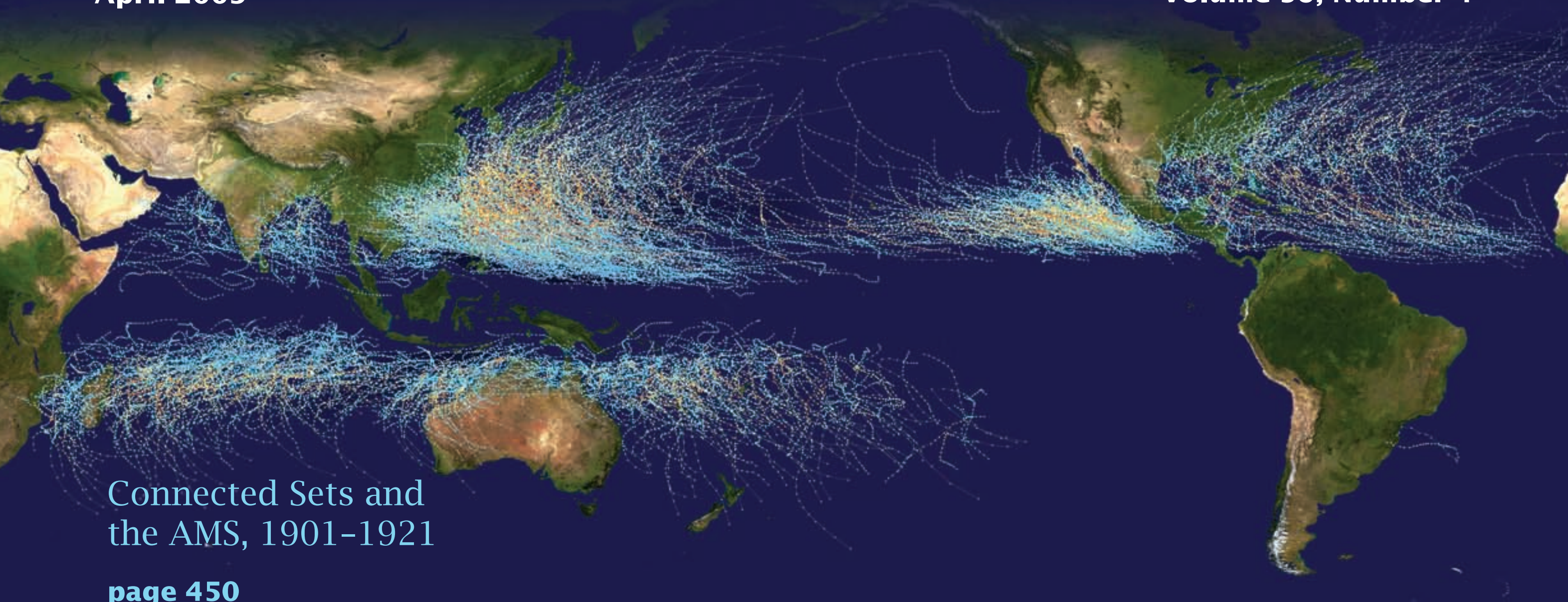
# Notices

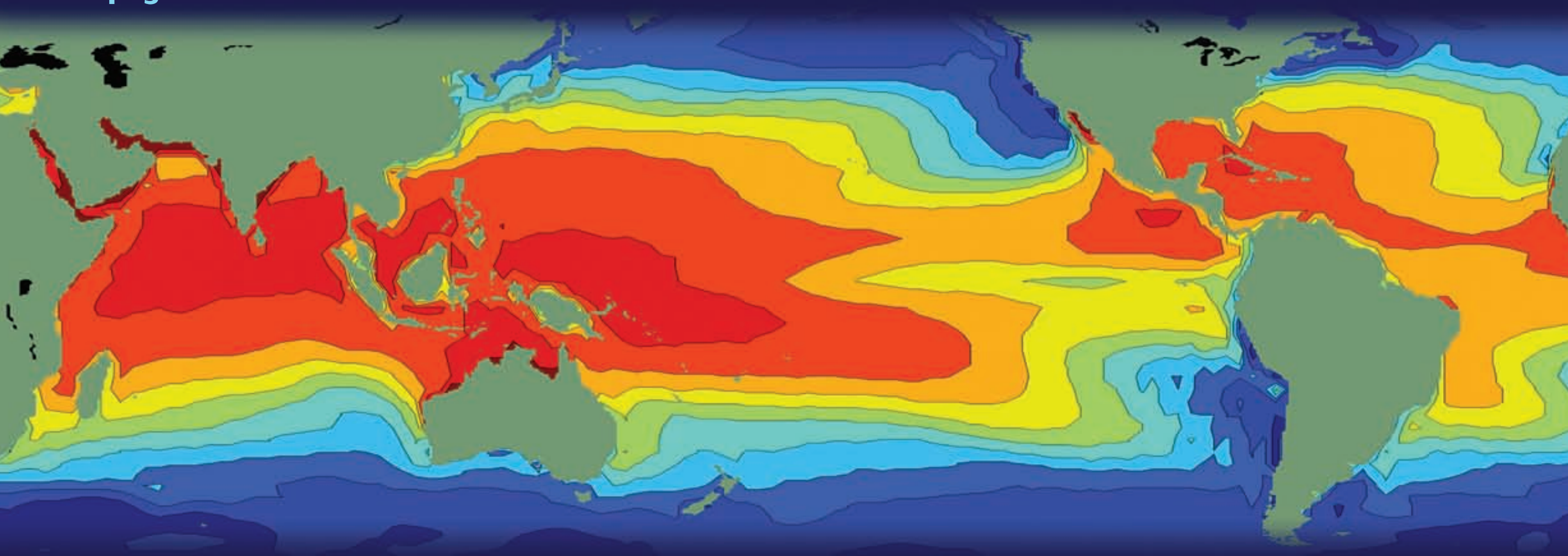
## of the American Mathematical Society

April 2009

Volume 56, Number 4







*Tracking hurricanes* *(see page 487)*

# New and Forthcoming

## Explorations in Harmonic Analysis

### with Applications to Complex Function Theory and the Heisenberg Group

**Steven G. Krantz**, Washington University, St. Louis, MO, USA

This self-contained text provides an introduction to modern harmonic analysis in the context in which it is actually applied, in particular, through complex function theory and partial differential equations. It takes the novice mathematical reader from the rudiments of harmonic analysis (Fourier series) to the Fourier transform, pseudodifferential operators, and finally to Heisenberg analysis. Within the textbook, the new ideas on the Heisenberg group are applied to the study of estimates for both the Szegö and Poisson–Szegö integrals on the unit ball in complex space.

2009. XIV, 360 P. 26 ILLUS. HARDCOVER
ISBN 978-0-8176-4668-4 CA. $69.95
APPLIED AND NUMERICAL HARMONIC ANALYSIS

## Distributions

### Theory and Applications

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This text is a concise, application-oriented introduction to the theory of distributions. It presents distributions as a natural method of analysis from both a mathematical and physical point of view. Methods are developed to justify many formal calculations that do not make sense in the classical framework. The discussion emphasizes applications to the general study of linear partial differential equations. The topics include an introduction to distributions, differentiation, convergence, and convolution of distributions, as well as Fourier transformations and spaces of distributions having special properties.

2009. APPROX. 350 P. 25 ILLUS. HARDCOVER
ISBN 978-0-8176-4672-1 CA. $59.95
CORNERSTONES

## Stochastic Models, Information Theory, and Lie Groups

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**Gregory S. Chirikjian**, The John Hopkins University, Baltimore, MD, USA

The subjects of stochastic processes, information theory, and Lie groups are usually treated separately from each other. This unique textbook presents these topics in a unified setting, thereby building bridges among fields that are rarely studied by the same individuals. Volume I establishes the geometric and statistical foundations required to understand the fundamentals of continuous-time stochastic processes, differential geometry, and the statistical branch of information theory.

2009. APPROX. 410 P. 15 ILLUS. HARDCOVER
ISBN 978-0-8176-4802-2 CA. $54.95
APPLIED AND NUMERICAL HARMONIC ANALYSIS

## Mathematics for Multimedia

**M. Victor Wickerhauser**, Washington University, St. Louis, MO, USA

This textbook presents the mathematics that is foundational to multimedia applications. Featuring a rigorous survey of selected results from algebra and analysis, the work examines tools used to create application software for multimedia signal processing and communication. Key features include over 100 exercises with complete solutions; many sample programs in Standard C and illustrations based on data from real studies; suggestions for further reading at the end of each chapter; and a companion website providing the computer programs described in the book as well as additional references and data files, such as images and sounds, to enhance the reader's understanding of key topics.

2009. APPROX. 310 P. 50 ILLUS. HARDCOVER
ISBN 978-0-8176-4879-4 CA. $79.95
APPLIED AND NUMERICAL HARMONIC ANALYSIS

## Families of Conformally Covariant Differential Operators, Q-Curvature and Holography

**Andreas Juhl**, Humboldt-Universität Berlin, Germany

This book studies structural properties of Q-curvature from an extrinsic point of view by regarding it as a derived quantity of certain conformally covariant families of differential operators which are associated to hypersurfaces. The new approach is at the cutting edge of central developments in conformal differential geometry in the last two decades (Fefferman-Graham ambient metrics, spectral theory on Poincaré-Einstein spaces, tractor calculus, Verma modules and Cartan geometry). The theory of conformally covariant families is inspired by the idea of holography in the AdS/CFT-duality. Among other things, it naturally leads to a holographic description of Q-curvature. The methods admit generalizations in various directions.

2009. APPROX. 500 P. HARDCOVER
ISBN 978-3-7643-9899-6 $119.00
PROGRESS IN MATHEMATICS, VOL. 275

## Nonlinear Partial Differential Equations

### Asymptotic Behavior of Solutions and Self-Similar Solutions

**Mi-Ho Giga; Yoshikazu Giga**, both Giga Laboratory, University of Tokyo, Japan; **Jürgen Saal**, University of Konstanz, Germany

This work will serve as an excellent first course in modern analysis. Key topics in nonlinear PDEs as well as several fundamental tools and methods are presented. Challenging exercises, examples, and illustrations help explain the rigorous analytic basis for the Navier–Stokes equations, mean curvature flow equations, and other important equations describing real phenomena.

2009. APPROX. 350 P. 20 ILLUS. HARDCOVER
ISBN 978-0-8176-4173-3 CA. $99.00
PROGRESS IN NONLINEAR DIFFERENTIAL EQUATIONS AND THEIR APPLICATIONS

# Notices
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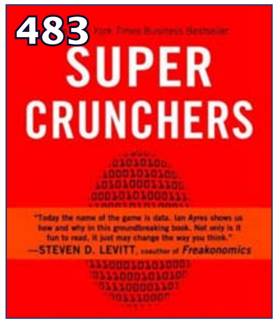
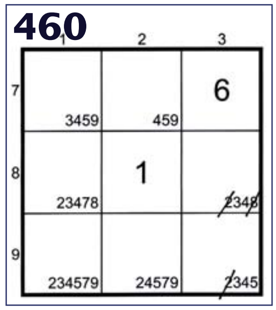
## Communications

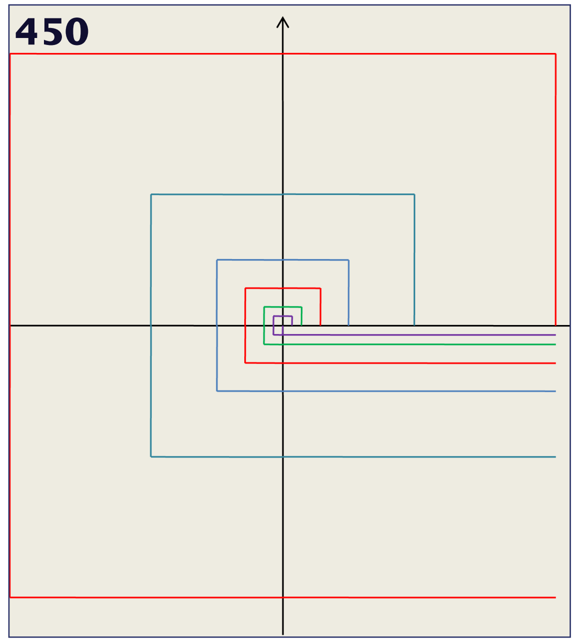


## Commentary






## Features

# Notices

of the American Mathematical Society



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## Departments



## From the AMS Secretary

## Opinion

# Climate Change: Can Mathematics Help Clear the Air?

Does mathematics have a crucial role to play in understanding climate change? At least one third of the students in my First Year Seminar on Mathematics and Climate Change don't think so. And they are bright students who have signed up for a class on the topic! Hopefully their views will shift as the semester progresses, but it's easy to see why this is their first reaction. The physics of global warming is clear: the greenhouse effect means that increasing carbon concentrations reflect more and more of the long wavelength radiation emitted by the Earth itself, thus heating up the atmosphere. The chemistry too is clear: carbon that is the result of human activity can be distinguished by isotope, and it is this type of carbon that is increasing in concentration in the atmosphere. The evidence is now accumulating that the Earth has already warmed significantly. Why do we need to know anything more? For it is in the drive to know more about exactly what will happen that mathematics is brought in.

Prediction and prophesy of future events have fueled human emotions since time immemorial. From fortune-telling and astrology to the great plays of Ancient Greece, the word of those making predictions has carried great authority but has also attracted controversy. We would expect then that predictions of serious climate change would prompt similarly skeptical and severe reactions. But surely founding those predictions on sound mathematical modeling should exempt them from such a furor? One might argue that mathematical models of climate are of no use because we know that the weather is unpredictable after a few days, and the climate models are based on the same equations. So how can we even dream of making predictions decades into the future? The generally held explanation of the breakdown of weather prediction, credited to Lorenz, is that the system is sensitive to initial conditions, i.e., it is chaotic. But climate is about averages, and not specifics like whether it will rain over New York on April 1, 2009; wanted are average annual temperature, rainfall, and sea-level rise in regional climatic zones. This gives us reason for hope, as chaotic systems can have well-defined and robust statistical averages.

Predicting the climate involves modeling the entire Earth system in all its complexity. Beyond the obvious functioning of the atmosphere, critical elements include: sea ice and its dynamics, land ice and the way it might melt, ocean circulation, land use and deforestation, cloud formation and motion, as well as the socio-economics of carbon production. None of these are well understood nor do we have definitive—or, in some cases such as sea ice and clouds—even adequate, models for them. We bravely model the climate system anyway and use whatever information and models are available. This is clearly the right thing to do. But what do we make of the output?

We can certainly infer general trends from these predictions, but the social and political pressures to provide something more concrete are enormous. The response of the scientific community has largely been to focus on producing ever more complex models with ever increasing resolution. This makes good sense if this process of improving approximations is convergent. However, it is not at all clear that this process converges in any sense that we would trust, either mathematically or operationally.

The idea of a convergent prediction process has nevertheless put mathematics on the hot seat of climate change (and I suppose it goes without saying that it will only get hotter). I suspect that the mathematical community has, perhaps unconsciously, shied away from the area for this reason: something is being done in our name with which we are not completely comfortable.

Tunnel vision about climate prediction has obscured the enormous amount we have to offer the study of climate change. As mentioned earlier, critical processes, such as sea ice dynamics, cloud formation, and ocean circulation, are not well understood. Mathematical models will play a crucial role as our understanding of these processes develops and improves. Applied mathematics is about producing ideas for the modeling, analysis, approximation, and computation of models such as these. The models of these climate processes are tremendously complex, multifaceted (think of coupling socio-economic and physical models), and multi-scale, to mention just a few of their complexities. But this all goes toward making them fascinating objects of study.

As a discipline, applied mathematics does not claim to solve the big questions of the universe, and predicting the climate in 2100 may rank as such a question at this point in time. We are highly innovative technicians who get our hands dirty with details and produce ideas that can trigger unimagined advances. This triggering will happen only if we play in the right sandbox, and the sandbox of climate change processes badly needs us to jump in and get our hands into what is frighteningly looking like the sands of time.

*—Christopher K. R. T. Jones*
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"Mathematics and Climate" is the theme for Mathematics Awareness Month (MAM) 2009. Mathematics departments and individuals across the country celebrate MAM each year in April to highlight the beauty and importance of mathematics. The 2009 MAM theme poster, theme essays, a sample press release, and other resources are available at http://www.mathaware.org. The May 2009 issue of the *Notices*, which will appear in mid-April, will also carry an MAM-themed article about modeling sea ice.

AMERICAN MATHEMATICAL SOCIETY

# TEXTBOOKS
## FOR COURSE ADOPTION

Graduate and undergraduate level publications suitable for use as textbooks and supplementary course reading


### Algebra
### A Graduate Course
◆ GRADUATE

**I. Martin Isaacs**, *University of Wisconsin, Madison, WI*

**Graduate Studies in Mathematics**, Volume 100; 1994; 516 pages; Hardcover; ISBN: 978-0-8218-4799-2; List US$79; AMS members US$63; Order code GSM/100

### Approximately Calculus
◆ UNDERGRADUATE

**Shahriar Shahriari**, *Pomona College, Claremont, CA*

2006; 292 pages; Hardcover; ISBN: 978-0-8218-3750-4; List US$49; AMS members US$39; Order code ACALC

### Real Analysis
◆ UNDERGRADUATE

**Frank Morgan**, *Williams College, Williamstown, MA*

2005; 151 pages; Hardcover; ISBN: 978-0-8218-3670-5; List US$41; AMS members US$33; Order code REAL

### The Mathematics of Finance
### Modeling and Hedging
◆ UNDERGRADUATE

**Victor Goodman** and **Joseph Stampfli**, *Indiana University, Bloomington, IN*

**Pure and Applied Undergraduate Texts**, Volume 7; 2001; 250 pages; Hardcover; ISBN: 978-0-8218-4793-0; List US$62; AMS members US$50; Order code AMSTEXT/7

### Numerical Analysis
### Mathematics of Scientific Computing, Third Edition
◆◆ UNDERGRADUATE GRADUATE

**David Kincaid** and **Ward Cheney**, *University of Texas at Austin, TX*

**Pure and Applied Undergraduate Texts**, Volume 2; 2002; 788 pages; Hardcover; ISBN: 978-0-8218-4788-6; List US$89; AMS members US$71; Order code AMSTEXT/2

### Partial Differential Equations
◆ GRADUATE

**Lawrence C. Evans**, *University of California, Berkeley, CA*

**Graduate Studies in Mathematics**, Volume 19; 1998; 662 pages; Hardcover; ISBN: 978-0-8218-0772-9; List US$83; AMS members US$66; Order code GSM/19

### Roots to Research
### A Vertical Development of Mathematical Problems
◆◆ UNDERGRADUATE GRADUATE

**Judith D. Sally**, *Northwestern University, Evanston, IL*, and **Paul J. Sally, Jr.**, *University of Chicago, IL*

2007; 338 pages; Hardcover; ISBN: 978-0-8218-4403-8; List US$49; AMS members US$39; Order code MBK/48

### Geometry for College Students
◆ UNDERGRADUATE

**I. Martin Isaacs**, *University of Wisconsin, Madison, WI*

**Pure and Applied Undergraduate Texts**, Volume 8; 2001; 222 pages; Hardcover; ISBN: 978-0-8218-4794-7; List US$62; AMS members US$50; Order code AMSTEXT/8

### Basic Quadratic Forms
◆ GRADUATE

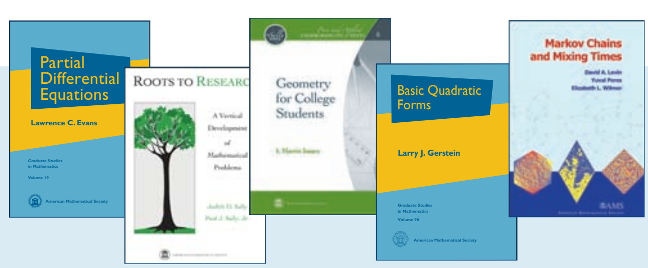
**Larry J. Gerstein**, *University of California, Santa Barbara, CA*

**Graduate Studies in Mathematics**, Volume 90; 2008; 255 pages; Hardcover; ISBN: 978-0-8218-4465-6; List US$55; AMS members US$44; Order code GSM/90

### Markov Chains and Mixing Times
◆◆ UNDERGRADUATE GRADUATE

**David A. Levin**, *University of Oregon, Eugene, OR*, **Yuval Peres**, *Microsoft Research, Redmond, WA, and University of California, Berkeley, CA*, and **Elizabeth L. Wilmer**, *Oberlin College, OH*

2009; 371 pages; Hardcover; ISBN: 978-0-8218-4739-8; List US$65; AMS members US$52; Order code MBK/58

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# Letters to the Editor

## Why the Sky Is Still Falling

In an article in the January 2009 *Notices*, David Bressoud is alarmed by the declining enrollment in math departments and obtains much of his data from enrollments in calculus courses at several levels. In North America, more students than ever take calculus in high school but fewer than ever take advanced calculus in university. This is significant because, as Bressoud observes, "calculus is at the heart of the mathematics curriculum" (p 22). If we want to understand this pattern of declining interest in mathematics, our view is that we need look no further than that statement.

We are convinced that the increasing adoption of calculus as the ultimate course in the high school curriculum has had a significant negative effect on mathematics enrollments in university. The reason is simple. Students learn (and learn how to learn!) by "playing"—reinventing, reconstructing—and calculus is not so easy to play with, nor is it particularly enticing for most students. Certainly students in high school are not ready and able to play with calculus, except possibly in the hands of an exceptional teacher. As Bressoud's data confirms, the introduction to higher mathematics provided by calculus convinces most of them that it's an important and sophisticated subject, but not for them.

Our view is that the final high school course should work with problems and investigations that bring together and build on the methods of algebra, geometry, and functions that have been developed in the earlier grades and open the way to a number of more sophisticated ideas from, for example, probability, recursive thinking, stability, invariance, transformation, and mathematical analysis. The problems that we use to do this should draw them in and challenge them. Given that, they will spend the time playing with their analysis, both working with one another and inventing their own solutions, and they will finally gain that crucial sense of mastery that one needs to move confidently forward in the subject.

As things stand, the final high school course is not at all like that. Why is that? Where does the responsibility lie for the growing emphasis on high school calculus? In our view it is the fact that calculus is the default mathematics service course for students in science, business, health, and several other areas, in their freshman year at college or university. It is also the default filter for future teachers of mathematics—and that generates a damaging feedback loop into high school mathematics classrooms. A good part of the reason for this is historical. There was a brief movement in the early 1980s, anticipating the advent of universal computer power, that promoted algebra and discrete mathematics. But a vigorous response in the late 1980s and early 1990s which emphasized the beauty and historical importance of mathematical analysis led to the highly successful calculus reform movement. And it has to be said that this movement carried with it new ideas of mathematical modeling and investigative approaches to problem solving. However, in a context focused on completing calculus early, and with teachers filtered through calculus as "the heart of the mathematics curriculum", the content lists continue to dominate the promising possibilities of reform teaching.

Now, twenty years later, maybe it's time to look again at what we teach when and why. And perhaps this time there are two questions that we might bear down upon:

(1) student engagement—what types of problems will entice the student into a sustained active learning mode?

(2) professional needs—what mathematics does the student need after graduation, and moving through the profession or the workplace?

We feel that the second question alone would lead to a mathematics program, at both the school and university level, that was much more algebraic, geometric, and discrete, emphasizing a number of the big ideas above, rather then the systematic coverage of calculus and differential equations we see at the moment. At the university level, this applies particularly to our extremely important "service" courses for students from a wide range of disciplines such as biology, psychology, economics. For these students we would like to see a course that is more collaborative, literate, and problems-based. We favor an approach that looks for the world in a grain of sand, and in the lively exchanges we would have with our students.

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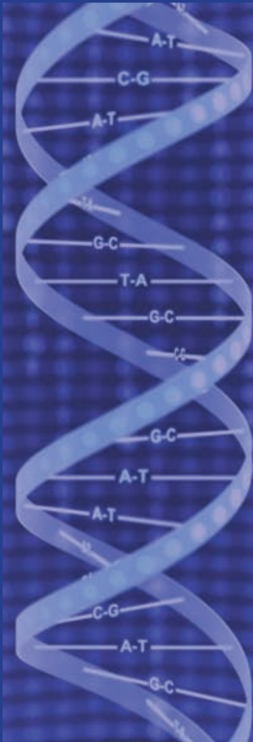
### Submitting Letters to the Editor

The *Notices* invites readers to submit letters and opinion pieces on topics related to mathematics. Electronic submissions are preferred (notices-letters@ams.org); see the masthead for postal mail addresses. Opinion pieces are usually one printed page in length (about 800 words). Letters are normally less than one page long, and shorter letters are preferred.




The American Mathematical Society presents

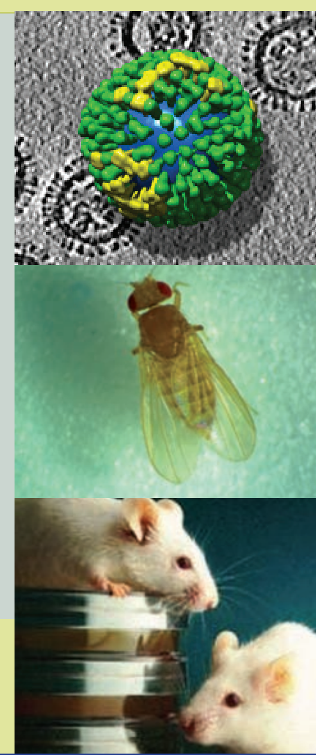
# The AMS Einstein Public Lecture in Mathematics

## Michael Waterman

Professor of Biological Sciences, Mathematics, and Computer Science;
University of Southern California

## Reading DNA Sequences: 21st Century Technology with 18th Century Mathematics

**Saturday, April 4, 2009**
**7:00 p.m.**
**North Carolina State University**
**Nelson Auditorium (3400 Nelson Hall)**



With the discovery of the double helix in 1953, it became clear that determining DNA sequences was an important goal. The Sanger method was invented in 1975 and by 2001 refinements of that method allowed sequencing of the human genome. Today an exciting new generation of sequencing methods is rapidly increasing the speed of DNA sequencing. This lecture will consider the mathematical and computational challenges of sequencing DNA.

Sponsored by the American Mathematical Society.
Hosted by the Department of Mathematics at North Carolina State University.
This event is part of the AMS 2009 Spring Southeastern Section Meeting, April 4-5.



**www.ams.org/meetings/einstein-lect.html**

# Connected Sets and the AMS, 1901–1921

*David E. Zitarelli*

Chapter 1 of Kelley's famous book *General Topology* introduces the most fundamental concepts of a topological space. One such notion is defined as follows [1]:

> A topological space $(X, \tau)$ is **connected** if and ony if $X$ is not the union of two nonvoid separated subsets, where $A$ and $B$ are **separated** in $X$ if and only if $\overline{A} \cap B = \emptyset$ and $\overline{A} \cap B = \emptyset$.

As usual, $\overline{Y}$ denotes the closure of a subset $Y$ of $X$.

Kelley's book has been a staple for several generations of graduate students, many of whom must have wondered what this formal definition had to do with their intuitive notion of a connected set. Frequently, such queries can be answered by an historical investigation, and the aim here is to trace the development of the formal concept of a connected set from its origins in 1901 until its ultimate ascension into the ranks of mathematical concepts worthy of study for their own sake twenty years later. Much of this development took place at the University of Chicago under E. H. Moore, and the evolution of connected sets exemplifies one specific way in which ideas that germinated there would be promulgated by his descendants. Although Moore exerted little direct influence, his department's core of outstanding graduate students, like the well-known Oswald Veblen, and its cadre of small-college instructors and high school teachers from across the country who pursued degrees during summer sessions, like the lesser-known N. J. Lennes, would play a decisive role.

An overarching theme is how the rapidly evolving AMS abetted this development in two ways. For one, local and national meetings provided venues where researchers could present their work and keep abreast of the progress of others. For another, the two AMS publications, the *Bulletin* and the *Transactions*, provided outlets for publishing these findings. Neither journal had widespread readership across the Atlantic so, as we will see, the study of connected sets would proceed in Europe independently of advances in America. Initially, European initiatives appeared in a Polish journal and were based on a classic book by Hausdorff, but ultimately the two schools of topology would interact symbiotically over connected sets. One of the contributors who engendered the ensuing international collaboration was Anna Mullikin, a second-generation Moore descendant who became the first American to publish a paper devoted to connected sets. We end our account by examining one of her chief examples, Mullikin's nautilus, to illustrate the power of the general definition first proposed by N. J. Lennes. We begin by introducing the latter's life and work, emphasizing the formulation of connected sets he announced fifty years before the appearance of Kelley's classic.

## The Pioneer N. J. Lennes

It seems appropriate that the person who pioneered the modern definition of a connected set would be a pioneer himself in a geographic sense. Nels Johann Lennes (1874–1951) came to the U.S. from his native Norway at age sixteen and, like many Scandinavians, settled in Chicago. Recall that the University of Chicago opened its doors in 1892;

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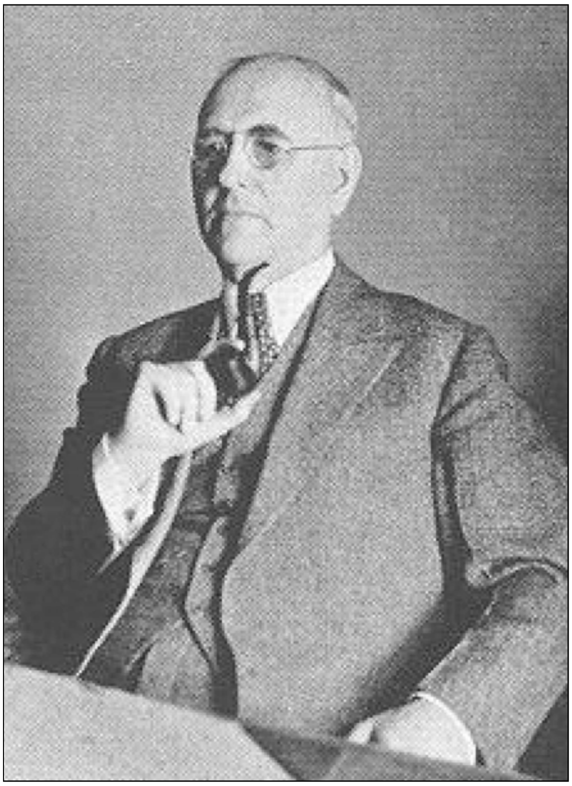


**N. J. Lennes**

Lennes enrolled four years later and earned a bachelor's degree in just two years. Upon graduation he became a high school teacher (1898–1907), taking graduate courses at Chicago all the while. With his Ph.D. in hand he then taught at the Massachusetts Institute of Technology and Columbia University for three years each before his pioneering move to distant Missoula, Montana, where he was professor of mathematics and head of the department from 1913 until retirement in 1944. ([2] provides an overview of his life and work; he is described as "one of the precursors of modern abstract mathematics".)

This biographical vignette indicates that while Lennes was a student at Chicago he rubbed elbows with two other students who would ultimately make important contributions to this development, Oswald Veblen (1880–1960) and R. L. Moore (1882–1974). The mathematics department in Eckhart Hall was a cauldron of activity, and this trio emerged during a ten-year period that produced such legendary figures as L. E. Dickson (1874–1954), G. A. Bliss (1876–1951), and G. D. Birkhoff (1884–1944).

Veblen, recently profiled in the *Notices* [3], enrolled at Chicago in 1900 after having spent a year at Harvard obtaining a second bachelor's degree. It is known that he first impressed E. H. Moore during the fall 1901 seminar "Foundations of Geometry", and that his subsequent proof of the Jordan Curve Theorem (JCT) was inspired by discussions in the seminar. It is not so widely known that Lennes played a decisive role with the JCT too. In fact, Veblen's first paper on topology reported that Lennes, in his 1903 master's thesis, proved the special case of the JCT for a simple polygon [4, p. 83]. Because the idea of a curve dividing a plane into separated subsets suggests the definition of a disconnected set, as implicitly defined by Lennes, we date our history from 1901.

The Moore seminar was pivotal for the careers of Veblen and Lennes, and as usual the AMS played a major role. The Chicago cauldron's mix of topological ingredients simmered at the April 1903 meeting of the Chicago Section, where Moore's advanced graduate students delivered noteworthy presentations of research they had begun in the seminar. The twenty-two-year-old Veblen announced major results that would appear in his dissertation, one of which included a proof independent of Lennes that "The boundary of a simple polygon lying entirely in a plane $\alpha$ decomposes $\alpha$ into two regions" [5, p. 365]. Veblen was in the process of establishing the first rigorous proof of the JCT, which he labeled "The fundamental theorem of Analysis Situs" in a paper read at the AMS meeting that preceded the International Congress at the St. Louis World's Fair in 1904 [4, p. 83]. The JCT remains a benchmark of mathematical rigor today. (See [7] for a modern, computer-oriented account of this phenomenon.)

At the April 1903 meeting, Lennes, six years Veblen's senior, presented results from his master's thesis, "Theorems on the polygon and the polyhedron". In what was to become customary for him, he would not submit this work for publication for another seven years even though he would then assert that only "minor changes and additions have been made since that time" [8, p. 37]. The chief result was that "the polygon and polyhedron separate the plane and the three-space respectively into two mutually exclusive sets" [*Ibid.*], an affirmation of the inspiration for his definition of a connected set in terms of separated domains.

Even though primarily engaged with teaching high school, Lennes continued his activity with the AMS by presenting two papers at the December 1904 meeting of the Chicago Section. One dealt with Hilbert's theory of area and resulted in a *Transactions* publication the next year, reflecting an ongoing interest in geometrical topics. The other was concerned with improper definite integrals, resulting in a paper in the *American Journal*. During this time he also published a paper on uniform continuity in the *Annals*, his first publication *not* read first before an AMS audience. Moreover, Lennes submitted a paper on real function theory that was read by title at the annual AMS summer meeting in September 1905.

The focus of Nels Lennes's research program was analysis, a topic he was pursuing in earnest with Oswald Veblen, who remained at Chicago for two years after receiving his Ph.D. in 1903. It is known that Veblen played a central role in mentoring R. L. Moore and directing his dissertation, but the symbiotic relationship between Veblen and Lennes seems to have escaped attention. Their joint activity can be seen in Veblen's dissertation, where he expressed his "deep gratitude to Professor E. H. Moore…and also to Messrs. N. J. Lennes and R. L. Moore, who have critically read parts of the manuscript" [5, p. 344].

*[Lennes's definition] represented a dramatic shift from the geometric, constructive approach…*

Veblen and Lennes also collaborated on a textbook aimed to "be used as a basis for a rather short theoretical course on real functions" [9, p. iii]. Three years before the text appeared in 1907, Veblen revealed that "The equivalence [of the Heine-Borel theorem with the Dedekind cut proposition] in question suggested itself to Mr. N. J. Lennes and myself while we were working over some elementary propositions in real function theory" [6, p. 436]. The central feature of the book was the "Heine-Borel property", today called compactness, which Lennes had discussed at an AMS meeting in December 1905. Moreover, the final chapter, described as "more advanced in character than the other chapters and intended as an introduction to the study of a special subject" [9, p. iii], elaborated upon Lennes's paper on improper integrals.

Before embarking on Lennes's formulation of connected sets, it is instructive to examine the intuitive approach that preceded his more general advance. This can be seen in the doctoral dissertation of L. D. Ames that was published in the October 1905 issue of the *American Journal*. One of the "preliminary fundamental conceptions" he presented was the following definition, whose wording shows that set theory was still in its formative stage [10, p. 366]:

> An assemblage is *connected* … if $P_0(x_0, y_0, z_0)$ and $P_1(x_1, y_1, z_1)$ are any two points of the assemblage, then it is possible to draw a simple curve
>
> $$x = \lambda(t),\ y = \mu(t),\ z = \upsilon(t),$$
>
> $$t_0 \le t \le t_1$$
>
> having $P_0$ and $P_1$ as end points and such that all points of the curve are points of the assemblage.

Such a property is called arcwise (or pathwise) connected today.

Lewis Darwin Ames (b. 1869) was no slouch. While teaching at a normal school from 1890 to 1900, he spent the summers of 1897 and 1898 taking courses at the University of Chicago. He earned bachelor's degrees from Missouri in 1899 and Harvard in 1901. Ames remained at Harvard for another two years, the first as an instructor and second as a graduate scholar, before returning to the University of Missouri in the fall of 1903. During that academic year he completed his dissertation under the well-known analyst William Fogg Osgood (1864–1943), thus becoming the first of Osgood's four doctoral students and showing that research using the notion of a connected set was taking place outside Chicago. It is conceivable that Lennes and Ames crossed paths during their summer studies but no evidence supports such a link.

Just two months after Ames's paper appeared, Lennes delivered three lectures at a Chicago Section meeting of the AMS that exhibit his depth and versatility as well as the breadth of offerings within Moore's department. One was the work cited above on the Heine-Borel Theorem. Another elaborated a fundamental theorem in the calculus of variations. From the present vantage point, however, the third was the most important. We turn to it now.

## The Genesis of Connected Sets

The remaining paper that Nels Lennes delivered at that December 1905 meeting, "Curves in non-metrical analysis situs", announced the earliest formulation of a connected set [11, pp. 284–5]:

> A set of points is connected if in every pair of complementary subsets at least one subset contains a limit point of points in the other set.

The abstract, including the specific wording, was published in the March 1906 issue of the *Bulletin*. This marked the first time such a formulation appeared in print, but initially it elicited little interest. Though expressed only for subsets of a Euclidean space, the definition extends unchanged to more general spaces. Importantly, it represented a dramatic shift from the geometric, constructive approach championed in Ames's paper to an abstract, nonconstructive formulation requiring proof by contradiction.

Over the next year Lennes developed his paper into a doctoral dissertation with the expansive title "Curves in non-metrical analysis situs with an application in the calculus of variations". It was written under the direction of E. H. Moore and resulted in Lennes's Ph.D. in 1907. Yet once again Lennes did not rush into print, publishing his thesis only in 1911. He emphasized, however, that no critical advances had taken place in the meantime, writing, "Changes made since then are entirely unimportant" [12, p. 287]. Therefore, our analysis will center on this paper. Here one can also see the distinction between the older, geometric definition of connectedness and the abstract formulation. Initially Lennes supplied an arcwise connected definition only slightly more general than the one adopted by Ames [12, p. 293]:

> An entirely open set of points is said to be connected if for any two points of the set there is a broken line connecting them which lies entirely in the set.

But then he presented the standard definition equivalent to the one in Kelley [12, p. 303]:

> A set of points is a "connected set" if at least one of any two complementary subsets contains a limit-point of points in the other set.

It is germane to point out that the paper itself was not devoted to connected sets *per se*, but to simple arcs (curves) in nonmetric spaces. The formal definition of a connected set was given along with several other terms about midway through the paper. He then supplied the following critical definition [12, p. 308]:

> A continuous simple arc connecting two points $A$ and $B$, $A \neq B$, is a bounded, closed, connected set of points $[A]$ containing $A$ and $B$ such that no connected proper subset of $[A]$ contains $A$ and $B$.

In motivating this definition Lennes served notice of his complete understanding of the role he was about to play, asserting, "This definition seems to be very near the obvious intuitional meaning of the term 'arc' or 'curve' " [12, p. 289]. Although not referring to connected sets, his comment on arcs could apply equally well to his formulation of this important concept. Next Lennes moved to his primary goal of proving properties of arcs in the plane, such as the following: for every interior point $C$ of an arc $AB$, the arcs $AC$ and $BC$ are closed, are connected, and have only $C$ in common.

As the expanded title of the paper indicates, the origin of connected sets lay in the calculus of variations, a subject that was one of the specialties at the University of Chicago, notably with Oskar Bolza and Gilbert Bliss. Concerning the concluding section, Lennes wrote that "the general theory of the paper is applied to the problem of proving the existence of minimizing curves in an important class of problems in the calculus of variations" [12, p. 290]. Moreover, he supplied a very useful history of the need for a proper definition of the concept of connectedness going back to G. Cantor and W. H. Young, concluding with a Veblen paper from their Chicago days together.

Lennes had an impressive résumé by the time of his doctorate, having published six papers in every American outlet available to him (the *Annals*, *Transactions*, *Bulletin* (2), *American Journal*, and *Monthly*), as well as the book with Veblen. But it was his definition of connected sets over the long haul, and his definition of a continuous simple arc for a shorter period, that represent his biggest contributions to mathematics. (As a curious aside, Kelley's résumé included papers in the *American Journal*, *Duke Journal*, and *Proceedings of the National Academy of Sciences* when he sought employment after receiving his 1940 doctorate at Virginia under G. T. Whyburn.)

After receiving his Ph.D., Lennes left his high school post for an instructorship at MIT, where he remained from 1907–10 but did not publish one work. At that time MIT was fifteen years away from becoming the top-notch research institution it is today, beginning with the hiring of Norbert Wiener and Dirk Struik. But then Lennes moved to Columbia (1910–13), where he experienced a spurt of nine publications, including the forty-page paper based on his dissertation.

In February 1911 Lennes delivered three lectures at an AMS meeting in New York, each of which resulted in a paper published before the year was out. Two months later he returned to Chicago for an historic AMS meeting. Founded in 1888, the Society remained mainly a local organization in New York City until the enterprising faculty at the upstart University of Chicago inspired national expansion six years later and established a western outpost called the Chicago Section in 1897. Yet it was April 1911 when, at the invitation of the Chicago Section, the Society became truly national by holding its first meeting outside New York City (with the exception of summer affairs). AMS secretary F. N. Cole gushed, "This was in many ways a remarkable occasion…arranged [so] that this reunion of the eastern and western members should be especially marked by the delivery of President Bôcher's retiring address.… As was under these circumstances to be expected, the meeting was in every way a most successful and inspiring one" [13, p. 505]. The meeting was successful and inspiring too for Lennes, who gave two lectures. The first, "Curves and surfaces in analysis situs", showed that his definition of a simple continuous arc (shortened here, as then, to *arc*) "applies without any change whatever to arcs in space" [13, p. 525]. The primary aim of this work, however, was to provide a rigorous proof that a closed continuous surface separates space into two connected sets.

*…the origin of connected sets lay in the calculus of variations…*

That October, six months later, Lennes delivered yet another paper at an AMS meeting back in New York that extended results from the April meeting [14, p. 165]. This turned out to be the last time he referred to connected sets in print, but it did not signal the end of his research, as he presented four more papers at AMS meetings, two in April 1912 and two in February 1913. It is telling from this activity, however, that his career would take a dramatic turn when he left New York that fall, as only one of those presentations resulted in a published paper. The other three were perhaps consigned to piles in his office that would remain fixed points during the thirty-one years he headed the department, because once Lennes left Columbia for the University of Montana later in 1913, his research output virtually ground to a halt, numbering only one minor paper (in the *Monthly*) on the fundamental theorem of calculus and another on nonmathematical logic (in the *Mathematics Teacher*). Nonetheless, he resumed writing textbooks at all levels, from high school through college, an activity he had begun in collaboration with H. E. Slaught while still at Chicago. Ultimately Lennes's numerous textbooks became so successful commercially that the house he built on campus provides the residence for the president of the University of Montana to this day. The mathematics department at the university has held the Lennes Exam for undergraduate students since shortly after his death.

*Like Lennes, the four Pennsylvanians benefited enormously from AMS meetings and journals.*

Lennes's record illustrates the vital role the AMS played in three distinct ways. First, the periods when he published papers occurred while he was in Chicago and New York, the two foci of the Society. Columbia had served as AMS headquarters since its founding in 1888, while Chicago inspired the transformation from a local to a national organization and became the first official section. Secondly, Lennes normally vetted his results before AMS audiences prior to submitting them for publication. Finally, his papers often appeared in the two AMS journals. But the time was ripe for his general definition to take hold, and although he played no role in its advance, various mathematicians made use of it over the next ten years, most of them allied with the University of Chicago. We turn to this development next.

## The Pennsylvanians

Shortly after Nels Lennes went into research hibernation in Montana, another product of E. H. Moore awoke from a prolonged slumber in an entirely different part of the country to feast on the savory pickings that Lennes had left behind. R. L. Moore had been a graduate student at Chicago from 1903–05, and Veblen's expressed gratitude to Lennes and Moore for critically reading Veblen's dissertation suggests that this trio of companions collaborated quite closely. However, after receiving his Ph.D. in 1905, R. L. Moore endured six years of academic thaw, publishing only two papers, both based on work done in graduate school. Whereas Lennes did little research after 1913, R. L. Moore tilled fertile soil at the University of Pennsylvania, resulting in seventeen papers during 1911–20, several of which dealt with connected sets. As well, all three Ph.D. students he mentored at Penn made use of Lennes's pioneering work. Like Lennes, the four Pennsylvanians benefited enormously from AMS meetings and journals.

R. L. Moore's connection to connected sets began with a paper delivered at an AMS meeting in April 1914 in New York and published later that year [15]. However, his investigation was not concerned with connected sets *per se*. Rather he sought to characterize linear continua in terms of point and limit by extending a set of axioms given by F. Riesz at the 1908 International Congress of Mathematicians in Rome regarding postulates enunciated by David Hilbert in his classic book on the foundations of geometry. Moore began by stating Lennes's definition of a connected set, thereby becoming the first person to make use of the power and generality of the reformulation almost nine years after its initial pronouncement. Then he listed four axioms that extended Riesz's three, one of which read, "If $P$ is a point of $S$, then $S - P$ is composed of two connected subsets neither of which contains a limit point of the other" [15, p. 124]. This idea of expressing the complement of a set as the union of two separated, connected sets would bear fruit in subsequent investigations by Moore and his students.

Frigyes (Frederick in English) Riesz himself played a curious role in the development of connected sets, having stated independently of Lennes an equivalent definition of a connected set just a month after Lennes presented his at the December 1905 AMS meeting. While Lennes's influence was restricted to American mathematicians, Riesz's definition seems to have remained unknown until an investigation by R. L. Wilder on the evolution of connected sets seventy-two years later [16]. (See [17] for an analysis of Riesz's contributions to topology.)

One year after Moore's initial foray, he presented a paper at another AMS meeting in which connected sets were defined among axioms for the plane, leading to a paper in the *Bulletin* later that year [18]. It is of interest to note that his first Ph.D. student,

J. R. Kline, presented his dissertation at that April 1915 meeting, continuing E. H. Moore's policy of involving students in AMS affairs early in their careers. There is no need to examine this work of R. L. Moore because he soon extended its major result appreciably in perhaps his most important paper, "On the foundations of plane analysis situs" [19]. This long and detailed work which we, like Moore, abbreviate F. A., firmly solidified his reputation as a first-rate researcher. Furthermore, he used its sequence of theorems in his classes over the next fifteen years to form the basis for what would come to be known as the Moore Method of teaching.

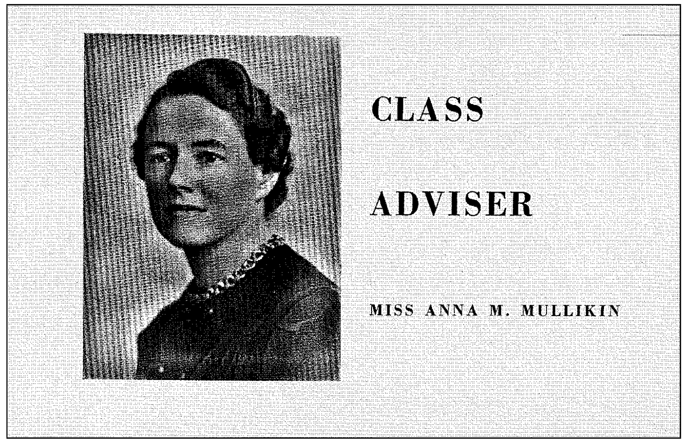
The use of connected sets abounds in F. A., starting with their definition in the section following the introduction and continuing throughout the paper. In one part Moore quoted Lennes's definition of an arc and defined a *domain* as a connected set of points $M$ such that if $P$ is a point of $M$, then there exists a region that contains $P$ and lies in $M$. These definitions form the basis for Moore's intricate proof of a major theorem [19, p. 136]:

> If $A$ and $B$ are distinct points of a domain $M$, there exists an arc from $A$ to $B$ that lies wholly in $M$.

Although the proofs of almost all 52 theorems in F. A. involve connected sets, such sets were not the primary object of study. Rather, connectedness remained a tool for characterizing other kinds of sets.

The AMS role would repeat itself at an October 1916 meeting where both Moore and Kline found Lennes's formulation of connected sets to be highly profitable. Moore's paper was aimed at proving the property that any two points on a continuous curve $C$ in any number of dimensions form the extremities of an arc lying entirely in $C$. Once again he found it necessary to supply the definition of a connected set beforehand [20, p. 233]. This would not mark Moore's swan song with connected sets, but his student John Robert Kline (1891–1955) became more active in this regard over the next few years. J. R. Kline had come under R. L. Moore's spell shortly after entering Penn in the fall of 1913 and, as we have seen, presented the results of his dissertation at an AMS meeting in his second year of graduate study. He remained at Penn for two years after receiving his Ph.D. in June 1916. At the AMS meeting that October he proved the converse of the following theorem on open curves that Moore had proved in F. A. [21, p. 178]:

> If $\ell$ is an open curve in a universal set $S$, then $S - \ell = S_1 \cup S_2$, where $S_1$ and $S_2$ are connected sets such that every arc from a point of $S_1$ to a point of $S_2$ contains at least one point of $\ell$.




**Anna Mullikin in the 1941 yearbook from Germantown High School.**

As an indication of the extent to which connected sets had become a primary tool, Kline presented another paper at the annual AMS meeting held in New York just two months later. Its aim was to generalize a result from Hausdorff's classic *Grundzüge der Mengenlehre* that the complement of a countable set in $n$-dimensional space is always connected. Kline, like R. L. Moore before him, still felt obliged to state Lennes's definition of a connected set, though without attribution this time. He did not find it necessary, however, to state that Lennes's formulation was equivalent to the one Hausdorff supplied in his 1914 book. Apparently Hausdorff had come upon his definition in ignorance of Lennes.

J. R. Kline taught at Yale from 1918–19 and Illinois from 1919–20 before returning to Penn for the rest of his life. Before leaving Penn in 1918 he wrote a joint paper with R. L. Moore, the only one that Moore ever co-authored, providing necessary and sufficient conditions for a closed and bounded set $M$ to be a subset of an arc in terms of closed, connected subsets of $M$ [22]. Thus the central structures of interest remained arcs and open curves; connected sets were relegated to auxiliary status.

Two other former students of E. H. Moore also made use of connected sets at this time. Arthur Dunn Pitcher (1880–1923) arrived in Chicago in 1907 right after Lennes had left. Pitcher received his Ph.D. three years later and then embarked on a research program in Moore's general analysis, resulting in the paper "Biextremal connected sets", read at the same annual AMS meeting as Kline in December 1916. In spite of the title, connected sets were still used only as a tool. Actually, Pitcher had worked with Edward Wilson Chittenden (1885–1977), a 1912 Chicago Ph.D., several years earlier when the latter read their joint paper at a Chicago Section meeting in March 1913. Their joint work would ultimately be published in two papers in the *Transactions*, with [23] containing results announced at meetings in 1913 and 1916. Incidentally, A. D. Pitcher is the father of longtime AMS secretary (1967–88) Arthur Everett Pitcher (1912–2006).

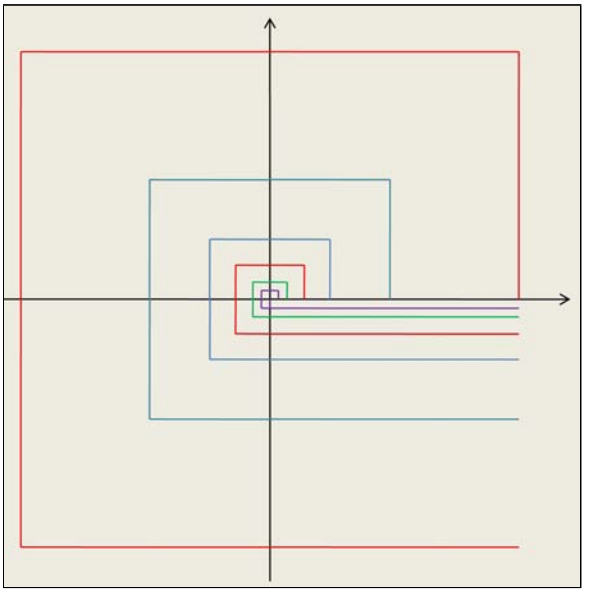
R. L. Moore must have been a very proud *Doktorvater* at the April 1918 AMS meeting in New York. Even though he did not present a paper, his former student Kline delivered one characterizing simple curves in terms of connected domains, and his second student, G. H. Hallett, announced theorems that appeared in his dissertation for the Ph.D. he earned two months later. George H. Hallett Jr. (1895–1985), like Kline, wrote his thesis in geometry inspired by Moore's early mentor G. B. Halsted. Hallett would ultimately pursue a career in government, but before embarking on that path he too initiated a research program in topology, resulting in a paper whose sole purpose was to prove that the boundedness assumption in Lennes's characterization of an arc was superfluous. When this result appeared in print, Hallett added, "Since I wrote this paper it has been pointed out to me by Professor R. L. Moore that a modification of [his argument in F. A.] …would accomplish the same result" [24, p. 325]. This paper was cited as late as 1927 by one of R. L. Moore's initial successes at the University of Texas, Gordon Thomas Whyburn (1904–69), thus suggesting that Hallett could have become a successful research mathematician should he have chosen to remain in the field [25].

Before leaving Philadelphia, R. L. Moore mentored a third doctoral student, Anna Margaret Mullikin (1893–1975), who enrolled in the fall of 1918, right after George Hallett graduated. It is not known what motivated Mullikin to enroll at Penn but we offer a connection to Clara Bacon, who attended the October 1911 meeting where Lennes spoke about connected sets. Bacon was a long-time professor of mathematics at Goucher College, including Mullikin's undergraduate years, 1911–15. Earlier she had pursued graduate studies during summer sessions at the University of Chicago (1901–04), when she likely came in contact with fellow graduate students Lennes, Veblen, and R. L. Moore. Moreover, Bacon kept abreast of research developments, becoming the first woman to receive a Ph.D. in mathematics at Johns Hopkins in 1911. Thus it is conceivable that she knew about the success of R. L. Moore at Penn and the achievements of his students Kline and Hallett. Unfortunately we have no firm evidence to support this contention.[1]

Miss Mullikin, as she came to be known, progressed quickly under R. L. Moore's special tutelage during her first year in his class. A theorem that had been only recently proved by W. Sierpiński read [26]:

> A closed, bounded, connected set $M$ in $\mathfrak{R}^n$ cannot be expressed as a countable union of disjoint closed sets.

Moore, well known for meticulous examinations of axioms, challenged Miss Mullikin to discover what would happen if any of the conditions in this theorem were relaxed. By the following October, at the start of only her second year in graduate school, she was prepared to announce her discovery at an AMS meeting in New York [27]. The published account states, "It will be shown in the present paper that for the case where $n = 2$, this theorem does not remain true if the stipulation that $M$ is closed be removed" [28, p. 144]. In summarizing her paper, F. N. Cole reported, "In one dimension no countably infinite collection of mutually exclusive closed point sets ever has a connected sum [union]. One might rather naturally be inclined to believe that this proposition holds true also in two dimensions. Miss Mullikin shows by an example that this is, however, not the case" [29, p. 147].



**Mullikin nautilus.**

The example, now called the Mullikin nautilus, is shown in the figure. The nautilus $M$ is the union of a countably infinite collection of arcs $M_n$, $n = 1, 2, \ldots$, each composed of four line segments running from $(\frac{1}{2^n}, 0)$ to $(\frac{1}{2^n}, \frac{1}{2^n})$ to $(\frac{-1}{2^n}, \frac{1}{2^n})$ to $(\frac{-1}{2^n}, \frac{-1}{2^n})$ to $(1, \frac{-1}{2^n})$. The fact that $M$ is connected is not obvious in terms of the traditional geometric approach of connecting any two points of $M$ while remaining within $M$. Yet it can be proved easily with the Lennes definition, as follows. Assume $M$ is the union of two separated sets $A$ and $B$. Notice that the restrictions $A_n$ and $B_n$ of $A$ and $B$ to each arc $M_n$ separate $M_n$. Since $M_n$ is connected, either $A_n = M_n$ or $B_n = M_n$. Thus $A$ and $B$ are collections of arcs, one of which must be infinite. It is then

[1] *We are indebted to Thomas L. Bartlow for suggesting this possible link between Mullikin and R. L. Moore.*

easy to see that $A$ and $B$ must have a limit point in common, contradicting the assumption that they are separated. This proves that the Mullikin nautilus $M$ is connected, and hence serves as an example that not every connected set is arcwise connected. Importantly, it illustrates the need for the shift from the earlier constructive, geometric definition.

Moore arranged an instructorship for Miss Mullikin at Texas for 1920–21 so she could complete her thesis there, and during that year two of her papers were read at AMS meetings in New York, both dealing with connected sets. The nautilus in [27] and theorems announced in [30] and [31] formed the basis for her Ph.D. dissertation, titled "Certain theorems relating to plane connected point sets", which was published in the *Transactions* in 1922 [28]. Miss Mullikin thus became the first American to study properties of connected sets in their own right. Her work was scrutinized in a recent paper that discusses its fifty-year mathematical legacy and details its role in subsequent collaborations between the emerging schools of topology in Poland and the U.S. [32]. Overall, then, all three R. L. Moore doctoral students at Penn contributed to the development of connected sets.

## Beyond the AMS

Miss Mullikin was not the first person in the world to publish a paper in which connected sets were the primary object of study. In reviewing the history of this topological concept, the famed mathematician/historian R. L. Wilder (1896–1982) observed that "the first paper devoted to the study of connected sets was not published until 1921; we refer here to the classic paper *Sur les ensembles connexes* of B. Knaster and C. Kuratowski [33]" [16, p. 724]. In a strict sense, Wilder is absolutely correct about this fifty-page survey. Nonetheless, *Fundamenta Mathematicae*, the prestigious Polish journal where [33] appeared, included four earlier papers that established various properties of connected sets but received no mention in [16]. We cite them briefly. The second paper ever published in *Fundamenta*, written by Wacław Sierpiński, explored properties of connected sets that contain no subsets that are continua. The other three predecessors of [33] appeared the following year, 1921. In the first, Sierpiński provided proofs of several properties of connected sets; for instance, the complement of a connected set in $R^n$ containing no subsets that are continua is always connected. *Fundamenta* also included two short notes by Stefan Mazurkiewicz solving problems posed by Sierpiński, one of which established the existence of a connected set in the plane having no connected and bounded subsets, while the other introduced the notion of a quasi-connected set. The latter note was followed immediately by [33]. In addition to these four papers, the short note by Sierpiński in 1918 that motivated the Mullikin nautilus seems also to have escaped Wilder's attention.

It was [33] together with [28] that elevated connected sets from secondary tools to primary objects. As we have seen, a twenty-year gestation period in three phases preceded this elevation, beginning with the proof of the Jordan Curve Theorem, centering on the published definition by Lennes in 1911, and continuing with the work of several graduates of E. H. Moore at Chicago and R. L. Moore at Penn. Connected sets did not remain the exclusive dominion of these Moore schools in the U.S., but they certainly accounted for the most lasting contributions. And at the center of this flurry of activity was the increasingly influential AMS with its meetings in New York and Chicago and its two journals, the *Bulletin* and the *Transactions*.

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# William Benter Prize in Applied Mathematics

## Call for NOMINATIONS

**The William Benter Prize in Applied Mathematics** has been set up by the Liu Bie Ju Centre for Mathematical Sciences (LBJ Centre) of City University of Hong Kong in honor of Mr. William Benter for his dedication and generous support to the enhancement of the University's strength in mathematics.

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

The prize will be given once every two years. The prize amount is US$100,000.

### Nominations

The right to nominate is open to everyone. Nominations should not be made known to the nominee and self-nominations are not acceptable.

Nominations, with justifications and CVs of the nominees as well as two supporting letters, should be sent to:

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c/o Liu Bie Ju Centre for Mathematical Sciences
City University of Hong Kong
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Or **by email to: mclbj@cityu.edu.hk**

**Deadline for nominations: 30 September 2009**

### Presentation of Award

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# A Pencil-and-Paper Algorithm for Solving Sudoku Puzzles

*J. F. Crook*

The puzzle Sudoku has become the passion of many people the world over in the past few years. The interesting fact about Sudoku is that it is a trivial puzzle to solve. The reason it is trivial to solve is that an algorithm exists for Sudoku solutions. The algorithm is a tree-based search algorithm based on backtracking in a tree until a solution is found.

If all a person needs to do is sit down at their personal computer, punch in the numbers given in the puzzle, and then watch a computer program compute the solution, we can reasonably ask why a person would bother to struggle to solve Sudoku puzzles. The reason is that people enjoy struggling with pencil and paper to work out Sudoku solutions. Herzberg and Murty (2007, p. 716) give two reasons for the enjoyment of this struggle:

First, it is sufficiently difficult to pose a serious mental challenge for anyone attempting to do the puzzle. Secondly, simply by scanning rows and columns, it is easy to enter the "missing colors", and this gives the solver some encouragement to persist.

This paper develops an algorithm for solving any Sudoku puzzle by pencil and paper, especially the ones classified as *diabolical*.

## Definition of the Sudoku Board

Sudoku is played on a $9 \times 9$ board. There are eighty-one cells on the board, which is broken down into nine $3 \times 3$ subboards that do not overlap. We call these subboards *boxes* and number them from 1 to 9 in typewriter order beginning in the upper left-hand corner of the board, as displayed in Figure 1.

The notation for referring to a particular cell on the board is to give the row number followed by the column number. For example, the notation $c\,(6,7)$—where $c$ denotes *cell*—denotes the cell at the intersection of row 6 and column 7.

The theory we develop in the next section uses the widely known concept of *matching numbers across cells*. Various authors, as suits their whim, name matching numbers differently. For example, Sheldon (2006, p. xiv) names them *partnerships*, whereas Mepham (2005, p. 9) names the concept *number sharing*. Here, we will use the name *preemptive sets*, which is more precise from a mathematical point of view. The theory developed here applies to Sudoku boards of all sizes.[1]

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*I thank John Hohn, Kathryn Cooper, David Gill, and Libby Neely for reading my paper. I also thank Loretta Nethercot for giving me my first two Sudoku books—on Christmas Day, 2005, and on my seventieth birthday in 2007.*

[1] *Sudoku boards can be classified into regular and nonregular boards. The formula for regular Sudoku boards is: Let $m$ denote the width and height of a Sudoku subboard, where $m \geq 2$. Then the width and height of a regular Sudoku board is $m^2$. The sizes of regular subboards and boards are given for a few values of $m$ in the following table:*

| *Subboard Width and Height* $m$ | *Board Width and Height* $m^2$ | *Number of Cells on the Board* $m^2 \times m^2$ |
|---|---|---|
| 2 | 4 | 16 |
| 3 | 9 | 81 |
| 4 | 16 | 256 |
| 5 | 25 | 625 |
| 6 | 36 | 1296 |

*The most common nonregular Sudoku board is the $6 \times 6$, which consists of six nonoverlapping $2 \times 3$ subboards. The newspaper* USA Today *publishes $6 \times 6$ puzzles regularly.*

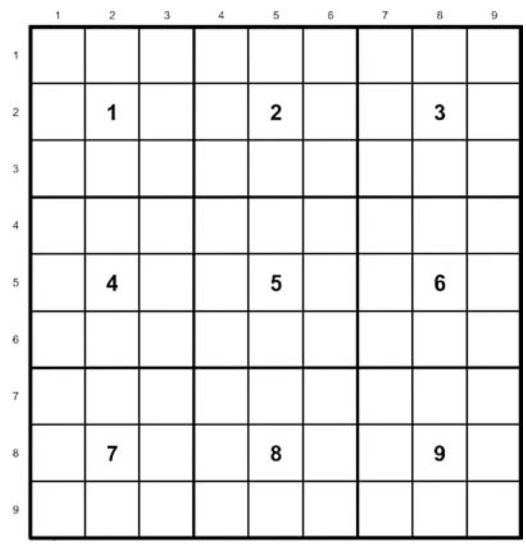

**Figure 1. The Sudoku board.**

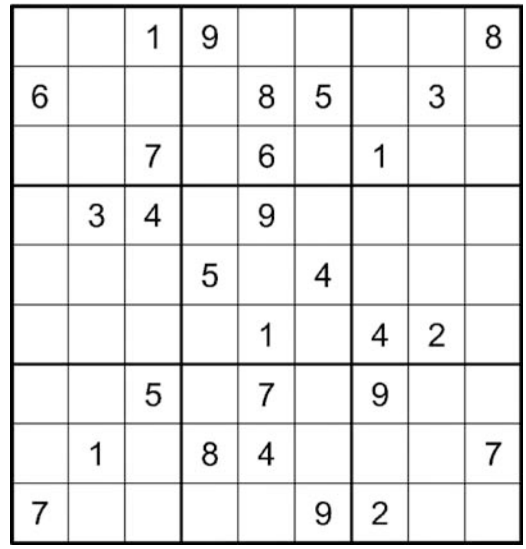

**Figure 2. Example of a Sudoku puzzle.**

## Preemptive Sets and the Occupancy Theorem

The single most important tool for solving Sudoku puzzles is based on the definition of the *solution* of a Sudoku puzzle.

**Definition 1** (Sudoku Solution)**.** *The solution of a Sudoku puzzle requires that every row, column, and box contain all the numbers in the set* $[1, 2, \ldots, 9]$ *and that every cell be occupied by one and only one number.*

This definition implies that no row, column, or box will have any number repeated. An example of a Sudoku puzzle is shown in Figure 2. The more difficult puzzles can only be solved efficiently by writing down in each empty cell the *possible* numbers that can occupy the cell. This list of possible numbers for each cell is called the *markup of the cell.* The markup of the example puzzle in Figure 2 is shown in Figure 3.

We now define preemptive sets, which is the primary tool for solving Sudoku puzzles up to the point where either (1) a solution is found or (2) continuation requires randomly choosing one of two or more numbers from the markup of an empty cell.

**Definition 2** (Preemptive Sets)**.** *A preemptive set is composed of numbers from the set* $[1, 2, \ldots, 9]$ *and is a set of size m,* $2 \le m \le 9$, *whose numbers are potential occupants of m cells exclusively, where exclusively means that no other numbers in the set* $[1, 2, \ldots, 9]$ *other than the members of the preemptive set are potential occupants of those m cells.*

*A preemptive set is denoted by*

$$\{[n_1, n_2, \ldots, n_m], [c(i_1, j_1), c(i_2, j_2), \ldots, c(i_m, j_m)]\},$$

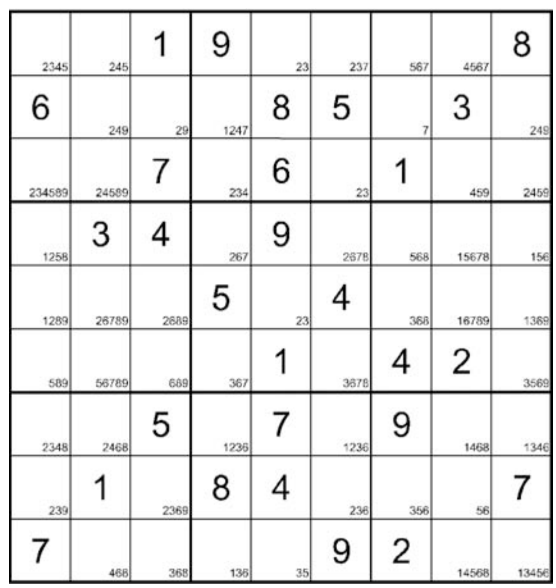

**Figure 3. Markup of the example puzzle in Figure 2.**

*where* $[n_1, n_2, \ldots, n_m]$, $1 \le n_i \le 9$ *for* $i = 1, 2, \ldots, m$, *denotes the set of numbers in the preemptive set and* $[c(i_1, j_1), c(i_2, j_2), \ldots, c(i_m, j_m)]$ *denotes the set of m cells in which the set* $[n_1, n_2, \ldots, n_m]$, *and subsets thereof, exclusively occur.*

**Definition 3** (Range of a Preemptive Set)**.** *The range of a preemptive set is a* $row$, $column$, *or* $box$ *in which all of the cells of the preemptive set are located. When* $m = 2$ *or* 3, *the range can be one of the sets* $[row, box]$ *or* $[column, box]$.

A description of a preemptive set is that it is a set of $m$ distinct numbers from the set $[1, 2, \ldots, 9]$ and a set of $m$ cells exclusively occupied by the

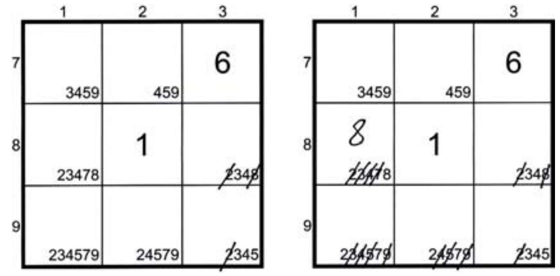

**Figure 4. A box with a preemptive set of size 4.**

$m$ numbers, or subsets of them, with the property that the distribution of the $m$ numbers across the $m$ cells is not known at the time the preemptive set is discovered. The distribution of the $m$ numbers into the $m$ cells will be revealed as the solution of the puzzle progresses.

An example of a preemptive set is displayed in Figure 4, where the large-sized numbers are the numbers given in the puzzle and the list of small-sized numbers in the lower right-hand corner of each cell is the markup. In Figure 4 we observe the preemptive set

$$\{[3,4,5,9],[c(7,1),c(7,2),c(8,3),c(9,3)]\},$$

which is of size 4, a preemptive quadruple, in the box on the left.

Since 8 is a singleton in the markup of this box, we can cross out the 2, 3, 4, and 7 in $c(8,1)$ and enter 8 in $c(8,1)$. Now, the crossing out of numbers in the preemptive quadruple in cells other than those in the quadruple in the left-hand box in Figure 4 results in the preemptive pair $\{[2,7],[c(9,1),c(9,2)]\}$ in the right-hand box.

**Theorem 1 (Occupancy Theorem).** *Let X be a preemptive set in a Sudoku puzzle markup. Then every number in X that appears in the markup of cells not in X over the range of X cannot be a part of the puzzle solution.*

*Proof.* If any number in $X$ is chosen as the entry for a cell not in $X$, then the number of numbers to be distributed over the $m$ cells in $X$ will be reduced to $m-1$, which means that one of the $m$ cells in $X$ will be unoccupied, which violates the Sudoku solution definition. Hence, to continue a partial solution, all numbers in $X$ must be eliminated wherever they occur in cells not in $X$ over the range of $X$.

The literature on Sudoku frequently uses the notion of a hidden pair or hidden triple and so forth; see, for example, Mepham (2005, p. 9). Hidden pairs, triples, and so forth are simply preemptive sets waiting to be discovered, as we will now explain. An example of a hidden pair, the pair $[3,5]$, is presented in Figure 5 in the left-hand box. This hidden pair—called a hidden pair because of the presence of the 6 in one case and the 2 and 8 in the other—will turn out to be the preemptive set $\{[3,5],[c(2,7),c(3,8)]\}$, as follows: On a first examination of the left-hand box in Figure 5, we should immediately notice the presence of the preemptive set

$$\{[1,2,6],[c(1,7),c(1,9),c(2,9)]\},$$

which, after crossing out the 1's, 2's, and 6's in cells not in the preemptive set, produces the box in the middle of Figure 5, where we observe the singleton 8 in $c(1,8)$, which means that 8 is the only entry possible in $c(1,8)$ and the 8 in the markup of $c(3,8)$ must, therefore, be crossed out. The result in the right-hand box is the revelation of the preemptive pair

$$\{[3,5],[c(2,7),c(3,8)]\}.$$

We now state a theorem the reader can easily prove that establishes preemptive sets as the basic tool for solving Sudoku puzzles.

**Theorem 2 (Preemptive Sets).** *There is always a preemptive set that can be invoked to unhide a hidden set, which then changes the hidden set into a preemptive set except in the case of a singleton.*

Hidden tuples are, however, quite useful, because they are often easier to spot than the accompanying preemptive set, especially hidden singletons and pairs.

The three boxes in Figure 5 are an excellent example of the process of breaking down the preemptive set in a box, row, or column that is present by default as soon as the markup of a puzzle is completed. That is to say, the box on the left in Figure 5, for example, is *covered* by the preemptive set

$$\{[1,2,3,5,6,8],[c(1,7),c(1,8),\\ c(1,9),c(2,7),c(2,9),c(3,8)]\}$$

by default. Now, the right-most box in Figure 5 is covered by the preemptive set

$$\{[1,2,3,5,6],[c(1,7),c(1,9),c(2,7),\\ c(2,9),c(3,8)]\},$$

but this preemptive set is the union of the two smaller preemptive sets

$$\{[1,2,6],[c(1,7),c(1,9),c(2,9)]\}\\ \text{and } \{[3,5],[c(2,7),c(3,8)]\}.$$

The fact that both of these preemptive sets occur in the same box means that their intersection must be empty. That is to say, $[1,2,6]\cap[3,5]=\emptyset$ and $[c(1,7),c(1,9),c(2,9)]\cap[c(2,7),c(3,8)]=\emptyset$. The remarks here also apply to rows and columns, of course.

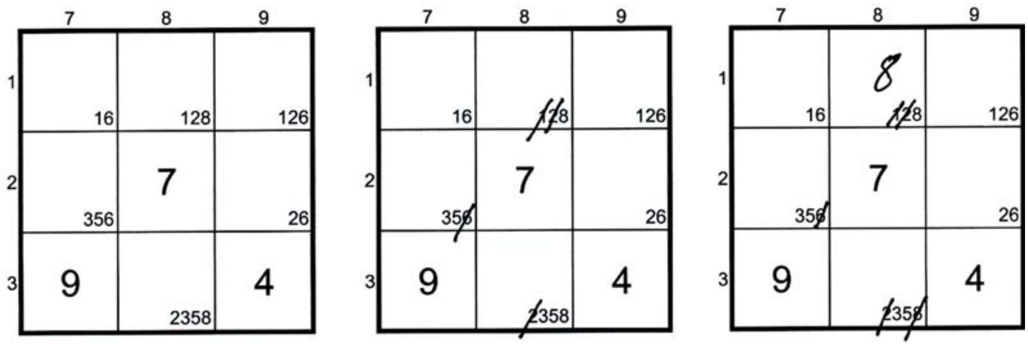

**Figure 5. Changing a hidden pair into a preemptive pair.**

## An Algorithm for Solving Sudoku Puzzles

In this section we develop an algorithm that solves Sudoku puzzles.[2] The first puzzle we use as an example only requires the use of preemptive sets to arrive at a solution.

The second puzzle uses preemptive sets to reach the point where continuation requires random choice. After the random choice of a number for entry into a cell is made, the algorithm returns to the use of preemptive sets until a solution is reached or another random choice has to be made, and so forth.

One should always begin the solution of a Sudoku puzzle by looking for cells within boxes to enter numbers within that box that are missing. The easiest approach is to begin with the highest frequency number(s) given in the puzzle. The method proceeds by finding a box that is missing this high-frequency number and determining whether there is one and only one cell into which this number can be entered. If such a cell exists, the entry of that number into the cell is *forced*. When no more of this number can be forced, continue with the number with the next highest frequency number and so forth until no more numbers can be forced into cells.

Our example puzzle for finding a solution using only preemptive sets is Will Shortz's 301 (Shortz, 2006, puzzle 301), which we shall refer to as Shortz 301. The puzzle is shown in Figure 6. Shortz 301 is classified as *Beware! Very Challenging.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | 9 | 5 | | | | | |
| | | | 8 | | | | 7 | |
| | | | | 1 | | 9 | | 4 |
| 1 | | | 4 | | | | | 3 |
| | | | | | | | | |
| | | 7 | | | | 8 | 6 | |
| | | 6 | 7 | | 8 | 2 | | |
| | 1 | | | 9 | | | | 5 |
| | | | | | 1 | | | 8 |

**Figure 6. Will Shortz's puzzle 301.**

[2] *The solution of a Sudoku puzzle is not necessarily unique, which is apparently widely known among serious Sudoku players (see the section "On the Question of the Uniqueness of Sudoku Puzzle Solutions"). Some experts, such as Sheldon (2006, p. xx), argue that all published Sudoku puzzles should have unique solutions. However, this point of view is not universal. As a matter of fact, Thomas Snyder of the USA, who won the 2007 World Sudoku Championship in Prague, Czech Republic, solved a puzzle that has exactly two solutions to win the championship. The puzzle Snyder solved is*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | | | 2 | | | 3 | |
| 2 | | | | | 1 | 7 | | 8 |
| 4 | | 7 | 6 | | | | | |
| | | | | | 5 | | | |
| 5 | 2 | | | | | | 4 | 7 |
| | | | 7 | | | | | |
| | | | | | 3 | 5 | | 4 |
| 3 | | 6 | 5 | | | | | 1 |
| | 9 | | | 7 | | | 6 | |

*(see* `http://wpc.puzzles.com/sudoku/jigsawFinals.htm`*). We found two solutions for this puzzle, and they differ only in one of the* $2 \times 2$ *squares that straddles boxes 5 and 6, as follows:*

$$\begin{array}{ccc} & {\scriptstyle 6} & {\scriptstyle 7} \\ {\scriptstyle 5} & 6 & 8 \\ {\scriptstyle 6} & 8 & 6 \end{array} \quad \text{and} \quad \begin{array}{ccc} & {\scriptstyle 6} & {\scriptstyle 7} \\ {\scriptstyle 5} & 8 & 6 \\ {\scriptstyle 6} & 6 & 8 \end{array}.$$

*The puzzle is, of course, hard, but application of the algorithm given in this paper resulted in a solution in less than one hour. The* London Times *reported that Snyder took about five minutes to find a solution, including checking that his solution was valid.*

*Herzberg and Murty (2007, Figures 3–5, pp. 711–12) display a puzzle with the same properties as the one Snyder solved.*

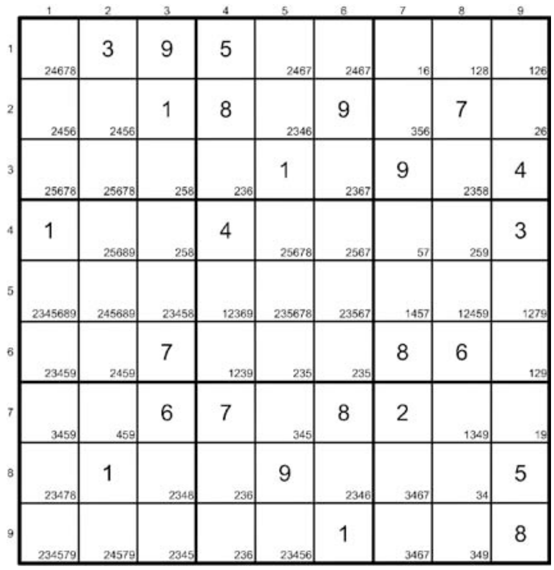

**Figure 7. The markup of Shortz 301.**

## The Solution of Shortz 301

There are two forced numbers in Shortz 301: 1 in $c\,(2,3)$ and 9 in $c\,(2,6)$. After entering these numbers into the puzzle, we mark up the puzzle. The markup of a Sudoku puzzle can be done either manually or by a computer program. The sensible approach is to use a computer program for this tedious task, which is prone to error when done manually.[3] The markup of Shortz 301, along with the inclusion of the two forced numbers, is shown in Figure 7.

The reader is strongly advised to make a copy of Figure 7 and make the entries and cross-outs described below on the copy.

On a first scan through the puzzle we note the preemptive triple

(*) $\{[1,2,6],[c\,(1,7),c\,(1,9),(2,9)]\}$

in box 3, which the reader will recognize from Figure 5. Hence, cross out all 1's, 2's, and 6's in cells not in $(*)$ in box 3, and as a result enter 8 in $c\,(1,8)$ in Figure 8.

The purpose of subscripting the 8 in $c\,(1,8)$ in Figure 8 is to denote the sequential place of entry in the progress toward a solution of the puzzle. When a number is entered into a cell, all other instances of that number in the markup of the cells of the appropriate row, column, and box must be crossed out, so we cross out the 8 in $c\,(1,1)$ in Figure 7, as shown in Figure 8.

In the markup of column 9 in Figure 7 there is the hidden singleton 7 in $c\,(5,9)$, so cross out the 1, 2, and 9 in $c\,(5,9)$ in Figure 8 and enter $7_2$, and then cross out the 7's in $c\,(4,7)$, $c\,(5,5)$, $c\,(5,6)$, and $c\,(5,7)$, as shown in Figure 8.[4]

The entries $5_3$ up to $5_5$ in Figure 8 are self-explanatory. Next, we note the preemptive triple $\{[2,3,6],[c\,(3,4),c\,(8,4),c\,(9,4)]\}$ in column 4 of Figure 7. Therefore, we cross out all 2's, 3's, and 6's in the other cells of column 4, as shown in Figure 8. This crossing out in column 4 results in the preemptive pair $[1,9]$ in column 4 and box 5. There are no 1's or 9's to be crossed out in the other cells of box 5, so the presence of this pair does not result in pushing the solution forward immediately.

There is a preemptive pair $[2,8]$ in column 3 in cells $c\,(3,3)$ and $c\,(4,3)$ of Figure 8, which gives rise to the preemptive quadruple

$$\{[3,4,5,9],[c\,(7,1),c\,(7,2),c\,(8,3),c\,(9,3)]\}$$

in box 7, which the reader will recognize from Figure 4; the preemptive pair

$$\{[3,4],[c\,(8,3),c\,(8,8)]\}$$

in row 8; the preemptive pair

$$\{[2,7],[c\,(9,1),c\,(9,2)]\}$$

in row 9; and the preemptive pair

$$\{[2,6],[c\,(8,4),c\,(8,6)]\}$$

in row 8 and box 8.

Now, as a result of discovering these five preemptive sets, there is a singleton 7 in row 8 in the markup of $c\,(8,7)$ in Figure 8, so enter $7_6$ in $c\,(8,7)$.

There is also a singleton 8 in the markup of $c\,(8,1)$ and a singleton 3 in the markup of $c\,(9,4)$, so enter $8_7$ and $3_8$ in $c\,(8,1)$ and $c\,(9,4)$ respectively. Lastly, at this point, the preemptive pair $\{[4,5],[c\,(9,3),c\,(9,5)]\}$ implies $6_9$ and $9_{10}$.

The remaining entries required to arrive at a solution are easy to follow, beginning with $1_{11}$ in $c\,(7,9)$ in Figure 8 up to the last one: $3_{56}$ in $c\,(5,1)$. Figure 9 displays the solution of Shortz 301 in "clean form".

## A Sudoku Puzzle Whose Solution Requires Random Choice

The technique of random choice will be required for continuation when the following condition is met:

**Condition 1 (Random Choice).** When no preemptive set in any row, column, or box can be broken into smaller preemptive sets, then an empty cell

---

[3] *J. F. Crook (2007).* Visual Basic program for marking up Sudoku puzzles. *The program runs as a macro under Microsoft's Excel spreadsheet program. Excel was chosen because the Excel data structure is perfect for holding Sudoku puzzles.*

[4] *The discovery of the preemptive quadruple*

$$\{[1,2,6,9],[c\,(1,9),c\,(2,9),c\,(6,9),c\,(7,9)]\}$$

*in column 9 of Figure 7 would also have revealed the singleton 7 in column 9.*

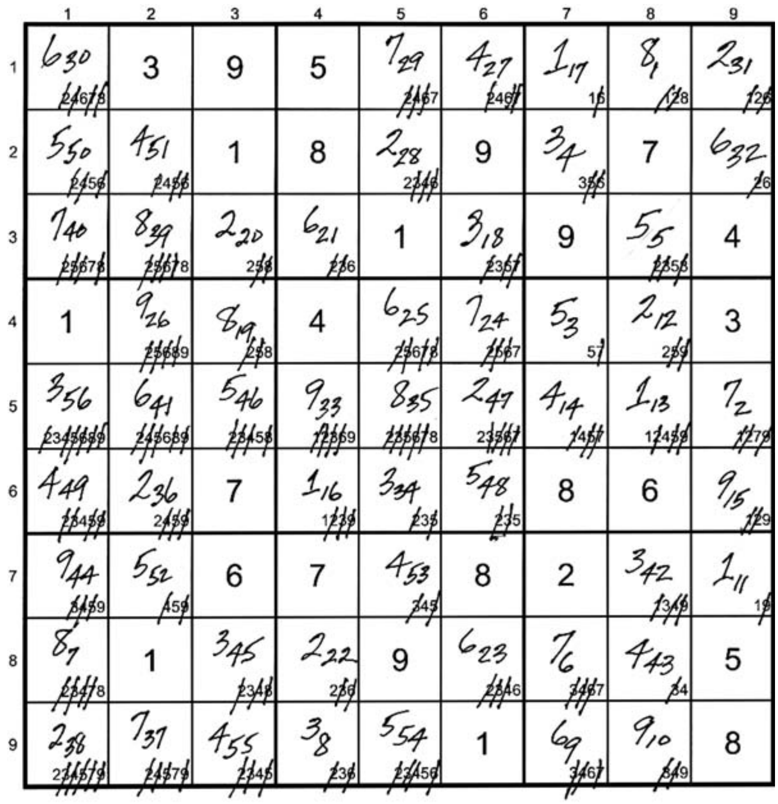

**Figure 8. Shortz 301 solution.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6 | 3 | 9 | 5 | 7 | 4 | 1 | 8 | 2 |
| 5 | 4 | 1 | 8 | 2 | 9 | 3 | 7 | 6 |
| 7 | 8 | 2 | 6 | 1 | 3 | 9 | 5 | 4 |
| 1 | 9 | 8 | 4 | 6 | 7 | 5 | 2 | 3 |
| 3 | 6 | 5 | 9 | 8 | 2 | 4 | 1 | 7 |
| 4 | 2 | 7 | 1 | 3 | 5 | 8 | 6 | 9 |
| 9 | 5 | 6 | 7 | 4 | 8 | 2 | 3 | 1 |
| 8 | 1 | 3 | 2 | 9 | 6 | 7 | 4 | 5 |
| 2 | 7 | 4 | 3 | 5 | 1 | 6 | 9 | 8 |

**Figure 9. Shortz 301 solution, again.**

must be chosen and a number randomly chosen from that cell's markup in order to continue solving the puzzle.

The existence of preemptive sets means that the solution is still partial, because there are no preemptive sets in a solution.

The cell chosen to begin the continuation becomes the vertex of a search path that we *generate on the fly*, and the number chosen by random choice from the markup of that vertex is the label of the vertex.[5] The easiest way to keep track of the various paths in a "puzzle" tree is to use pencils of different colors. The path coloring scheme we use here is red for the first path, green for any path that begins at the end of the red path, and then blue and so forth.

Before continuing we define a Sudoku violation:

**Definition 4** (Sudoku Violation)**.** *A violation in Sudoku occurs when the same number occurs two or more times in the same row, column, or box.*

The point of using a colored pencil to record a path is that if a *violation* occurs while generating the path, backtracking is easy when one can identify, by their color, which entries on the board have to be erased. An erasure of a path would also include, of course, erasing all cross-outs of numbers with that path's color.

[5] *There are, in this context, two kinds of trees. The kind we are talking about here are built from scratch as required and never consist of more than a path through the tree. Hence, we say that they are generated on the fly.*

*The other kind of tree exists in "storage" as complete trees that can be accessed for various uses. For example, a binary search tree of n names and associated data is a permanent data object on which various operations such as searching can be performed as required.*

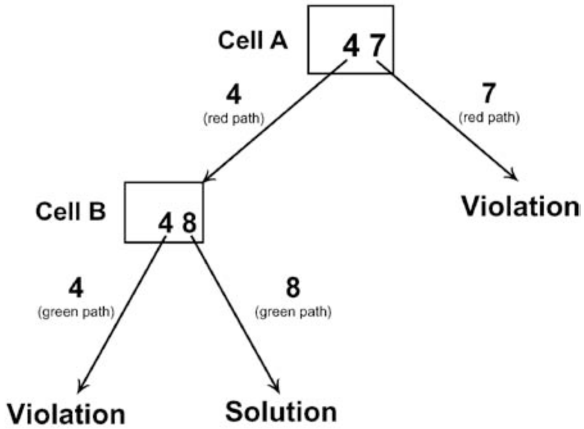


**Figure 10. An example search tree with three paths.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 9 | | 7 | | | 8 | 6 | |
| | 3 | 1 | | | 5 | | 2 | |
| 8 | | 6 | | | | | | |
| | | 7 | | 5 | | | | 6 |
| | | | 3 | | 7 | | | |
| 5 | | | | 1 | | 7 | | |
| | | | | | | 1 | | 9 |
| | 2 | | 6 | | | 3 | 5 | |
| | 5 | 4 | | | 8 | | 7 | |

**Figure 11. The Mepham diabolical Sudoku puzzle.**

When one has completely erased a path that led to a violation, one can begin a new path with the erased color. Now, assume that two green paths lead to violations where only two green paths are possible. Then, you must erase not only the second green path but also the red path that is its parent, because the first green path has already led to a violation.

After erasing the red path, delete the number that led to the violation from the red path's choice set, which is initially the markup of the vertex, and then randomly choose a number from the reduced choice set as the new label of the vertex.

In the absence of an epiphany concerning the likely path to a solution, always choose a preemptive pair if one exists, because one of the two numbers will be the correct choice for its cell and will force the choice in the other cell of the preemptive pair. If no preemptive pair exists,

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 9 | 5 | 7 | 34 | 134 | 8 | 6 | 134 |
| 47 | 3 | 1 | 8 | 6 | 5 | 49 | 2 | 47 |
| 8 | 47 | 6 | 1249 | 2349 | 12349 | 459 | 1349 | 13457 |
| 1349 | 148 | 7 | 249 | 5 | 249 | 249 | 13489 | 6 |
| 1469 | 146 | 29 | 3 | 8 | 7 | 2459 | 149 | 145 |
| 5 | 48 | 2389 | 249 | 1 | 6 | 7 | 3489 | 348 |
| 367 | 678 | 38 | 5 | 2347 | 234 | 1 | 48 | 9 |
| 179 | 2 | 89 | 6 | 479 | 149 | 3 | 5 | 48 |
| 139 | 5 | 4 | 19 | 39 | 8 | 6 | 7 | 2 |

**Figure 12. Markup of Mepham's diabolical puzzle.**

then choose the cell with the smallest number of numbers in its markup.

In Figure 10 we have diagrammed an example search tree that has three paths, only one of which leads to a solution. The three possible paths through this tree are

$$\left(\underrightarrow{4}, \underrightarrow{4}\right), \left(\underrightarrow{4}, \underrightarrow{8}\right), \left(\underrightarrow{7}\right).$$

The path $\left(\underrightarrow{4}, \underrightarrow{8}\right)$—4 for cell A and 8 for cell B—leads to a solution, but the probability of choosing this path is only $\frac{1}{4}$, and therefore the odds against choosing this path are 3 to 1.

In the next section we display and solve a Sudoku puzzle whose solution requires the use of random choice.

## The Mepham Diabolical Sudoku Puzzle

The puzzle appearing in Figure 11 was published by Mepham (2005, p. 14), who characterizes this puzzle as *diabolical* because it requires generating search paths on the fly. We shall refer to this puzzle as *Mepham's D*.

After entering the forced numbers in Mepham's D and marking it up, it is transformed into the puzzle shown in Figure 12.

The preemptive pair

$$\{[4,7], [c(2,1), c(2,9)]\}$$

in row 2 of Figure 12 isolates the singleton 9 in $c(2,7)$. Hence, we enter $9_1$, which is shown in large boldface type in Figure 13. The preemptive triple

$$\{[2,4,9], [c(4,4), c(4,6), c(4,7)]\}$$

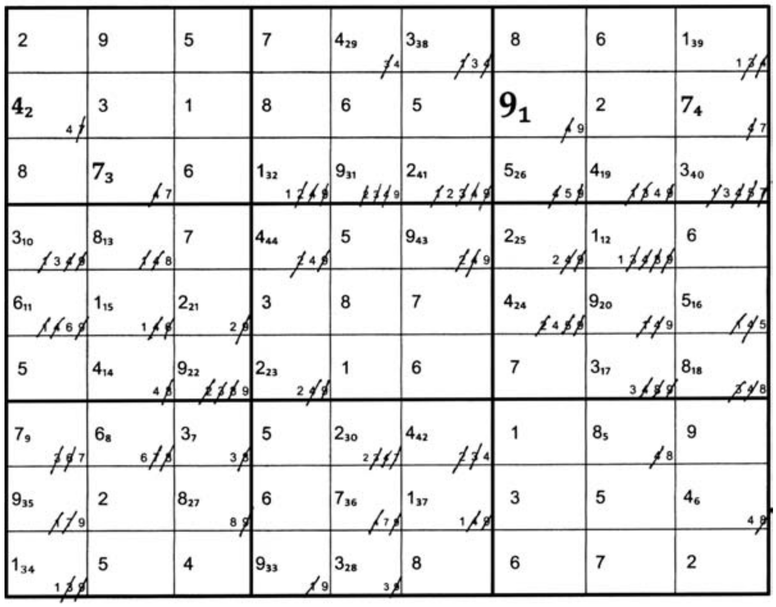


**Figure 13. Solution of Mepham's diabolical Sudoku puzzle.**

in row 4 in Figure 12 results in the preemptive triple $\{[1,3,8],[c(4,1),c(4,2),c(4,8)]\}$ in row 4 after appropriate crossing out.

Since there are no more undiscovered preemptive sets at this point, we choose the cell $c(2,1)$, which is a member of the preemptive pair $\{[4,7],[(2,1),(3,2)]\}$ in box 1, as the vertex of the search path that we will generate on the fly. We then randomly choose one of the two numbers $[4,7]$ in the markup of $c(2,1)$ by flipping a coin. The choice was 4. The red path is denoted by the boldface type in Figure 13 and is the sequence $4_2$, $7_3$, $7_4$.

The red path in Figure 13 plays out quickly and does not, through crossouts, generate any new preemptive subsets, so we begin a green path by choosing randomly from the set $[4,8]$ in $c(7,8)$. The choice was 8. We denote the green path in Figure 13 by non-boldface type. The green path in Figure 13, which is the sequence $8_5$, $4_6$, …, $4_{44}$, leads to the solution of Mepham's D displayed in Figure 13.

The search tree for Mepham's D is the one we gave as an example in Figure 10. In Figure 14 we display the solution of Mepham's D in "clean form".

## Summary: Statement of the Algorithm

The steps in the algorithm for solving Sudoku puzzles are:

(1) Find all forced numbers in the puzzle.
(2) Mark up the puzzle.
(3) Search iteratively for preemptive sets in all rows, columns, and boxes—taking appropriate crossout action as each new preemptive set is discovered—until
(4) either
  (a) a solution is found or
  (b) a random choice must be made for continuation.
(5) If 4(a), then end; if 4(b), then go to step 3.

## On the Question of the Uniqueness of Sudoku Puzzle Solutions

In the context of mathematics a Sudoku puzzle can be recast as a vertex coloring problem in graph theory. Indeed, just replace the set $[1,2,\dots 9]$ in a Sudoku puzzle with a set of nine different *colors* and call the Sudoku board a *graph* and call the cells of the Sudoku board *vertices*.

The proper language to use here is to speak of coloring a graph in such a way that each of the nine colors appears in every row, column, and box of the puzzle. Such a coloring is a solution of the puzzle and is known in graph theory as a *proper coloring*. The minimum number of colors required for a proper coloring of $G$ is called the chromatic number of $G$, and for Sudoku graphs the chromatic number is, of course, 9.

Now, the chromatic polynomial of a graph $G$ is a function of the number of colors used to color $G$, which we denote by $\lambda$. The function computes the number of ways to color $G$ with $\lambda$ colors.

Herzberg and Murty (2007, p. 709) prove the following important theorem:

**Theorem 3 (Completion Chromatic Polynomial).** *Let $G$ be a finite graph with $v$ vertices. Let $C$ be a*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 9 | 5 | 7 | 4 | 3 | 8 | 6 | 1 |
| 4 | 3 | 1 | 8 | 6 | 5 | 9 | 2 | 7 |
| 8 | 7 | 6 | 1 | 9 | 2 | 5 | 4 | 3 |
| 3 | 8 | 7 | 4 | 5 | 9 | 2 | 1 | 6 |
| 6 | 1 | 2 | 3 | 8 | 7 | 4 | 9 | 5 |
| 5 | 4 | 9 | 2 | 1 | 6 | 7 | 3 | 8 |
| 7 | 6 | 3 | 5 | 2 | 4 | 1 | 8 | 9 |
| 9 | 2 | 8 | 6 | 7 | 1 | 3 | 5 | 4 |
| 1 | 5 | 4 | 9 | 3 | 8 | 6 | 7 | 2 |

**Figure 14. Solution of Mepham's diabolical Sudoku puzzle, again.**

*partial coloring of $t$ vertices of $G$ using $d_0$ colors. Let $p_{G,C}(\lambda)$ be the number of ways of completing the coloring using $\lambda$ colors to obtain a proper coloring of $G$. Then $p_{G,C}(\lambda)$ is a monic polynomial (in $\lambda$) with integer coefficients of degree $v - t$ for $\lambda \geq d_0$.*

The value of $p_{G,C}(9)$ must be 1 for the coloring (solution) of the graph (puzzle) to be unique.[6] The computation of the integer coefficients of $p_{G,C}(9)$ is easily done by running an implementation of the inductive proof of Theorem 3 (see Herzberg and Murty, p. 710). The inductive proof is essentially the *deletion-contraction* algorithm, which is thoroughly discussed by Brualdi (Brualdi, 2004, p. 529).

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[4] Tom Sheldon (2006), *Sudoku Master Class*, Plume (Penguin), New York.

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[6]*Herzberg and Murty (2007, p. 712) prove that a necessary condition for a unique coloring (solution) is that $C$, the puzzle, must use at least eight colors (numbers), that is, $d_0 \geq 8$.*

# Interview with John G. Thompson and Jacques Tits

*Martin Raussen and Christian Skau*

John G. Thompson and Jacques Tits are the recipients of the 2008 Abel Prize of the Norwegian Academy of Science and Letters. On May 19, 2008, prior to the Abel Prize celebration in Oslo, Thompson and Tits were jointly interviewed by Martin Raussen of Aalborg University and Christian Skau of the Norwegian University of Science and Technology. This interview originally appeared in the September 2008 issue of the *Newsletter of the European Mathematical Society*.

## Early Experiences

***Raussen & Skau:*** *On behalf of the Norwegian, Danish, and European Mathematical Societies we want to congratulate you for having been selected as Abel Prize winners for 2008. In our first question we would like to ask you when you first got interested in mathematics: Were there any mathematical results or theorems that made a special impression on you in your childhood or early youth? Did you make any mathematical discoveries during that time that you still remember?*

**Tits:** I learned the rudiments of arithmetic very early; I was able to count as a small child, less than four years, I believe. At the age of thirteen, I was reading mathematical books that I found in my father's library and shortly after, I started tutoring youngsters five years older than me who were preparing for the entrance examination at the École Polytechnique in Brussels. That is my first recollection. At that time I was interested in analysis but later on, I became a geometer. Concerning my work in those early years, I certainly cannot talk about great discoveries, but I think that some of the results I obtained then are not without interest.

My starting subject in mathematical research has been the study of strictly triple transitive groups; that was the subject essentially given to me by my professor [Paul Libois]. The problem was this: We knew axiomatic projective geometry in dimension greater than one. For the one-dimensional case, nobody had given an axiomatic definition. The one-dimensional case corresponds to $PSL(2)$. My teacher gave me the problem of formulating axiomatics for these groups. The idea was to take triple transitivity as the first axiom. So I started by this kind of problem: giving axiomatics of projective geometry based on triple transitivity. Of course, I was then led naturally to consider quadruple and quintuple transitivity. That is how I rediscovered all the Mathieu groups, except, strangely enough, the biggest one, the quintuple transitive. I had to rediscover that one in the literature!

***R & S:*** *So you didn't know about the Mathieu groups when you did this work?*

**Tits:** No, I didn't.

***R & S:*** *How old were you at that time?*

**Tits:** Eighteen years old, I suppose. In fact, I first found all strictly quadruple transitive groups. They were actually known by Camille Jordan. But I didn't know the work of Camille Jordan at the time. I rediscovered that.

***R & S:*** *You must have been much younger than your fellow students at the time. Was it a problem to adjust in an environment where you were the youngest by far?*

**Tits:** I am very grateful to my fellow students and also to my family, because I was what is sometimes called a little genius. I was much quicker than all the others. But nobody picked up on that, they just let it go. My father was a little bit afraid that I would go too fast. My mother knew that this was exceptional, but she never boasted about it. In fact, a female neighbor said to my mother: "If I had a son like that, I would go around and boast about it." My mother found that silly. I was not at all put on a pedestal.

***R & S:*** *Hardy once said that mathematics is a young man's game. Do you agree?*

**Tits:** I think that it is true to a certain extent. But there are people who do very deep things at a later age. After all, Chevalley's most important work was done when he was more than forty years old and even perhaps later. It is not an absolute rule. People like to state such rules. I don't like them really.

**Thompson:** Well, it is true that you don't have any childhood geniuses in politics. But in chess, music, and mathematics, there is room for childhood exceptional-

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ism to come forth. This is certainly very obvious in the case of music and chess and to some extent in mathematics. That might sort of skew the books in a certain direction.

As far as Hardy's remark is concerned I don't know what he was feeling about himself at the time he made that remark. It could be a way for person to say: "I am checking out now, I reached the age where I don't want to carry on." I don't know what the sociologists and psychologists say; I leave it to them. I have seen mathematicians reach the age of fifty and still be incredible lively. I don't see it as a hard and fast rule. But then Tits and I are really in no position to talk given our age.

***R & S:*** *John von Neumann said, exaggerating a little, that whatever you do in mathematics beyond thirty is not worth anything, at least not compared to what you had done before thirty. But when he himself reached the age of thirty, he pushed this limit. Experience comes in, etc.*

**Thompson:** But he was a prodigy. So he knows the childhood side of it.

**Tits:** We all have known very young and bright mathematicians. The point is that to find deep mathematics, it is not necessary to have all the techniques. They can find results that are deep without having all of those techniques at hand.

***R & S:*** *What about your memories on early mathematical experiences, Professor Thompson?*

**Thompson:** I don't have any particularly strong memories. I have an older brother, three years older than me, who was very good at math. He was instrumental, I guess, in interesting me in very elementary things. He was obviously more advanced than I was.

We also played cards in our family. I liked the combinatorics in card play. At that time, I was ten or twelve years old. I also liked playing chess. I never got any good at it but I liked it. When my brother went to the university, he learned about calculus and he tried to explain it to me. I found it totally incomprehensible, but it intrigued me. I did get books out of the library myself. But I didn't make too much progress without him.

## Early Group Theory

***R & S:*** *You have received this year's Abel Prize for your achievements in group theory. Can we start with a short historical introduction to the subject? We would like to ask you to tell us how the notion of a group came up and how it was developed during the nineteenth century. In fact, Norwegian mathematicians played quite an important role in that game, didn't they?*

**Tits:** Well, when you talk about groups it is natural to talk about Galois. I think Abel did not use groups in his theory—do you know?

**Thompson:** At least implicitly. I think the equation of the fifth degree comes in there. It was a great eye opener. I myself looked at a very well-known paper of Lagrange, I think around 1770, before the French revolution. He examined equations and he also said something about equations of degree five. He was definitely getting close to the notion of a group. I don't know about the actual formal definition. I guess we have to attribute it to Galois. Anyway, it was certainly he who came up with the notion of a normal subgroup. I am pretty sure that was Galois's idea. He came up with the idea of a normal subgroup, which is really basic.

**Tits:** But the theorem on the equation of degree five was discovered first by Abel, I think. Of course Galois had a technique that helped with many equations of different types that Abel did not have. Galois was really basically an algebraist, whereas Abel was also an analyst. When we now talk about abelian functions, these ideas go back to Abel.

***R & S:*** *Can you explain why simple groups are so important for the classification of finite groups in general? That realization came about, we guess, with Camille Jordan and his decomposition theorem. Is that correct?*

**Tits:** You see, I think that one of the dreams of these people was always to describe *all* groups. And if you want to describe all groups you decompose them. The factors are then simple. I think that was one of the aims of what they were doing. But of course they didn't go that far. It is only very recently that one could find all finite simple groups, a solution to the problem to which John Thompson contributed in a major way.

***R & S:*** *What about Sylow and Lie in the beginning of group theory?*

**Thompson:** Those are two other Norwegians.

**Tits:** Lie played an important role in my career. In fact, practically from the beginning, the main subject of my work has centered around the so-called exceptional Lie groups. So the work of Lie is basic in what I have done.

***R & S:*** *Could you comment on the work of Frobenius and Burnside?*

**Thompson:** Of course. After the last half of the nineteenth century Frobenius among other things put the theory of group characters on a solid basis. He proved the orthogonality relations and talked about the transfer map. Burnside eventually got on the wagon there. And eventually he proved his $p^a q^b$- theorem, the two prime theorem, using character theory, namely that groups of these orders are solvable. That was a very nice step forward, I feel. It showed the power of character theory, which Frobenius had already done. Frobenius also studied the character theory of the symmetric groups and multiply transitive permutation groups. I don't know how much he thought of the Mathieu groups. But they were pretty curious objects that had been discovered before character theory. For a while there was quite a bit of interest in multiply transitive permutation groups, quite complicated combinatorial arguments. Burnside and Frobenius were very much in the thick of things at that stage.

**Tits:** When I was a young mathematician. I was very ignorant of the literature. For instance, I rediscovered a lot of the results that were known about multiply transitive groups, in particular, on the strictly 4-fold and 5-fold transitive groups. Fortunately, I did this with other methods than the ones that were used before. So these results were in fact new in a certain sense.

***R & S:*** *Was it a disappointment to discover that these results had been discovered earlier?*

**Tits:** Not too much.

***R & S:*** *Burnside was also interesting because he posed problems and conjectures that you and others worked on later, right?*

**Thompson:** Right—well, I sort of got started on working on the Frobenius conjecture, which was still open. I think it was Reinhold Baer or maybe Marshall Hall who told me about the Frobenius conjecture: The Frobenius kernel of the Frobenius group was conjectured to be nilpotent. I liked that conjecture for the following reason: If you take the group of proper motions of the Euclidean plane, it is a geometric fact that every proper motion is either a translation or is a rotation. I hope kids are still learning that. It is a curious phenomenon. And the translations form a normal subgroup. So that is something you could actually trace back to antiquity.

No doubt Frobenius knew that. So when he proved his theorem about the existence of the normal complement, that was a link back to very old things to be traced in geometry, I feel. That was one of the appeals. And then the attempt to use Sylow's theorems and a bit of character theory, whatever really, to deal with that problem. That is how I first got really gripped by pure mathematics.

***R & S:*** *Mathieu discovered the first sporadic simple groups, the Mathieu groups, in the 1860s and 1870s. Why do you think we had to wait one hundred years before the next sporadic group was found by Janko, after your paper with Feit? Why did it take so long a time?*

**Thompson:** Part of the answer would be the flow of history. The attention of the mathematical community was drawn in other directions. I wouldn't say that group theory, certainly not finite group theory, was really at the center of mathematical development in the nineteenth century. For one thing, Riemann came along, topology gained and exerted tremendous influence, and as Jacques has mentioned, analysis was very deep and attracted highly gifted mathematicians. It is true, as you mentioned earlier, that Frobenius was there and Burnside; so group theory wasn't completely in the shadows. But there wasn't a lot going on.

Now, of course, there is a tremendous amount going on, both within pure and applied mathematics. There are many things that can attract people, really. So why there was this gap between these groups that Mathieu found and then the rather rapid development in the last half of the twentieth century of the simple groups, including the sporadic groups, I have to leave that to the historians. But I don't find it all that mysterious, really. You know, mathematics is a very big subject.

Photo: Heiko Junge/Scanpix.

**Jacques Tits receives the Abel Prize from King Harald. John Griggs Thompson to the left with the prize.**

## The Feit-Thompson Theorem

***R & S:*** *The renowned Feit-Thompson theorem—finite groups of odd order are solvable—that you proved in the early 1960s: that was originally a conjecture by Burnside, right?*

**Thompson:** Burnside had something about it, yes. And he actually looked at some particular integers and proved that groups of that order were solvable. So he made a start.

***R & S:*** *When you and Feit started on this project were there any particular results preceding your attack on the Burnside conjecture that made you optimistic about being able to prove it?*

**Thompson:** Sure. A wonderful result of Michio Suzuki, the so-called CA theorem. Absolutely basic! Suzuki came to adulthood just at the end of the Second World War. He was raised in Japan. Fortunately, he came to the University of Illinois. I think it was in 1952 that he published this paper on the CA groups of odd order and proved they were solvable by using exceptional character theory. It is not a very long paper. But it is incredibly ingenious, it seems to me. I still really like that paper. I asked him later how he came about it, and he said he thought about it for two years, working quite hard. He finally got it there. That was the opening wedge for Feit and me, really. The wedge got wider and wider.

**Tits:** Could you tell me what a CA group is?

**Thompson:** A CA group is a group in which the centralizer of every non-identity element is abelian. So we can see Abel coming in again: Abelian centralizer, that is what the A means.

***R & S:** The proof that eventually was written down by Feit and you was 255 pages long, and it took one full issue of the* Pacific Journal *to publish.*

**Thompson:** It was long, yes.

***R & S:** It is such a long proof and there were so many threads to connect. Were you nervous that there was a gap in this proof?*

**Thompson:** I guess so, right. It sort of unfolded in what seemed to us a fairly natural way; part group theory, part character theory, and this funny little number-theoretic thing at the end. It all seemed to fit together. But we could have made a mistake, really. It has been looked at by a few people since then. I don't lose sleep about it.

***R & S:** It seems that, in particular in finite group theory, there did not exist that many connections to other fields of mathematics like analysis, at least at the time. This required that you had to develop tools more or less from scratch, using ingenious arguments. Is that one of the reasons why the proofs are so long?*

**Thompson:** That might be. It could also be that proofs can become shorter. I don't know whether that will be the case. I certainly can't see that the existing proofs will become tremendously shorter in my lifetime. These are delicate things that need to be explored.

**Tits:** You see, there are results that are intrinsically difficult. I would say that this is the case of the Feit-Thompson result. I personally don't believe that the proof will be reduced to scratch.

**Thompson:** I don't know whether it will or not. I don't think mathematics has reached the end of its tether, really.

**Tits:** It may of course happen that one can go around these very fine proofs, like John's proof, using big machinery like functional analysis. That one suddenly gets a big machine which crushes the result. That is not completely impossible. But the question is whether it is worth the investment.

## The Theory of Buildings

***R & S:** Professor Tits, you mentioned already Lie groups as a point of departure. Simple Lie groups had already been classified to a large extent at the end of the nineteenth century, first by Killing and then by Élie Cartan, giving rise to a series of matrix groups and the five exceptional simple Lie groups. For that purpose, the theory of Lie algebras had to be developed. When you started to work on linear algebraic groups, there were not many tools available. Chevalley had done some pioneering work, but the picture first became clear when you put it in the framework of buildings, this time associating geometric objects to groups. Could you explain to us how the idea of buildings, consisting of apartments, chambers, all of these suggestive words, how it was conceived, what it achieved, and why it has proven to be so fruitful?*

**Tits:** First of all, I should say that the terminology like buildings, apartments, and so on is not mine. I discovered these things, but it was Bourbaki who gave them these names. They wrote about my work and found that my terminology was a shambles. They put it in some order, and this is how the notions like apartments and so on arose.

I studied these objects because I wanted to understand these exceptional Lie groups geometrically. In fact, I came to mathematics through projective geometry; what I knew about was projective geometry. In projective geometry you have points, lines, and so on. When I started studying exceptional groups I sort of looked for objects of the same sort. For instance, I discovered—or somebody else discovered, actually—that the group $E_6$ is the collineation group of the octonion projective plane. And a little bit later, I found some automatic way of proving such results, starting from the group to reconstruct the projective plane. I could use this procedure to give geometric interpretations of the other exceptional groups, e.g., $E_7$ and $E_8$. That was really my starting point.

Then I tried to make an abstract construction of these geometries. In this construction I used terms like skeletons, for instance, and what became apartments were called skeletons at the time. In fact, in one of the volumes of Bourbaki, many of the exercises are based on my early work.

***R & S:** An additional question about buildings: This concept has been so fruitful and made connections to many areas of mathematics that maybe you didn't think of at the time, like rigidity theory for instance?*

**Tits:** For me it was really the geometric interpretations of these mysterious groups, the exceptional groups, that triggered everything. Other people have then used these buildings for their own work. For instance, some analysts have used them. But in the beginning I didn't know about these applications.

***R & S:** You asked some minutes ago about CA groups. Maybe we can ask you about BN-pairs: what are they and how do they come in when you construct buildings?*

**Tits:** Again, you see, I had an axiomatic approach towards these groups. The BN-pairs were an axiomatic way to prove some general theorems about simple algebraic groups. A BN-pair is a pair of two groups, $B$ and $N$, with some simple properties. I noticed that these properties were sufficient to prove, I wouldn't say deep, but far-reaching results, for instance, proving the simplicity property. If you have a group with a BN-pair you have simple subgroups free of charge. The notion of BN-pairs arises naturally in the study of split simple Lie groups. Such groups have a distinguished conjugacy class of subgroups, namely the Borel subgroups. These are the $B$s of a distinguished class of BN-pairs.

## The Classification of Finite Simple Groups

***R & S:*** *We want to ask you, Professor Thompson, about the classification project, the attempt to classify all finite simple groups. Again, the paper by Feit and you in 1962 developed some techniques. Is it fair to say that without that paper the project would not have been doable or even realistic?*

**Thompson:** That I can't say.

**Tits:** I would say yes.

**Thompson:** Maybe, but the history has bifurcations so we don't know what could have happened.

***R & S:*** *The classification theorem for finite simple groups was probably the most monumental collaborative effort done in mathematics, and it was pursued over a long period of time. Many people have been involved, the final proof had 10,000 pages, at least, originally. A group of people, originally led by Gorenstein, are still working on making the proof more accessible.*

*We had an interview here five years ago with the first Abel Prize recipient Jean-Pierre Serre. At that time, he told us that there had been a gap in the proof, that only was about to be filled in at the time of the interview with him. Before, it would have been premature to say that one actually had the proof. The quasi-thin case was left.*

*How is the situation today? Can we really trust that this theorem finally has been proved?*

**Thompson:** At least that quasi-thin paper has been published now. It is quite a massive work itself, by Michael Aschbacher and Stephen Smith—quite long, well over 1,000 pages. Several of the sporadic simple groups come up. They characterize them because they are needed in quasi-thin groups. I forget which ones come up, but the Rudvalis group certainly is among them. It is excruciatingly detailed. It seems to me that they did an honest piece of work. Whether one can really believe these things is hard to say. It is such a long proof that there might be some basic mistakes. But I sort of see the sweep of it, really. It makes sense to me now. In some way it rounded itself off. I can sort of see why there are probably no more sporadic simple groups, but not really conceptually. There is no conceptual reason that is really satisfactory.

But that's the way the world seems to be put together. So we carry on. I hope people will look at these papers and see what the arguments are and see how they fit together. Gradually this massive piece of work will take its place in the accepted canon of mathematical theorems.

**Tits:** There are two types of group theorists. Those who are like St. Thomas: they don't believe because they have not seen every detail of the proof. I am not like them, and I believe in the final result although I don't know anything about it. The people who work on or who have worked on the classification theorem may of course have forgotten some little detail somewhere. But I don't believe these details will be very important. And I am pretty sure that the final result is correct.

***R & S:*** *May we ask about the groups that are associated with your names? You have a group that's called the Thompson group among the sporadic simple groups. How did it pop up? How were you involved in finding it?*

**Thompson:** That is in fact a spin-off from the Monster Group. The so-called Thompson group is essentially the centralizer of an element of order three in the Monster. Conway and Norton and several others were beavering away—this was before Griess constructed the Monster—working on the internal structure where this group came up, along with the Harada-Norton group and the Baby Monster. We were all working trying to get the characters.

The Monster itself was too big. I don't think it can be done by hand. Livingstone got the character table, the ordinary complex irreducible characters of the Monster. But I think he made very heavy use of a computing machine. And I don't think that has been eliminated. That's how the figure 196,883 came about, the degree of the smallest faithful complex representation of the Monster Group. It is just too big to be done by hand. But we can do these smaller subgroups.

***R & S:*** *The Tits group was found by hand, wasn't it? And what is it all about?*

**Tits:** Yes, it was really sort of a triviality. One expects that there would be a group there except that one must take a subgroup of index two so that it becomes simple. And that is what I know about this.

***R & S:*** *Professor Tits, there is a startling connection between the Monster Group, the biggest of these sporadic groups, and elliptic function theory or elliptic curves via the $j$-function. Are there some connections with other exceptional groups, for instance in geometry?*

**Tits:** I am not a specialist regarding these connections between the Monster Group, for instance, and modular functions. I don't really know about these things, I am ashamed to say. I think it is not only the Monster that is related to modular forms, also several other sporadic groups. But the case of the Monster is especially satisfactory because the relations are very simple in that case. Somehow smaller groups give more complicated results. In the case of the Monster, things sort of round up perfectly.

## The Inverse Galois Problem

***R & S:*** *May we ask you, Professor Thompson, about your work on the inverse Galois problem? Can you explain first of all what the problem is all about? And what is the status right now?*

**Thompson:** The inverse Galois problem probably goes back already to Galois. He associated a group to an equation, particularly to equations in one variable with integer coefficients. He then associated to this equation a well-defined group now called the Galois group, which is a finite group. It captures quite a bit of the nature of the roots, the zeros, of this equation. Once one has the notion of a field, the field generated by the roots of an equation has certain automorphisms, and these automorphisms give us Galois groups.

The inverse problem is: Start with a given finite group. Is there always an equation, a polynomial with one indeterminate with integer coefficients, whose Galois group is that particular group? As far as I know it is completely open whether or not this is true. And as a test case, if you start with a given finite simple group, does it occur in this way? Is there an equation waiting for it? If there is one equation there would be infinitely many of them. So we wouldn't know how to choose a standard canonical equation associated to this group. Even in the case of simple groups, the inverse problem of Galois theory is not solved. For the most general finite groups, I leave it to the algebraic geometers or whoever else has good ideas whether this problem is amenable. A lot of us have worked on it and played around with it, but I think we have just been nibbling at the surface.

For example the Monster is a Galois group over the rationals. You can't say that about all sporadic groups. The reason that the Monster is a Galois group over the rationals comes from character theory. It is just given to you.

**Tits:** This is very surprising: you have this big object, and the experts can tell you that it is a Galois group. In fact, I would like to see an equation.

***R & S:** Is there anything known about an equation?*

**Thompson:** It would have to be of degree of at least 1020. I found it impressive, when looking a little bit at the $j$-function literature before the days of computers, that people like Fricke and others could do these calculations. If you look at the coefficients of the $j$-functions, they grow very rapidly into the tens and hundreds of millions. They had been computed in Fricke's book. It is really pleasant to see these numbers out there before computers were around. Numbers of size 123 millions. And the numbers had to be done by hand, really. And they got it right.

**Tits:** It is really fantastic what they have done.

***R & S:** Could there be results in these old papers by Fricke and others that people are not aware of?*

**Thompson:** No, people have gone through them, they have combed through them.

**Tits:** Specialists do study these papers.

## The $E_8$ Story

***R & S:** There is another collaborative effort that has been done recently, the so-called $E_8$ story: a group of mathematicians has worked out the representations of the $E_8$. In fact, they calculated the complete character table for $E_8$. The result was publicized last year in several American newspapers under the heading "A calculation the size of Manhattan" or something like that.*

**Thompson:** It was a little bit garbled maybe. I did see the article.

***R & S:** Can you explain why we all should be interested in such a result? Be it as a group theorist, or as a general mathematician, or even as man on the street?*

**Thompson:** It is interesting in many ways. It may be that physicists have something to do with the newspapers. Physicists, they are absolutely fearless as a group. Any mathematical thing they can make use of they will gobble right up and put in a context that they can make use of, which is good. In that sense mathematics is a handmaiden for other things. And the physicists have definitely gotten interested in exceptional Lie groups. And $E_8$ is out there, really. It is one of the great things.

***R & S:** Is there any reason to believe that some of these exceptional groups or sporadic groups tell us something very important—in mathematics or in nature?*

**Thompson:** I am not a physicist. But I know physicists are thinking about such things, really.

**Tits:** It is perhaps naive to say this, but I feel that mathematical structures that are so beautiful like the Monster must have something to do with nature.

## Mathematical Work

***R & S:** Are there any particular results that you are most proud of?*

**Thompson:** Well, of course one of the high points of my mathematical life was the long working relationship I had with Walter Feit. We enjoyed being together and enjoyed the work that we did and of course the fusion of ideas. I feel lucky to have had that contact and proud that I was in the game there.

**Tits:** I had a very fruitful contact for much of my career with François Bruhat, and it was very pleasant to work together. It was really working together like you did, I suppose, with Walter Feit.

***R & S:** Was not Armand Borel also very important for your work?*

**Tits:** Yes, I also had much collaboration with Borel. But that was different in the following sense: when I worked with Borel, I had very often the impression that we both had found the same thing. We just put the results together in order not to duplicate. We wrote our papers practically on results that we had both found separately. Whereas with Bruhat, it was really joint work, complementary work.

***R & S:*** *Have either of you had the lightning flash experience described by Poincaré, of seeing all of a sudden the solution to a problem you had struggled with for a long time?*

**Tits:** I think this happens pretty often in mathematical research, that one suddenly finds that something is working. But I cannot recall a specific instance. I know that it has happened to me and it has happened to John, certainly. So certainly some of the ideas one had work out, but it sort of disappears in a fog.

**Thompson:** I think my wife will vouch for the fact that when I wake in the morning I am ready to get out there and get moving right away. So my own naive thinking is that while I am asleep there are still things going on. And you wake up and say: "Let's get out there and do it." And that is a wonderful feeling.

***R & S:*** *You have both worked as professors of mathematics in several countries. Could you comment on the different working environments at these places and people you worked with and had the best cooperation with?*

**Tits:** I think the country that has the best way of working with young people is Russia. Of course, the French have a long tradition, and they have very good, very young people. But I think Russian mathematics is in a sense more lively than French mathematics. French mathematics is too immediately precise. I would say that these are the two countries where the future of mathematics is the clearest. But of course Germany has had such a history of mathematics that they will continue. And nowadays, the United States have in a sense become the center of mathematics, because they have so much money. That they can…

***R & S:*** *…buy the best researchers.*

**Tits:** That's too negative a way of putting it. Certainly many young people go the United States because they cannot earn enough money in their own country.

***R & S:*** *And of course the catastrophe that happened in Europe in the 1930s with Nazism. A lot of people went to the United States.*

*What about you, Professor Thompson? You were in England for a long time. How was that experience compared to work at an American university?*

**Thompson:** Well, I am more or less used to holding my own role. People didn't harass me very much anyplace. I have very nice memories of all the places I have visited, mainly in the United States. But I have visited several other countries, too, for shorter periods, including Russia, Germany, and France. Mathematically, I feel pretty much comfortable everywhere I am. I just carry on. I have not really been involved in higher educational decision making. So in that sense I am not really qualified to judge what is going on at an international basis.

## Thoughts on the Development of Mathematics

***R & S:*** *You have lived in a period with a rapid development of mathematics, in particular in your own areas, including your own contributions. Some time ago, Lennart Carleson, who received the Abel Prize two years ago, said in an interview that the twentieth century had possibly been the Golden Age of Mathematics and that it would be difficult to imagine a development as rapid as we have witnessed.*

*What do you think: Have we already had the Golden Age of Mathematics, or will development continue even faster?*

**Tits:** I think it will continue at its natural speed, which is fast, faster than it used to be.

**Thompson:** I remember reading a quote attributed to Laplace. He said that mathematics might become so deep, that we have to dig down so deep, that we will not be able to get down there in the future. That's a rather scary image, really. It is true that prerequisites are substantial, but people are ingenious. Pedagogical techniques might change. Foundations of what people learn might alter. But mathematics is a dynamic thing. I hope it doesn't stop.

**Tits:** I am confident that it continues to grow.

***R & S:*** *Traditionally, mathematics has been mainly linked to physics. Lots of motivations come from there, and many of the applications are towards physics. In recent years, biology, for example with the Human Genome Project, economics with its financial mathematics, and computer science and computing have been around, as well. How do you judge these new relations? Will they become as important as physics for mathematicians in the future?*

**Tits:** I would say that mathematics coming from physics is of high quality. Some of the best results we have in mathematics have been discovered by physicists. I am less sure about sociology and human science. I think biology is a very important subject but I don't know whether it has suggested very deep problems in mathematics. But perhaps I am wrong. For instance, I know of Gromov, who is a first class mathematician, and who is interested in biology now. I think that this is a case where really mathematics, highbrow mathematics, goes along with biology. What I said before about sociology, for instance, is not true for biology. Some biologists are also very good mathematicians.

**Thompson:** I accept that there are very clever people across the intellectual world. If they need mathematics they come up with mathematics. Either they tell mathematicians about it or they cook it up themselves.

### Thoughts on the Teaching of Mathematics

*R & S: How should mathematics be taught to young people? How would you encourage young people to get interested in mathematics?*

**Thompson:** I always give a plug for Gamow's book *One Two Three … Infinity* and Courant and Robbins' *What is Mathematics?* and some of the expository work that you can get from the libraries. It is a wonderful thing to stimulate curiosity. If we had recipes, they would be out there by now. Some children are excited, and others are just not responsive, really. You have the same phenomenon in music. Some children are very responsive to music, others just don't respond. We don't know why.

**Tits:** I don't know what to say. I have had little contact with very young people. I have had very good students, but always advanced students. I am sure it must be fascinating to see how young people think about these things. But I have not had the experience.

*R & S: Jean-Pierre Serre once said in an interview that one should not encourage young people to do mathematics. Instead, one should discourage them. But the ones that, after this discouragement, still are eager to do mathematics, you should really take care of them.*

**Thompson:** That's a bit punitive. But I can see the point. You try to hold them back and if they strain at the leash then eventually you let them go. There is something to it. But I don't think Serre would actually lock up his library and not let the kids look at it.

*R & S: Maybe he wants to stress that research mathematics is not for everyone.*

**Thompson:** Could be, yeah.

**Tits:** But I would say that, though mathematics is for everyone, not everyone can do it with success. Certainly it is not good to encourage young people who have no gift to try to do something, because that will result in sort of a disaster.

### Personal Interests

*R & S: In our final question we would like to ask you both about your private interests besides mathematics. What are you doing in your spare time? What else are you interested in?*

**Tits:** I am especially interested in music and, actually, also history. My wife is a historian; therefore I am always very interested in history.

*R & S: What type of music? Which composers?*

**Tits:** Oh, rather ancient composers.

*R & S: And in history, is that old or modern history?*

**Tits:** Certainly not contemporary history, but modern and medieval history. All related to my wife's speciality.

**Thompson:** I would mention some of the same interests. I like music. I still play the piano a bit. I like to read. I like biographies and history; general reading, both contemporary and older authors. My wife is a scholar. I am interested in her scholarly achievements. Nineteenth century Russian literature—this was a time of tremendous achievements. Very interesting things! I also follow the growth of my grandchildren.

**Tits:** I should also say that I am very interested in languages, Russian, for instance.

*R & S: Do you speak Russian?*

**Tits:** I don't speak Russian. But I have been able to read some Tolstoy in Russian. I have forgotten a little. I have read quite a lot. I have learned some Chinese. In the course of years I used to spend one hour every Sunday morning studying Chinese. But I started a little bit too old, so I forgot what I learned.

*R & S: Are there any particular authors you like?*

**Tits:** I would say all good authors.

**Thompson:** I guess we are both readers. Endless.

*R & S: Let us finally thank you very much for this pleasant interview, on behalf of the Norwegian, the Danish, and the European Mathematical Societies. Thank you very much.*

**Thompson:** Thank you.

**Tits:** Thank you for the interview. You gave us many interesting topics to talk about!

## Mathematics Awareness Month - April 2009

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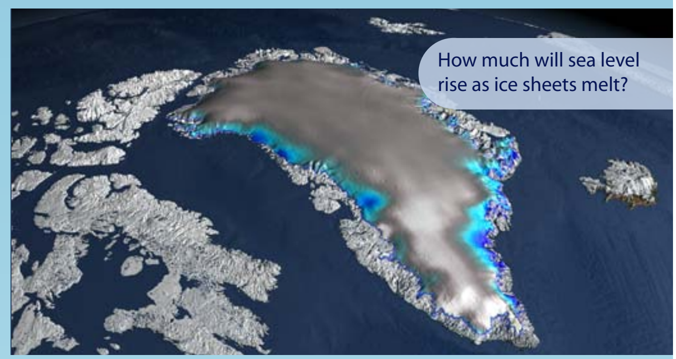


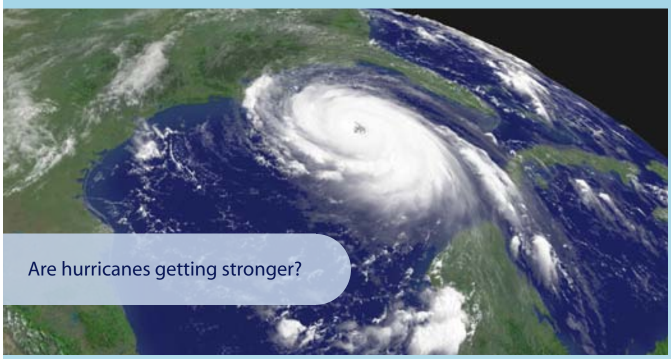



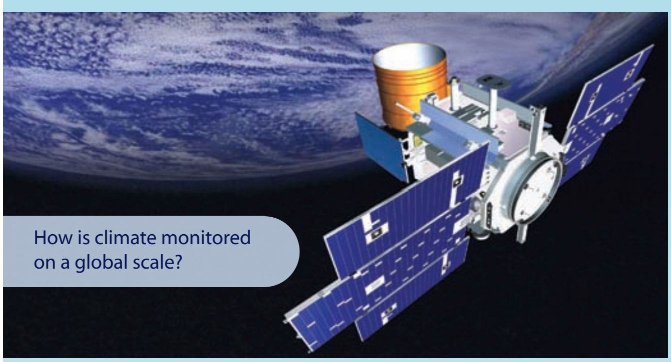


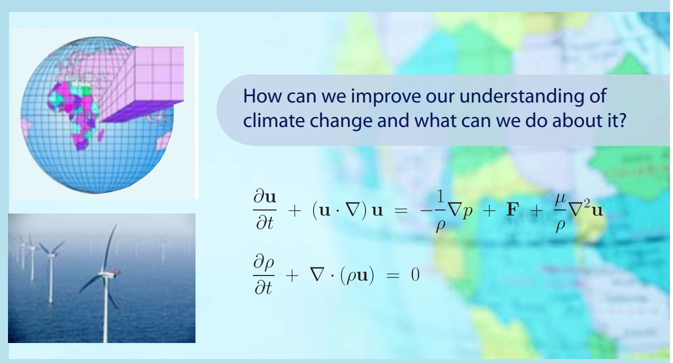


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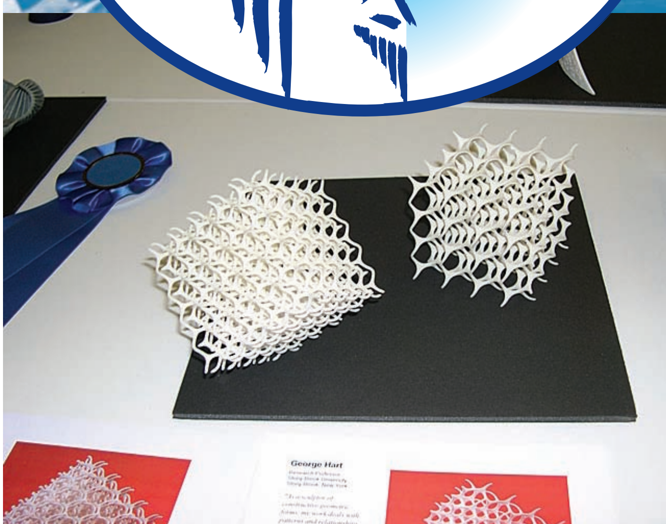



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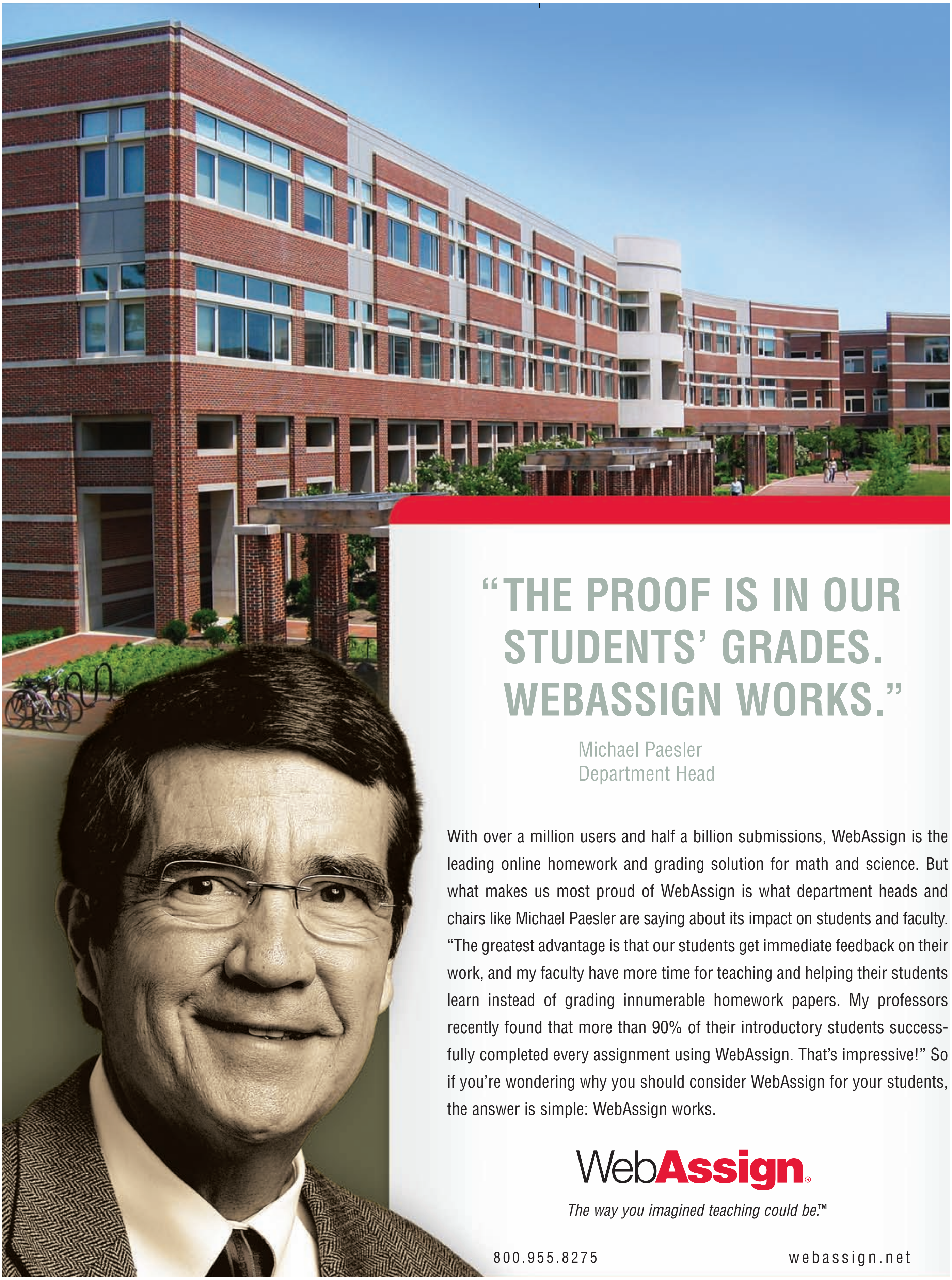
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# Doting on Data

*Book Review by Rebecca Goldin*

**Super Crunchers: Why Thinking-by-Numbers Is the New Way to Be Smart**
*Ian Ayres*
*Hardcover, Bantam, 2007*
*US$25.00, 272 pages*
*ISBN-13: 978-0-553-80540-6*
*Paperback, Bantam, 2008*
*US$14.00, 320 pages*
*ISBN-13: 978-0-553-38473-4*

I remember driving halfway across the country for summer vacation with my parents—a trip that invariably included hours of "Twenty Questions" with my sister. I would typically pick a noun that was suggested by the environment—"tree", "license plate", or "sign"—and she had to figure out what it was I had in mind by asking yes/no questions. Eventually, I lost interest in the game—by picking a sufficiently obscure object, it was too easy to avoid discovery.

Until I found the website `http://www.20q.net/`, which can read my mind. While the computer suggested that I use only nouns that most people would recognize, it "guessed" I had "igloo" in my mind after nineteen questions, and I wasn't able to fool it for more than thirty questions until I tried "differential equation" which, admittedly, isn't a commonly known noun. The most impressive feature of the game is how it can make a good guess when the questions are so vague. How did the program get igloo by knowing it was hard and bigger than a breadbox?

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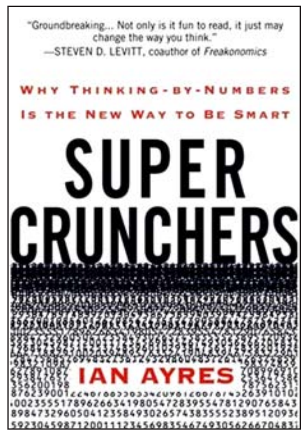
The game is an example of a super cruncher, a computer equipped with huge amounts of data that it can analyze and use to make predictions. The theme of the book *Super Crunchers: Why Thinking-by-Numbers Is the New Way to Be Smart* by Ian Ayres is that super crunchers are better than humans at predicting outcomes—from whether a computer user will click on an ad to how good the wine will be this year.

## A Good Read with Some Statistics Thrown In

For Ayres, "super crunching" is a catch-all term used for any computer activity involving data—sometimes super crunching means doing regression analysis, and other times it involves factors that are correlated with outcome. *Super Crunchers* is filled with amusing and illustrative stories of how society interacts with crunching computers. Some of these are banal—like how Amazon suggests you might like a book based on what you have purchased (and what you have browsed) and what others with similar Amazon-behavior have done. It's no surprise that sellers and advertisers want your information—and pay money to collect and organize it—in order to target you better for advertisements and future sales. What may be surprising is just how far this goes. Every time you use your discount card at the grocery store, you are participating in their data collection efforts on your eating habits in exchange for discounts on your purchases. Every time you swipe your credit card, you are sharing your shopping life with huge data-collection companies that will likely sell this information, perhaps even to a company that seems irrelevant to what you buy. Insurance companies, for example, would be happy to know your age and income, and the ages of your children, for targeted advertising. If you buy diapers, they know you have a baby. If you also shop at Gymboree (an upscale children's clothing store), they know your income is above a certain level. Ayres points out that, with just a little number crunching, they can predict how likely you are to get a divorce in the next three years.

But *Super Crunchers* also details more serious consequences of data combing. Some of these include making decisions on behalf of humans, for the better or for the worse. An example comes from the dubiously named "Sexually Violent Predators Act", passed by my state of Virginia in 2003. The law allows the state to consider committing a sexual offender to a mental institution, even after he has served his full prison term, if he is considered a sexually violent predator. The law is meant to keep imprisoned anyone "who suffers from a mental abnormality or personality disorder which makes the person likely to engage in the predatory acts of sexual violence". Since not all cases can be reviewed in a timely fashion, a computer makes an initial judgment, based on a short algorithm—a simple "number crunching" formula that is considered a good predictor for future acts of sexual violence. The formula includes variables for assault *charges* (not convictions) and whether the sex offense was committed against a male or female. The computer gives each offender a score—and a high enough score triggers a human review for commitment (which then goes to a judge). While humans are involved after the trigger, the stakes are high: computers are (ostensibly) predicting whether ex-sex offenders will offend again.




Similarly, computer algorithms can predict our likelihood to repay a loan, and hence what interest rate we should pay. Unfortunately these algorithms can also be used to exploit us, though Ayres does not elaborate on this problem. If the computer is designed to predict what interest rate we'd be *willing* to pay rather than what we should pay, those on the receiving end of the loan might get short shrift, while those initiating the loans—and, presumably, designing or contracting the software—will benefit.

Ayres makes the important point that super crunching is not only about how profiteers can better exploit information about us to their benefit. First of all, the benefits of super crunching can go both ways in a financial transaction. If an advertiser finds its audience more easily, then those who sell the products profit, but so do those who receive the ads (by receiving information that they're interested in). More importantly, super crunching can actually be a weapon against excess-profit seekers. For example, when I buy clothes for my kids, I do a quick search for a "free shipping" promotion coupon. Truth is, had the coupon not existed, I would have paid the shipping costs and the company would have profited. But in under five minutes, I can often find a discount that it was presumably offering to those who would have shopped at that company only if there was a discount. I have just profited from a super cruncher. Similarly, when buying plane tickets, many people bypass specific airline websites in favor of sites like Expedia, Sidestep, and Yahoo!, which can search for prices and itineraries on all the major carriers at once.

But the level at which crunching data can improve our lives is not limited to our Internet or shopping experience. Doctors are increasingly turning to evidence-based medicine, which helps them determine the impact of thousands of drugs and lifestyle choices on disease. Hospital error can be reduced by analyzing the circumstances under which it occurs. Crunching can even be used to prove discrimination. Computers are used to catch criminals (via face recognition), thwart ideologues (by exposing their lack of sound statistical evidence for ideas on such topics as gun control), and promote social progress (through clinical trials, or recognition of discrimination, among many examples). The book is rife with wonderful stories about how reasoning with numbers and crunching data "solved" a mystery or changed the world for the better.

## Mathematical Content

As far as turning us into super crunchers is concerned, the book falls short, leaving the reader with very limited explanations about how super crunchers actually work, aside from noting that they use large data bases. The main exception to this is a long and eloquent discussion on the meaning of "standard deviation" and normal curves, which should equip people who have never understood the topic with powerful machinery. I can only agree with the author that this concept is one of the most fundamental and ubiquitous statistical tools in existence. Readers—even savvy ones—will find the discussion refreshing and filled with real-world incidents in which understanding the mathematics can give one insight. For example, Ayres details how a colleague found corrupt sports betting based on data that didn't fit into a normal curve. He illustrates the notion of standard deviation with a discussion of IQ scores.

At one point, Ayres' language suggests a possible conflation of distinct concepts. Ayres points to a "head-to-head'' political survey, in which

Candidate A is preferred by 48 percent of the respondents, Candidate B is preferred by 52 percent, and there is a 2 percent margin of sampling error. What this means is that we can be 95 percent confident that the "true value" of Candidate B's support in the overall population from which the sample was drawn is somewhere between 50 and 54 percent. This does *not* mean, as Ayres states, that the true value has a 95 percent *chance* of being somewhere between 50 and 54 percent.

The distinction may be subtle, but it's an important one. Confidence intervals are based on a fixed true value, so that probability statements about the true value are inappropriate. Ayres seems to assume that the true value of a population's preferences is a random variable that is described by a Gaussian curve centered at 52 percent, and then asserts that there is a 97.5 percent chance that Candidate B is ahead of Candidate A based on this curve. But talking about the *chance* that the true value is greater than 50 percent does not make sense, since it either is or is not. It may be true, though Ayres does not explore the topic this way, that a probability could be defined making reference to many election polls in many elections—but additional assumptions would be needed.

Statistical subtleties aside, the notion that we *can* talk about standard deviations and interpret them is an important one, and except for the issue just mentioned, Ayres' description is excellent for a layman's understanding.

On another point, while Ayres provides an excellent defense of the strength of data, he does not always acknowledge the mathematical truths that can undermine the way numbers are interpreted. For one, Ayres frequently talks of past success as if it obviously engenders future success. If one person flips a coin 15 times in a row, the chance of getting at least 14 heads (or 14 tails) is less than 1 tenth of one percent. However, if 1,000 people flip coins 15 times, the likelihood that *someone* throws a coin and gets at least 14 heads (or 14 tails) is 62 percent. This classic experiment on the difference between a random occurrence and multiple testing is disregarded by Ayres.

The neglect of how multiple testing can affect modeling is reflected in his discussion, for example, of predictions of the quality of Bordeaux wines next year. He tells the very entertaining story of a modeler who was ignored by the skeptical wine-tasting experts but whose regression model ultimately proved a better predictor than the experts the following year. Since the best model is chosen based on *past* success (i.e., modeling how good the wine was in past seasons), without more information we cannot rule out the possibility that the model was successful at least partly by chance—like choosing the "best'' coin among the 1,000 coin flippers. Will the regression model predict the next year's wine any better than a coin with an excellent track record? And if the wine turns out to be as expected according to the regression model, does it mean that the model predicted the wine quality, or that the modeler got lucky?

Ayres notes that people are reluctant to admit that computers are better than people at certain predictive skills. A reader has to be self-conscious, then, in challenging this point of view. What computers can do that humans cannot is process very large quantities of data—and if computers have the right data, they can do more than humans. It's a credit to our current computer capacity that crunching can do so much good for the world—think of the world without weather predictions! But if computers have the wrong data, not enough data, or the wrong algorithm, super crunching can get it really wrong.

Unfortunately, Ayres is reluctant to talk about when computer predictions don't get it right due to a faulty model or faulty data. A recent example of such an occurrence reported in the *Washington Post* after Ayres' book appeared involves the banking crisis. AIG Financial Products got involved with credit-default swaps in part thanks to a computer model that had crunched historical data about corporate debt. The model suggested huge profits were to be had, with very little assumption of risk. Ten years later, its parent company AIG is at the heart of the economic crisis, and over 150 billion government dollars have been invested to keep the company afloat. The *Washington Post* quoted executives who felt that the model was too good to be true—but ironically they allowed their faith in the computer model to trump their intuition. These days, much of the criticism of "what went wrong" with the current financial crisis suggests that human oversight and judgment could have played a positive role.

## Super Crunching Requires Data

Super crunching has an implicit message: the data is "out there", and it's just a question of how to collect it and how to crunch it. There is certainly some truth in this—evidence-based medicine has made great progress due to huge amounts of data, thereby offering the possibility of decreases in hospital and doctor error and increases in effectiveness (again, Ayres has some great stories in this vein).

But sometimes, data is simply insufficient or unobtainable. Even worse, the existence of "related" data can lead us astray. What if the best predictors of whether a convicted sexual predator will commit another crime include whether he has a loving relationship with his parents, or whether he has experienced a self-awakening through therapy? While there are ways of "measuring" these factors (such as interviews and psychiatric evaluations), they are costly and time-intensive, and the *data* showing how they are related to subsequent acts of sexual violence may simply not exist.

Ayres tells the story of a successful model for teaching, called Direct Instruction (DI). Teachers using DI for reading must follow a carefully scripted and fairly tedious class plan to teach students to read. Many educators are up in arms about DI, Ayres notes, because advocating this way to teach reading takes away their autonomy. However, according to Ayres, it is the most successful program ever documented through "scientific means". Ayres touches on the complaint that this method of teaching could increase reading skills while killing the love of reading, diminishing creativity, and stymieing the development of verbal comprehension. (I would add that it also may not challenge intellectually those students who have an easy time reading.) He then dismisses these claims largely because they are not supported by the data—he argues that, for those who don't accept DI, the *philosophy* of teaching is trumping the *science* of teaching.

But Ayres doesn't address the problem that the very tests that show the success of DI *become* the meaning of the word "success" to those who believe that all educational success can be read in the data. A deep understanding of character development, the ability to make connections among texts that are read, and the ability to articulate the author's purposes are much more difficult to assess in a simple test format. If you believe that tests can measure progress in reading, you are bound to turn to a surrogate (reading "skills"). Direct Instruction may do the best at increasing scores on skills tests. However, data from skills tests is a partial indicator of the desired outcome and should not be used to the exclusion of other evaluative techniques. This is not to say that the program isn't effective—it's to say that the evidence is far from sufficient to conclude what Ayres does. There is a parallel issue in mathematics, though Ayres does not address DI in mathematics: Some skills are easy to measure, and others simply go unmeasured in any controlled environment. The stakes are high, as we see with the No Child Left Behind legislation, which mandates scientifically based educational techniques and places a high, explicit premium on standardized test performance as an outcome measure.

## The Ethics of Super Crunching

Like many people who deal with data crunching, Ayres notes that there is a strange bias in the world: Somehow, politically left-leaning people have deemed number crunching a tool for political conservatives, one that has vaguely demonic (or at least, inhuman) interests at heart. He argues vigorously against this view, maintaining that super crunching is by itself politically neutral and can be used by anyone to benefit. He cites his own laudable work in documenting discrimination in car loans. While many current uses of super crunching seem pro-business, Ayres notes the benefits to the average person. Super crunching is the way that Google targets its ads and can guess what you mean when you type an ambiguous phrase into its search engine. It's how a hospital can recognize dangerous drug interactions, and how governments can test social programs to decrease poverty. However, super crunching is not always used to benefit people—it's how airlines maximize their revenues, and how predatory lending companies got some people's personal information. Ayres predicts that consumer-driven crunching machines will become the norm, and websites will allow consumers to "fight back" against pricing schemes. He cites `http://farecast.com` as a prime example—it's a website that "predicts" whether airline fares are going up or down on a particular route (so you can decide to buy now or to wait before purchasing).

However, Ayres' book is remarkably silent on a host of important ethical issues surrounding super crunchers. While race cannot be explicitly used to determine a car loan rate, is it ethical to use one's mother's educational level, which has a high correlation with race? And if not, then what about other data about an individual, from where he or she lives to what he or she buys? Think of the "Twenty Questions'' game; with a fairly limited amount of data, a computer could predict race with high certainty. Would it be legal or ethical to use the kind of music one buys to determine his or her loan rate (along with a credit score, of course)?

The slope gets very slippery when we return to the Sexually Violent Predators Act from an ethical point of view. Are we looking at a future in which any trouble with the law could trigger a "review" that could lead to commitment to a mental institution for fear of future acts of violence? Perhaps we should just screen all people, rather than convicted offenders. What if we *could* find social factors that, via crunching large amounts, would allow us to determine who is likely to commit a crime and who is not (and should we arrest those who likely will, even if they haven't yet)? When does the individual stand separate from the statistic? The 1997 movie *Gattaca* told of a society in which one's life was determined by computer predictions based on genetics. Already, women can find out if they have a gene that will make them extremely likely to get breast cancer, and a simple blood test tells us if we are at high risk of heart disease. Super crunching has the possibility of constraining us if used incorrectly. Our ability to find correlations should be tempered by respect for our individuality.

Overall, Ayres' book is a good read, in the spirit of the well-known book *Freakonomics*, by Steven Levitt and Stephen J. Dubner. Don't expect you'll be a super cruncher when you're done, but you might turn to regression analysis to choose your wine.

## About the Cover

### Tracking hurricanes

This month's cover images appeared originally in the article "Hurricanes and climate", by Kerry Emanuel, available from the Math Awareness Month website at

`http://www.mathaware.org/mam/09/essays/Emanue.pdf`.

A companion audio file can be found at

`http://www.mathaware.org/mam/09/essays.html`.

April is Math Awareness Month, and the theme this year is *Mathematics and Climate*.

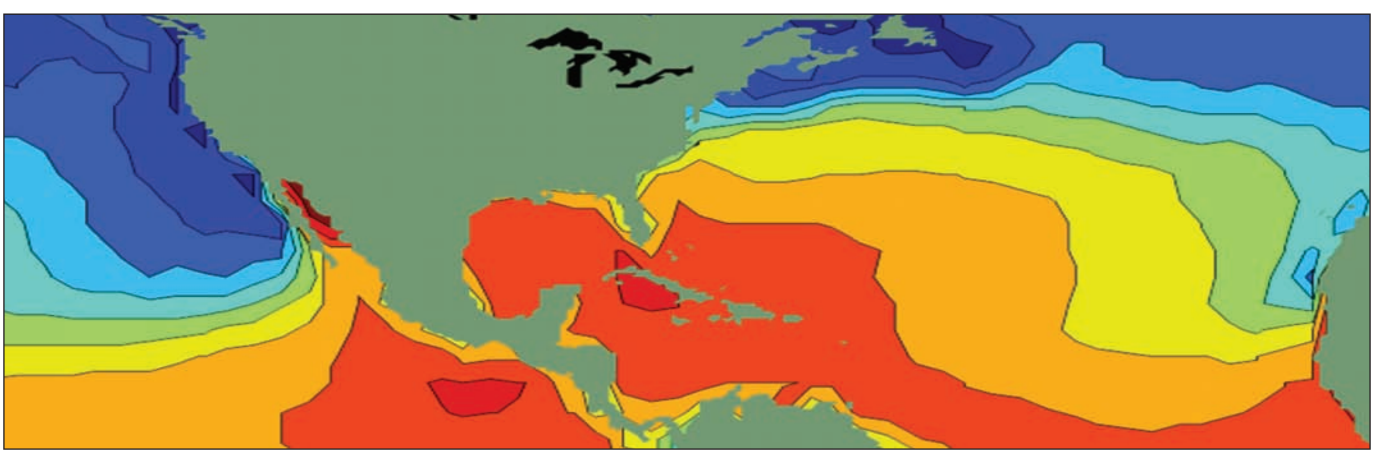
The beautiful map of hurricane (more properly "tropical cyclone") tracks (top) is from the Wikipedia Commons, and can be found in the Wikipedia article "Tropical cyclone".

The other image is based on computations by Kerry Emanuel. Details can be found in his article "Tropical cyclones" (which appeared in the *Annual Review of Earth and Planetary Science* (2003) and can also be found on his home page). The colors, more or less intuitively chosen, display computed values of what Emanuel calls the *potential intensity* of the local thermodynamic environment, a rough measure of maximum sustainable wind speed. As the MAM essay says, "Hurricanes always originate where the potential intensity is high … they never form within about 3° latitude of the equator, because there is not enough projection of the Earth's rotation axis."

Emanuel writes further, "…reanalysis data has been created by running a full-physics, operational numerical weather prediction model, assimilating observations from multiple sources, including surface and upper air measurements and satellite data. I solve [a differential equation from "Tropical cyclones"] at each grid node for reanalysis data averaged over each month, and then find (at each grid node) the maximum value over the 12 months."

Next month the *Notices* will continue the theme of mathematics and climate with an article by Kenneth Golden on mathematics and sea ice.

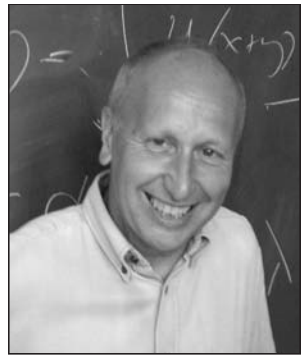
—*Bill Casselman, Graphics Editor*
(`notices-covers@ams.org`)



# 2009 Steele Prizes

I. G. Macdonald

Richard Hamilton



Luis Caffarelli

The 2009 AMS Leroy P. Steele Prizes were presented at the 115th Annual Meeting of the AMS in Washington, DC, in January 2009. The Steele Prizes were awarded to I. G. MACDONALD for Mathematical Exposition, to RICHARD HAMILTON for a Seminal Contribution to Research, and to LUIS CAFFARELLI for Lifetime Achievement.

## Mathematical Exposition: I. G. Macdonald

### Citation

*Symmetric Functions and Hall Polynomials*, Second edition. The Clarendon Press, Oxford University Press, New York, 1995.

I. G. Macdonald's book gathers a wealth of material related to symmetric functions into a beautifully organized exposition. Pioneering work of Frobenius, Schur, and others established important connections between symmetric functions and the representation theory of the symmetric group and complex general linear group. Since their work, many further connections were developed with representation theory, algebraic geometry, intersection theory, enumerative combinatorics, special functions, random matrix theory, and other areas. Until the first edition of Macdonald's book appeared in 1979, the theory of symmetric functions was scattered throughout the literature and very difficult to learn. This first edition collected, unified, and expanded such material as Schur functions, Hall polynomials, Hall-Littlewood symmetric functions, the characters of $GL_n(q)$, and the Hecke ring of $GL_n$ over a local field, none of which had previously received an adequate exposition. The second edition of 1995 added a huge amount of new material, including Jack polynomials and the two-parameter Macdonald polynomials, which have subsequently arisen in many unexpected areas, such as in the Hilbert scheme of $n$ points in the plane and in the representation theory of affine Hecke algebras and quantum affine algebras. An especially notable feature of Macdonald's book is the "examples" (really exercises with solutions) which include a vast variety of additional results, many of them original. The importance and popularity of Macdonald's book is evidenced by the more than 3,600 citations on Google Scholar. Macdonald's book has been and continues to be an invaluable resource to researchers throughout mathematics.

### Biographical Sketch

Ian Macdonald was born in Middlesex, England, in 1928. After army service he went to Cambridge University in 1949 and graduated in 1952. He spent the next five years in the British Civil Service (government administration). Subsequently, he held teaching positions successively at the universities of Manchester, Exeter, Oxford, Manchester (again), and London. He was elected a Fellow of the Royal Society of London in 1979 and was awarded the Pólya Prize by the London Mathematical Society in 1991.

His research since the 1960s has been mainly in the general area of Lie theory, in particular the combinatorial infrastructure (root systems, Weyl groups) and associated objects such as orthogonal polynomials and power series identities.

### Response

I am both honoured and delighted to be awarded a Steele Prize for Mathematical Exposition for my book, *Symmetric Functions and Hall Polynomials*.

The origins of that book go back to the beginning of my mathematical career at Manchester in the late 1950s. Whilst there, I learned about

Hall polynomials and what are now called Hall-Littlewood symmetric functions from Sandy Green, who had recently made crucial use of them in his determination of the character tables of the finite general linear groups. Some years later I was invited to write a survey article on Hall polynomials for the *Jahresbericht der DMV*. That article never got written, partly for the usual reasons but also partly because it became clear to me that such a survey would for the sake of clarity need to be prefaced by a self-contained account of the algebra of symmetric functions, which at that time was lacking in the mathematical literature. I hope my book may have been of service to students and others who need to know the basic facts about symmetric functions, even if their interest in Hall polynomials is minimal.

## Seminal Contribution to Research: Richard Hamilton

### Citation

The 2009 Leroy P. Steele Prize for Seminal Contribution to Research is awarded to Richard Hamilton for his paper "Three-manifolds with positive Ricci curvature", *J. Differential Geom.* **17** (1982), 255–306.

Differential geometry includes the study of Riemannian metrics and their associated geometric entities. These include the curvature tensor, geodesic distance function, natural differential operators on functions, forms, and tensors as well as many others. A given smooth manifold has an infinite-dimensional space of Riemannian metrics whose geometric behavior may vary dramatically. By its very nature geometry must be coordinate invariant, so two Riemannian metrics which are related by a diffeomorphism of the manifold must be considered equivalent. The question of choosing a natural metric from the infinite-dimensional family is nicely illustrated by the case of compact oriented two-dimensional surfaces. For surfaces of genus 0 there is a unique choice of equivalence class of metrics with curvature 1, while for genus 1 (respectively genus greater than 1) there is a finite-dimensional moduli space of inequivalent metrics with curvature 0 (respectively curvature -1).

The cited paper of Richard Hamilton introduced a profoundly original approach to the construction of natural metrics on manifolds. This approach is the Ricci flow, which is an evolution equation in the space of Riemannian metrics on a manifold. The stationary points (for the normalized flow) are the Einstein metrics (constant curvature in dimensions 2 and 3). The Ricci flow is a nonlinear diffusion equation which may be used to deform any chosen initial metric for a short time interval. In the cited paper Hamilton showed that, in dimension 3, if the initial metric has positive Ricci curvature, then the flow exists for all time and converges to a constant curvature metric. This implies the remarkable result that a three manifold of positive Ricci curvature is a spherical space form (a space of constant curvature). Over the next twenty years Hamilton laid the groundwork for understanding the long time evolution for an arbitrary initial metric on a three-manifold with an eye toward the topological classification problem. For this purpose he developed the idea of the Ricci flow with singularities in which the flow would be continued past singular times by performing surgeries in a controlled way. Finally, through the spectacular work of Grisha Perelman in 2002, the difficult issues remaining in the construction were resolved, and the program became successful.

In addition to the applications to the topology of three-manifolds, the Ricci flow has had, and continues to have, a wide range of applications to Riemannian and Kähler geometry. The cited paper truly fits the definition of a seminal contribution; that is, "containing or contributing the seeds of later development".

### Biographical Sketch

Richard Streit Hamilton was born in Cincinnati, Ohio, in 1943. He graduated from Yale summa cum laude in 1963, and received his Ph.D. from Princeton in 1966, writing his thesis under Robert Gunning. He has taught at Cornell University, the University of California at San Diego, and UC Irvine, where he held a Bren Chair. He is currently Davies Professor of Mathematics at Columbia University in New York City, where he does research on geometric flows. In 1996 Richard Hamilton was awarded the Oswald Veblen Prize of the American Mathematical Society, and he is a Member of the American Academy of Arts and Sciences and the National Academy of Sciences.

### Response

It is a great honor to receive the Steele Prize acknowledging the role of my 1982 paper in launching the Ricci flow, which has now succeeded even beyond my dreams. I am deeply grateful to the prize committee and the AMS.

When I first arrived at Cornell in 1966, James Eells Jr. introduced me to the idea of using a nonlinear parabolic partial differential equation to construct an ideal geometric object, lecturing on his brilliant 1964 paper with Joseph Sampson on harmonic maps, which was the origin of the field of geometric flows. This now encompasses the harmonic map flow, the mean curvature flow (used in physics to describe the motion of an interface, and also in image processing as well as isoperimetric estimates), the Gauss curvature flow (describing wear under random impact), the inverse mean curvature flow (used by Huisken and Ilmanen to prove the Penrose conjecture in relativity), and many others, including Ricci flow.

James Eells Jr. also first suggested I use analysis rather than topology to prove the Poincaré conjecture on the grounds that it is difficult for topologists to solve a problem where the hypothesis is the absence of topological invariants. And indeed as Lysander said, "Where the lion's skin will not reach, we must patch it out with the fox's." So I started thinking in the 1970s about how to use a parabolic flow to round out a general Riemannian metric to an Einstein metric by spreading the curvature evenly over the manifold. Now the Ricci curvature tensor is in a certain sense the Laplacian of the metric, so that zero Ricci curvature in the Riemannian case is really the elliptic equation for a harmonic metric, while in the Lorentzian case it is the hyperbolic wave equation for a metric, which is Einstein's theory of relativity. So it is only natural to guess that the parabolic heat equation for a metric is to evolve it by its Ricci curvature, which is the Ricci flow.

It is often the case that the credit for a discovery goes not to the first person to stumble upon a thing, but to the first who sees how to use it. So the significance of my 1982 paper was that it proves a very nice result in geometry, that a three-dimensional manifold with a metric of positive Ricci curvature is always a quotient of the sphere. To prove this I developed a number of new techniques and estimates that opened up the field, in particular using the maximum principle on systems to obtain pinching estimates on curvature. Right afterward Shing-Tung Yau pointed out to me that the Ricci flow would pinch necks, performing a connected sum decomposition. I was very fortunate that shortly after I moved to UCSD where I could collaborate with Shing-Tung Yau, Richard Schoen, and Gerhard Huisken, who coached me in the use of blow-ups to analyze singularities, making it possible to handle surgeries. It was also very important that Peter Li and Yau pointed out the fundamental importance of their seminal 1986 paper on Harnack inequalities, leading to my Harnack estimate for the Ricci flow, which is fundamental to the classification of singularities. And in 1997 I proved a surgical decomposition on four-manifolds with positive isotropic curvature. In 1999 I published a paper outlining a program for proving geometrization of three-manifolds by performing surgeries on singularities and identifying incompressible hyperbolic pieces as time goes to infinity, only as I was still lacking control of the injectivity radius, I had to assume a curvature bound. This was supplied four years later in 2003 by the brilliant work of Grigory Perelman in his noncollapsing estimate, which led to his remarkable pointwise derivative estimates, allowing him to complete the program.

But the importance of Ricci flow is not confined to three dimensions. For example, we can hope to prove results on four-manifold topology, which are far more difficult. The Ricci flow on canonical Kähler manifolds is well advanced, based on the work of Huai-Dong Cao and Grigory Perelman, which might lead to a theorem in algebra. Ricci flow also is closely connected to the renormalization group in string theory, and might be used to find stationary Lorentzian Einstein metrics in higher dimensions, giving applications to physics. And just recently we have the very lovely result of Richard Schoen and Simon Brendle using Ricci flow to prove the much stronger result in differential geometry of diffeomorphism rather than homeomorphism in the quarter-pinching theorem using the much weaker assumption of pointwise rather than global pinching. Now that many outstanding mathematicians are working on it, the story of the Ricci flow is just beginning.

## Lifetime Achievement: Luis Caffarelli

### Citation

Luis Caffarelli is one of the world's greatest mathematicians studying nonlinear partial differential equations (PDE). This is a difficult field: there are rarely exact formulas for solutions of nonlinear PDEs, and rarely will exact algebraic calculations yield useful expressions.

Instead researchers must typically invoke functional analysis to build "generalized" solutions for many important equations. What remains is the profound and profoundly technical problem of proving regularity for these weak solutions and, by universal acclaim, the greatest authority on regularity theory is Luis Caffarelli.

His breakthroughs are so many, and yet so technical, that they defy any simple recounting here. But it was certainly Caffarelli's work on "free boundary" problems that first showed his deep insights. Free boundary problems entail finding not only the solution of some PDEs, but also the very region within which the equation holds. Luis Caffarelli's vast work totally dominates this field, starting with his early papers on the obstacle problem. In estimate after estimate, lemma after lemma, he shows that the generalized solution and the free boundary have a bit more regularity than is obvious, then a bit more, and then more; until finally he proves under a mild geometric condition that the solution is smooth and the free boundary is a smooth hypersurface. The arguments are intricate, but completely elementary.

Later papers introduce countless technical innovations that broaden the analysis to PDE free boundary problems of all sorts. Caffarelli has likewise revolutionized the study of fully nonlinear elliptic PDEs, and particularly the Monge-Ampère equation. His breakthroughs here include boundary second derivative estimates, classifications of possible degeneracies for solutions, regularity theory for optimal mass transfer schemes, etc. In all this work Caffarelli is an endlessly inventive technical magician, for instance using the maximum principle in one paper to derive $L_p$ estimates for second derivatives of solutions.

During his years at the University of Minnesota, the University of Chicago, New York University, the Institute for Advanced Study, and now the University of Texas, Luis Caffarelli has collaborated widely and directed many Ph.D. students. He is extraordinarily generous, in both his personal and professional lives. One of his coauthors at a conference once described extending to a fully nonlinear equation some previous research on a linear PDE. He reported that the earlier workers on the linear equation used a formula for the solution, but that "we had something better than an exact formula. We had Luis."

**Biographical Sketch**

Luis A. Caffarelli was born in Buenos Aires, Argentina, in December of 1948. He completed his Ph.D. in mathematics at the Universidad de Buenos Aires in 1972 under the direction of Calixto Calderón. In 1973, he came to the United States with a postdoctoral fellowship to the University of Minnesota, where by 1979 he attained a professorship.

He has been a professor at the University of Chicago (1983–1986), the Courant Institute (1980–1982 and 1994–1997), and the Institute for Advanced Study (1986–1996).

Since 1997, Luis Caffarelli has been a professor in the Department of Mathematics and the Institute for Computational Engineering and Science at the University of Texas at Austin, holding the Sid Richardson Chair 1.

He is a member of several academies, including the National Academy of Sciences, holds several honorary degrees and professorships, and has been awarded several distinguished prizes, including the Bôcher Prize of the AMS and the Rolf Schock Prize of the Royal Swedish Academy of Sciences. Finally, he has delivered the AMS Colloquium Lectures; AMS Invited Addresses; and a plenary lecture at the International Congress of Mathematics in Beijing, 2002; and the International Congress of Industrial and Applied Mathematics in Zurich, 2007.

His main mathematical interests are in nonlinear analysis and partial differential equations. He has made contributions in areas concerning phase transitions, free boundary problems, the Landau-Ginzburg equation; fluid dynamics, Navier-Stokes and quasi-geostrophic flows; fully nonlinear equations from optimal control, the Monge-Ampère equation and optimal transportation; and more recently nonlinear homogenization in periodic and random media and nonlinear problems involving nonlocal diffusion processes.

**Response**

On this very happy occasion, I would like to thank the Selection Committee for having awarded me this great distinction.

I would also like to thank my parents, my wife Irene, and my children Alejandro, Nicolas, and Mauro, for accompanying me through the years and sharing with me their love and their encouragement.

I came to the United States to the University of Minnesota in January of 1973. There was no email, no fax, and even the telephone was very expensive. But I found at Minnesota and in the midwest an extraordinary group of people. My colleagues were extremely generous, dedicated, and friendly, and they taught me much of what I know. They shared their ideas and gave me guidance as I began my research program.

Through the years, I have had the opportunity to belong to wonderful institutions and to befriend and collaborate with extraordinary scientists all over the world. This led to further opportunities to mentor very talented young people who have invigorated my research with new ideas.

The Steele Prize, which so much honors me, should also serve to recognize the many mathematicians who have contributed in so many ways to make nonlinear analysis and applied mathematics a central part of science today.

## About the Prize

The Steele Prizes were established in 1970 in honor of George David Birkhoff, William Fogg Osgood, and William Caspar Graustein. Osgood was president of the AMS during 1905–1906, and Birkhoff served in that capacity during 1925–1926. The prizes are endowed under the terms of a bequest from Leroy P. Steele. Up to three prizes are awarded each year in the following categories: (1) Lifetime Achievement: 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) Mathematical Exposition: for a book or substantial survey or expository-research paper; (3) Seminal Contribution to Research: 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. Each Steele Prize carries a cash award of US$5,000.

The Steele Prizes are awarded by the AMS Council acting on the recommendation of a selection committee. For the 2009 prizes, the members of the selection committee were: Enrico Bombieri, Russel Caflisch, Lawrence C. Evans, Lisa C. Jeffrey, Nicholas M. Katz, Gregory F. Lawler, Richard M. Schoen, Julius L. Shaneson (chair), and Richard P. Stanley.

The list of previous recipients of the Steele Prize may be found on the AMS website at `http://www.ams.org/prizes-awards`.

# 2009 AMS-SIAM Birkhoff Prize

JOEL SMOLLER received the 2009 AMS-SIAM George David Birkhoff Prize in Applied Mathematics at the Joint Mathematics Meetings in Washington, DC, in January 2009.

## Citation

The 2009 George David Birkhoff Prize in Applied Mathematics is awarded 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. His classic text on shock waves has had far-reaching impact on the field. His work with Charles Conley led to many results on reaction-diffusion equations, with diverse applications to biology, physiology, and chemistry. His work with Arthur Wasserman on bifurcation theory, which introduced an equivariant version of the Conley index, was a tour de force of original methods, providing a rigorous analysis and characterization of radial stationary solutions of the Einstein Yang-Mills equations. He and Blake Temple developed a theory of shock wave propagation in general relativity and gave the first exact solution of the Einstein equations. Overall, his powerful intuition for innovative new directions and his forcefulness in cementing powerful collaborations have been emblematic of a career worthy of emulation.

Joel Smoller

## Biographical Sketch

Joel Smoller was born in New York City and was an undergraduate at Brooklyn College. He obtained his Ph.D. at Purdue University in 1963, writing a thesis in abstract functional analysis. He has spent his entire academic career at the University of Michigan and was promoted to full professor in 1969. Shortly after arriving at Michigan, his research interests changed to partial differential equations. He has supervised 27 Ph.D. students, including Tai-Ping Liu (Stanford), David Hoff (Indiana), Robert Gardner (University of Massachusetts), Blake Temple (University of California, Davis), and Zhouping Xin (Chinese University of Hong Kong). Smoller has held the Lamberto Cesari Chair of Mathematics at the University of Michigan since 1998. His awards include a senior Humboldt Fellowship, 2005–2008; Morningside Lecturer, International Congress of Chinese Mathematicians, 2001 and 2004; Rothschild Professor and Rothschild Lecture, University of Cambridge (UK), 2003; Patton Lecturer, Indiana University, 2001; Distinguished Alumnus Award, Purdue University, 2000; Excellence in Research Award, University of Michigan, 1996; Plenary Address, Marcel Grossman Conference in Physics (Stanford University), 1994; joint Harvard-MIT-Brandeis lecture, 1994; Margaret and Herman Sokol Award, University of Michigan, 1992; Ordway Lecturer, University of Minnesota, 1985; Guggenheim Fellowship, 1980–1981. Three issues of the journal *Methods and Applications of Analysis* **12**, nos. 2, 3, 4, displaying his picture on the covers, were dedicated to him in 2005. Smoller has been the editor for five journals (*Michigan Mathematics Journal, Applicable Analysis, Journal of Hyperbolic Differential Equations, Nonlinearity*), and he was the PDE editor for the *Transactions of the American Mathematical Society*, 1982–1986. National meetings were dedicated to his 60th and 70th birthdays at UC Davis and Stanford University, respectively.

## Response

It is a great honor to be chosen as the recipient of the 2009 George David Birkhoff Prize in Applied Mathematics. I am appreciative of the American Mathematical Society and to the Society for Industrial and Applied Mathematics for their recognition of my research accomplishments. Above all, I would like to thank my many collaborators for their generosity, their encouragement, and for patiently introducing me to a wealth of new ideas. Special thanks are due to Blake Temple, who has been a longtime collaborator and has shared many of his beautiful new ideas with me.

Many outstanding mathematicians have influenced me and affected the trajectory of my research career. In particular, I owe many thanks to Edward Conway, who taught me the mathematics of shock waves, and to Charles Conley, who was my friend, mentor, and collaborator for many years. Both Conway and Conley passed away unexpectedly more than twenty years ago, but I still miss them. James Glimm, Peter Lax, and Shing-Tung Yau have always supported and encouraged me, and for this I owe them many thanks. My younger collaborator Felix Finster, has greatly influenced my work by taking me into new and exciting directions. Finally, my many excellent students, including Blake Temple, David Hoff, Tai-Ping Liu, Zhouping Xin, and Robert Gardner, have had an impact on my career by being both my teachers and collaborators.

I have always been attracted to special problems whose analysis uncovers new phenomena in physical settings. I have tended to start in new directions, rather than work on more technical problems that finish up fields. Like most, I learn best through collaboration, and I have been extremely lucky to find brilliant colleagues who have led me into so many rewarding experiences.

### About the Prize

The Birkhoff Prize recognizes outstanding contributions to applied mathematics in the highest and broadest sense and is awarded every three years (until 2001, it was awarded usually every five years). Established in 1967, the prize was endowed by the family of George David Birkhoff (1884–1944), who served as AMS president during 1925–1926. The prize is given jointly by the AMS and the Society for Industrial and Applied Mathematics (SIAM). The recipient must be a member of one of these societies and a resident of the United States, Canada, or Mexico. The prize carries a cash award of US$5,000.

The recipient of the Birkhoff Prize is chosen by a joint AMS-SIAM selection committee. For the 2009 prize, the members of the selection committee were: Peter W. Jones (chair), George C. Papanicolaou, and Terence C. Tao.

Previous recipients of the Birkhoff Prize are Jürgen K. Moser (1968), Fritz John (1973), James B. Serrin (1973), Garrett Birkhoff (1978), Mark Kac (1978), Clifford A. Truesdell (1978), Paul R. Garabedian (1983), Elliott H. Lieb (1988), Ivo Babuška (1994), S. R. S. Varadhan (1994), Paul H. Rabinowitz (1998), John N. Mather (2003), Charles S. Peskin (2003), and Cathleen S. Morawetz (2006).

# 2009 Cole Prize in Algebra

Christopher Hacon and James McKernan received the 2009 AMS Frank Nelson Cole Prize in Algebra at the 115th Annual Meeting of the AMS in Washington, DC, in January 2009.

### Citation

The 2009 Frank Nelson Cole Prize in Algebra is awarded to Christopher Hacon and James McKernan for their groundbreaking joint work on higher-dimensional birational algebraic geometry. This work concerns the minimal model program, by which S. Mori and other researchers made great progress in understanding the geometry of three-dimensional projective algebraic varieties in recent decades. The case of dimension greater than three, however, remained largely open. The work of Hacon and McKernan has transformed the study of the minimal model program in higher dimensions, in particular regarding the existence and termination of flips and the finite generation of the canonical ring. Specifically, the prize is awarded for two joint papers of theirs: "Boundedness of pluricanonical maps of varieties of general type", *Invent. Math.* **166** (2006), 1–25, and "Extension theorems and the existence of flips" (in *Flips for 3-folds and 4-folds*, 76–110, Oxford Lecture Ser. Math. Appl., 35, Oxford Univ. Press, Oxford, 2007). The former paper, in addition to proving the result referred to in the title, also established their key lifting lemma for sections. The latter manuscript, which drew on their earlier paper, proved the inductive step on the existence of flips.

**Biographical Sketch: Christopher Hacon**

Christopher Hacon was born in Manchester, England, in 1970. He received his undergraduate degree in mathematics from the Università di Pisa and the Scuola Normale Superiore di Pisa in 1992, and he received his Ph.D. in mathematics from UCLA in 1998. His advisor was Robert Lazarsfeld. He was a postdoc at the University of Utah (1998–2000) and an assistant professor at the University of California, Riverside (2000–2002), and he has been a professor at the University of Utah since 2002. He received a Sloan Fellowship in 2003, an AMS Centennial Fellowship in 2006, and the Clay Research Award in 2007. His research interests are in algebraic geometry and, in particular, in the classification of higher-dimensional algebraic varieties.

**Biographical Sketch: James McKernan**

James McKernan was born in London, England, in 1964. He received his B.A. in mathematics from the University of Cambridge in 1985, while attending Trinity College, and his Ph.D. in mathematics from Harvard University under the supervision of Joseph Harris in 1991. He then held temporary positions at the University of Utah (1991–1993), the University of Texas at Austin (1993–1994), and Oklahoma State University, Stillwater (1994–1995). He joined the faculty at the University of California, Santa Barbara, in 1995 and the faculty at the Massachusetts Institute of Technology in 2007. In 2007 he received the Clay Research Award. His research interests are in algebraic geometry, especially birational geometry and the classification of algebraic varieties.

**Response: Christopher Hacon and James McKernan**

The minimal model program is an attempt to extend the classification of complex projective surfaces achieved by the Italian school of algebraic geometry at the beginning of the twentieth century to higher-dimensional complex projective varieties. The main idea is to produce an optimal representative of any smooth projective variety via a finite sequence of well understood birational maps called flips and divisorial contractions. This representative is called a minimal model. In dimension three this program was completed by S. Mori with his work on the existence of 3-dimensional flips.

In higher dimensions the main problem is to show that flips always exist and that there is no infinite sequence of flips.

It had always been our hope to say something significant about this problem. This dream became a reality when, by combining ideas of V. Shokurov and Y.-T. Siu, we were able to prove that flips exist in any dimension and that (under mild technical assumptions) carefully chosen sequences of divisorial contractions and flips always give a birational map to a minimal model.

**Christopher Hacon**

We are very happy that the Selection Committee decided to recognize this field of research. We would like to stress that our accomplishments are based on a long series of beautiful results obtained by Y. Kawamata, J. Kollár, S. Mori, M. Reid, V. Shokurov, Y.-T. Siu, and many others. We are also in debt to our co-authors C. Birkar and P. Cascini, who were instrumental in the completion of a significant part of this program, and to A. Corti for many useful conversations on the minimal model program.

One of the nicest things about receiving this award is that it gives us an opportunity to publicly acknowledge the invaluable aid we have received from others. Christopher Hacon would like to thank Aleksandra, Stefan, Ana, Sasha, and Kristina Jovanovic-Hacon, D. Hacon, C. Peters, and G. Gianelli for their support, love and encouragement; F. Catanese, R. Lazarsfeld, and J. Kollár for inspiring him to work in the field of higher-dimensional birational geometry; the mathematics department at the University of Utah (in particular A. Bertram, H. Clemens, and J. Carlson) for hiring him (twice!) and providing a wonderful research environment; and the NSF [National Science Foundation], NSA [National Security Agency], AMS, and the Clay and Sloan Foundations for their generous financial support. James McKernan would like to thank his family for their support. He would also like to thank his advisor J. Harris, for inspiring him with so much beautiful projective geometry; J. Kollár and S. Mori for their support and encouragement over the whole of his career; V. Shokurov, who is always so generous with his ideas; and Y. Kawamata and M. Reid for their help. He would like to thank the mathematics department at the University of California, Santa Barbara—where a considerable amount of this work was done—for providing such a great environment to do research; and the mathematics department at the Massachusetts Institute of Technology. He is also very grateful to the NSF, NSA, and the Clay Foundation for their generous financial support.

**James McKernan**

## About the Prize

The Cole Prize in Algebra is awarded every three years for a notable research memoir in algebra that has appeared during the previous six years. The awarding of this prize alternates with the awarding of the Cole Prize in Number Theory, also given every three years. These prizes were established in 1928 to honor Frank Nelson Cole on the occasion of his retirement as secretary of the AMS after twenty-five years of service. He also served as editor-in-chief of the *Bulletin* for twenty-one years. The Cole Prize carries a cash award of US$5,000.

The Cole Prize in Algebra is awarded by the AMS Council acting on the recommendation of a selection committee. For the 2009 prize, the members of the selection committee were: Alexander Beilinson, David Harbater (chair), and Victor Kac.

Previous recipients of the Cole Prize in Algebra are: L. E. Dickson (1928), A. Adrian Albert (1939), Oscar Zariski (1944), Richard Brauer (1949), Harish-Chandra (1954), Serge Lang (1960), Maxwell A. Rosenlicht (1960), Walter Feit and John G. Thompson (1965), John R. Stallings (1970), Richard G. Swan (1970), Hyman Bass (1975), Daniel G. Quillen (1975), Michael Aschbacher (1980), Melvin Hochster (1980), George Lusztig (1985), Shigefumi Mori (1990), Michel Raynaud and David Harbater (1995), Andrei Suslin (2000), Aise Johan de Jong (2000), Hiraku Nakajima (2003), and János Kollár (2006).

# 2009 Satter Prize

LAURE SAINT-RAYMOND received the 2009 AMS Ruth Lyttle Satter Prize in Mathematics at the 115th Annual Meeting of the AMS in Washington, DC, in January 2009.

## Citation

The Ruth Lyttle Satter Prize in mathematics is awarded to Laure Saint-Raymond for her fundamental work on the hydrodynamic limits of the Boltzmann equation in the kinetic theory of gases.

**Laure Saint-Raymond**

Saint-Raymond and François Golse established the definitive connection between weak solutions of the Boltzmann and the Leray solution of the incompressible Navier-Stokes equation for an important set of collision kernels in their paper, "The Navier-Stokes limit of the Boltzmann equation for bounded collision kernels", *Invent. Math.* **155** (2004), no. 1, 81–161.

Saint-Raymond also established the convergence of weak solutions of the Boltzmann equation to the dissipative solutions of the incompressible Euler equation in the most general setting in "Convergence of solutions to the Boltzmann equation in the incompressible Euler limit", *Arch. Ration. Mech. Anal.* **166** (2003), no. 1, 47–80.

The study of hydrodynamic limit theorems dates back to the work of Maxwell, Boltzmann, and Hilbert and has been extensively investigated by mathematicians and physicists. The results of Laure Saint-Raymond are a landmark in the subject.

## Biographical Sketch

Laure Saint-Raymond received her Ph.D. in applied mathematics from the Université Paris VII in 2000. She joined the Centre National de la Recherche Scientifique (CNRS) as a research scientist in the Laboratoire d'Analyse Numérique, Université Paris VI. In 2002, she became a professor in the Laboratoire J.-L. Lions, Université Paris VI. In 2007, she joined the École Normale Supérieure.

She has received several awards, including the Louis Armand Prize from the French Academy of Sciences, the Claude-Antoine Peccot Award from the Collège de France, and the Pius XI Gold Medal from the Pontificia Academia Scientiarum. In 2006, she was awarded, together with François Golse, the first SIAG/APDE Prize on behalf of the paper, "The Navier-Stokes limit of the Boltzmann equation for bounded collision kernels" published in *Inventiones Mathematicae*. In 2008 she received the European Mathematical Society Prize in Amsterdam.

Her research has focused on the study of problems in mathematical physics, including the Boltzmann equation and its fluid dynamic limits, the Vlasov-Poisson system and its gyrokinetic limit, and problems of rotating fluids coming from geophysics. Her most striking work concerns the study of the hydrodynamic limits of the Boltzmann equation in the kinetic theory of gases, where she answered part of a question posed by Hilbert within the framework of his sixth problem.

## Response

I am very grateful to the AMS and the Satter Prize Committee for awarding me this prize; it is truly encouraging to be recognized in this way. I am deeply indebted to my former adviser and collaborator François Golse, with whom part of the above cited work has been done.

I would like to use this opportunity to also thank all my American colleagues for their many kind invitations that I am too rarely able to honour. I thank especially mathematicians at Brown University, UCLA, MIT, Minnesota, and Harvard. I hope to have occasions in the future to develop more collaborations with them.

Finally, special thanks go to my family for their patience and their support.

## About the Prize

The Satter Prize is awarded every two years to recognize an outstanding contribution to mathematics research by a woman in the previous six years. Established in 1990 with funds donated by Joan S. Birman, the prize honors the memory of Birman's sister, Ruth Lyttle Satter. Satter earned a bachelor's degree in mathematics and then joined the research staff at AT&T Bell Laboratories during World War II. After raising a family she received a Ph.D. in botany at the age of forty-three from the University of Connecticut at Storrs, where she later became a faculty member. Her research on the biological clocks in plants earned her recognition in the U.S. and abroad. Birman requested that the prize be established to honor her sister's commitment to research and to encouraging women in science. The prize carries a cash award of US$5,000.

The Satter Prize is awarded by the AMS Council acting on the recommendation of a selection committee. For the 2009 prize, the members of the selection committee were: Benedict H. Gross (chair), Jane M. Hawkins, and Sijue Wu.

Previous recipients of the Satter Prize are: Dusa McDuff (1991), Lai-Sang Young (1993), Sun-Yung Alice Chang (1995), Ingrid Daubechies (1997), Bernadette Perrin-Riou (1999), Karen E. Smith (2001), Sijue Wu (2001), Abigail Thompson (2003), Svetlana Jitomirskaya (2005), and Claire Voisin (2007).

# 2009 Whiteman Prize

Jeremy J. Gray received the 2009 AMS Albert Leon Whiteman Memorial Prize at the 115th Annual Meeting of the AMS in Washington, DC, in January 2009.

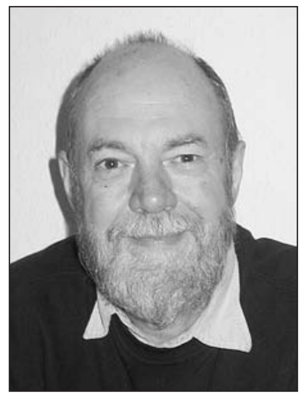
## Citation

In awarding the Albert Leon Whiteman Prize to Jeremy J. Gray of the Open University and the University of Warwick, the American Mathematical Society recognizes the value of 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. In addition, Gray's work as an editor, teacher, translator, and organizer of forums for historical work has helped invigorate the study of the history of modern mathematics internationally.

Gray's book *Ideas of Space* (1979) deals with geometrical studies through history, from the Babylonians to Einstein. His fascination with non-Euclidean geometry is evident in much of his work, and in this book he imparts to the reader a sense of the importance of the topic to mathematics and its history.

His book *Linear Differential Equations and Group Theory from Riemann to Poincaré* (1986) is outstanding for the broad spectrum of topics it covers, for the depth in which it covers them, and for the skill with which they are woven together. In addition, the lively style of the narrative passages and of the philosophical discussions makes reading it as entertaining as it is enlightening, although, inevitably, full understanding of the mathematical content demands concentrated work on the part of the reader.

*The Hilbert Challenge* (2000) is a worthy successor to the earlier works, again weaving together many strands of a story—this time the story of the Hilbert problems—to give the reader an appealing introduction to wide areas of modern mathematics.



**Jeremy J. Gray**

His publications have taken a great many forms and have covered very wide areas. He has edited and written introductions to works of Janos Bolyai and Julian Coolidge. He has produced, with John Fauvel, a compendious book of readings in the history of mathematics, originally for the Open University but since published by Macmillan. In addition to his undergraduate textbook on the history of geometry in the nineteenth century, *Worlds Out of Nothing* (2007), he has been co-editor of two volumes of scholarly contributions to the study of history of mathematics, *Episodes in the History of Modern Algebra* (1800–1950) with Karen Parshall, and *The Architecture of Modern Mathematics* with José Ferreirós. Among his many scholarly publications in journals, his translation and annotation of Gauss's Tagebuch in *Expositiones Mathematicae*, volume 4 (1984), is a particularly valuable contribution.

Jeremy Gray's spirited presentations of a wide range of subjects of nineteenth and twentieth century mathematics have earned the respect of his colleagues for the quality of both their historical scholarship and their mathematical accuracy and insight, exactly the traits that the Whiteman Prize is meant to recognize.

## Biographical Sketch

Jeremy Gray studied mathematics at the University of Oxford and obtained his Ph.D. at University of Warwick in 1980. He has taught at the Open University since 1974, where he became a professor of the history of mathematics in 2002, and he is an honorary professor at the University of Warwick, where he lectures on the history of mathematics. In 1996 he was a resident fellow at the Dibner Institute for the History of Science and Technology at the Massachusetts Institute of Technology, and in 1998 he gave an invited lecture at the International Congress of Mathematicians in Berlin. He lives in London with his wife, Sue Laurence, and their daughters, Martha and Eleanor.

### Response

I am honoured to receive the Albert Leon Whiteman Memorial Prize of the American Mathematical Society. Mathematicians work in an exciting and important profession. Their research, the quality of their ideas, the applications they develop, and their teaching all make vital contributions to the society around them, and many people from every country in the world can be drawn in to this endeavour. Historians of mathematics have the opportunity to describe this enterprise as it occurred in all its different cultural settings from 6,000 years ago to yesterday, and in this way enrich everyone's appreciation of mathematics. In the last fifty years much has been done by my colleagues around the world in the history of mathematics; their work has been an inspiration to me. When I began to work on the nineteenth century, that century was not so long ago. Now large periods of the twentieth century are open to historical analysis. This will be a particularly rich topic for anyone interested in modern mathematics, and the American Mathematical Society is to be congratulated on its support for the history of our subject. I wish to thank my colleagues at the Open University and the University of Warwick who have helped me so much and whose support for the history of mathematics has been very important to me. Especially I wish to thank my co-authors and co-editors who have contributed so much. Above all I thank my wife and children for the love and joy they have brought to my life and for all that that has made possible.

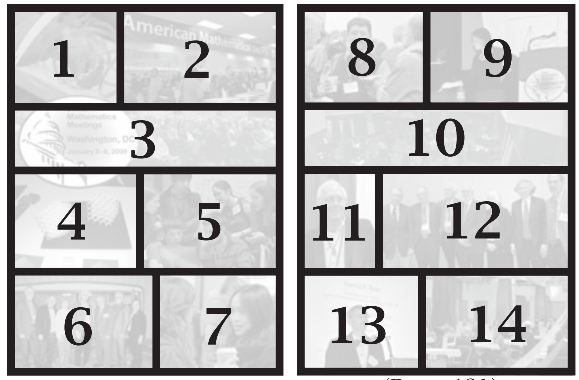
### About the Prize

The Whiteman Prize is awarded every three years (every four years until 2009) to recognize notable exposition and exceptional scholarship in the history of mathematics. The prize was established in 1998 using funds donated by Mrs. Sally Whiteman, in memory of her husband, the late Albert Leon Whiteman. The prize carries a cash award of US$5,000.

The Whiteman Prize is awarded by the AMS Council acting on the recommendation of a selection committee. For the 2009 prize, the members of the selection committee were: Bruce C. Berndt, Keith J. Devlin, and Harold M. Edwards (chair).

Previous recipients of the Whiteman Prize are Thomas Hawkins (2001) and Harold M. Edwards (2005).

## 2009 Washington, DC, Joint Mathematics Meetings Photo Key




(Page 480) (Page 481)

1. Glass art from the Mathematical Art Exhibit.
2. AMS booth in the Exhibits area.
3. Audience at a talk.
4. 3-D art from the Mathematical Art Exhibit.
5. Students around a computer.
6. Opening Ceremony for the Exhibits. Left to right: Robert Daverman (AMS), James Tattersall (MAA), Tina Straley (MAA), James Glimm (AMS), Joseph Gallian (MAA), John Ewing (AMS), Martha Siegel (MAA).
7. Participants conversing.
8. Networking.
9. MAA invited address speaker Maria Chudnovsky.
10. Networking Center.
11. John W. Neuberger, University of North Texas. Neuberger has attended 50 annual meetings.
12. Present and former AMS presidents and former Executive Director John Ewing. Left to right: George Andrews (2009–2010), James Arthur (2005–2006), James Glimm (2007–2008), Ewing, Cathleen Morawetz (1995–1996), Arthur Jaffe (1997–1998), David Eisenbud (2003–2004).
13. Harold A. Boas, of Texas A&M University, accepting the Chauvenet Prize. Boas was editor of the *Notices*, 2000–2003.
14. Employment Center.

# 2009 Conant Prize

John W. Morgan received the 2009 AMS Levi L. Conant Prize at the 115th Annual Meeting of the AMS in Washington, DC, in January 2009.

## Citation

The Levi L. Conant Prize for 2009 is awarded to John Morgan for his article, "Recent progress on the Poincaré Conjecture and the classification of 3-manifolds", *Bull. Amer. Math. Soc.* **42** (2005), 57–78.

**John W. Morgan**

The celebrated Poincaré Conjecture, formulated in modern terms, asks, "Is a closed 3-manifold having trivial fundamental group diffeomorphic to the 3-dimensional sphere?" This conjecture evolved from Poincaré's 1904 paper and inspired an enormous amount of work in 3-dimensional topology in the ensuing century. Thurston's Geometrization Conjecture subsumes the Poincaré Conjecture as a special case and speculates which 3-manifolds admit a Riemannian metric of constant negative curvature 1.

By proposing the existence of nice metrics on 3-manifolds, Thurston's far-reaching conjecture links together in an essential way the relevant topology and geometry and suggests a more analytic approach to classifying 3-manifolds. Hamilton's remarkable series of papers develops one such geometric-analytic approach using the Ricci flow and establishes crucial analytic estimates for evolving metrics and curvature. This set the stage for Perelman's much acclaimed work and the ultimate proof of these conjectures.

Morgan's paper was written in 2004 at a critical juncture in this story, just after the appearance of Perelman's papers and while they were still undergoing scrutiny by experts. It made the momentous developments surrounding the conjectures of Poincaré and Thurston accessible to a wide mathematical audience. The article captured key concepts and results from topology and differential geometry and conveyed to the reader the significance of the advances.

Morgan's exposition is elegant and mathematically precise. The paper transmits a great amount of information in a seemingly effortless flow of mathematical ideas from across a broad spectrum of topics. It was a valuable survey when it appeared and remains so today.

## Biographical Sketch

Morgan received his Ph.D. in mathematics from Rice University in 1969. From 1969 to 1972 he was an instructor at Princeton University, and from 1972 to 1974 an assistant professor at the Massachusetts Institute of Technology. From 1974 to 1976 he was member of Institut des Hautes Etudes Scientifiques in Paris. Since becoming a professor of mathematics at Columbia University in 1976, he has also been a visiting professor at Stanford, Harvard, the Institute for Advanced Study, the Mathematical Sciences Research Institute in Berkeley, Université Paris-Sud, and IHES. He will become the founding director of the Simons Center for Geometry and Physics in Stony Brook in September 2009.

Morgan's mathematical speciality is topology and geometry, and he has worked on high-dimensional surgery, the topology of Kähler manifolds, and the topology and geometry of manifolds of dimensions 3 and 4. He is an editor of the *Journal of the American Mathematical Society*.

Morgan lives in New York City with his wife. They have two children—Jake, who lives in London, and Brianna, who is an undergraduate at Columbia University.

## Response

I am honored to be awarded the 2009 Levi L. Conant Prize for my article, “Recent Progress on the Poincaré Conjecture and the Classification of 3-manifolds”.

This is one of the most amazing developments in mathematics, representing as it does the solution of a 100-year-old problem. The advance is even more interesting because it uses a beautiful combination of analytic and geometric tools to solve a topological problem. It was a great pleasure to decipher these arguments and to understand their beauty and power—and the pleasure was only increased in the telling of the story. In working through the arguments behind these results, I benefited from the insights of various people, and it is a pleasure to thank them. First and foremost is Gang Tian with whom I have had a collaboration spanning several years as we sorted out in great detail the arguments. I had many fruitful discussions with Bruce Kleiner, John Lott, and Tom Mrowka. Finally, my greatest gratitude goes to Richard Hamilton, who developed the theory of Ricci flow and suggested the program to use this method to solve the 3-dimensional problems, and above all to Grigory Perelman whose mathematical power and insight led to the resolution of the conjectures.

## About the Prize

The Conant Prize is awarded annually to recognize an outstanding expository paper published in either the *Notices of the AMS* or the *Bulletin of the AMS* in the preceding five years. Established in 2000, the prize honors the memory of Levi L. Conant (1857–1916), who was a mathematician at Worcester Polytechnic University. The prize carries a cash award of US$1,000.

The Conant Prize is awarded by the AMS Council acting on the recommendation of a selection committee. For the 2009 prize, the members of the selection committee were: Georgia Benkart, Stephen J. Greenfield, and Carl R. Riehm (chair).

Previous recipients of the Conant Prize are: Carl Pomerance (2001); Elliott Lieb and Jakob Yngvason (2002); Nicholas Katz and Peter Sarnak (2003); Noam D. Elkies (2004); Allen Knutson and Terence Tao (2005); Ronald M. Solomon (2006); Jeffrey Weeks (2007); and J. Brian Conrey, Shlomo Hoory, Nathan Linial, and Avi Wigderson (2008).

# 2009 Morgan Prize

AARON PIXTON received the 2009 AMS-MAA-SIAM Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student at the Joint Mathematics Meetings in Washington, DC, in January 2009. Receiving an honorable mention was ANDREI NEGUT.

## Citation: Aaron Pixton

Aaron Pixton is the winner of the 2009 Morgan Prize for Outstanding Research by an Undergraduate Student. The award is based on five impressive papers in addition to his Princeton senior thesis. One of Pixton's papers has already appeared in the *Proceedings of the American Mathematical Society*, two others have been accepted by *Forum Mathematicum* and the *International Journal of Number Theory*, and two others have been submitted. In addition to being creative, Pixton's work spans a remarkable range of topics, including combinatorial number theory, modular forms, algebraic topology, and Gromov-Witten invariants.

**Aaron Pixton**

Pixton participated in Research Experience for Undergraduates (REU) programs at Cornell University, the University of Wisconsin-Madison, and the University of Minnesota Duluth, and wrote interesting papers at all three. One of his mentors described his "ability to digest current research papers, to formulate interesting questions…, and within a week's time, to start solving [them]" as "simply astonishing" and considers his work as "probably stronger than many Ph.D. dissertations". Another mentor describes the "depth and breadth" of his papers as "amazing".

## Biographical Sketch: Aaron Pixton

Aaron Pixton was born in Binghamton, New York, and has lived in nearby Vestal, New York, all his life. He was interested in mathematics from an early age, when he enjoyed reading recreational math books. His formal study of mathematics began when he took various math classes from Binghamton University during high school.

Pixton spent the past four years studying mathematics at Princeton University, from which he graduated in June 2008. During this time, he took advantage of opportunities to work on original research both at Princeton during the school year and at REUs during the summers.

Pixton is currently at the University of Cambridge doing Part III of the Mathematical Tripos. Next fall, he will be returning to Princeton to enter the Ph.D. program there, where he plans to study some combination of number theory and algebraic geometry. Pixton's nonmathematical diversions include playing chess, reading fantasy books, and watching his seven cats.

## Response: Aaron Pixton

I am extremely honored to have been selected for the 2009 Morgan Prize by the AMS, MAA, and SIAM. I would like to thank everyone who has helped and encouraged me to do research. First, I thank my parents for always supporting my desire to think about mathematics. Next, I thank my coauthors, Tom Church, Carl Erickson, and especially Alison Miller; they not only collaborated and shared their ideas with me, but they also taught me a lot in the process of doing so. I would like to thank Tara Brendle, Ken Ono, and Joe Gallian for giving me interesting mathematics to think about during the enjoyable REUs that they ran. I thank the other students at these research programs for greatly enriching my mathematical experiences. Finally, I would like to thank everyone in the Princeton

Mathematics Department for providing a supportive and stimulating mathematical environment for the last four years; particular thanks are due to Manjul Bhargava for teaching the classes which made me most excited about being a mathematician and to Chris Skinner and Rahul Pandharipande for supervising the research I did at Princeton.

### Citation for Honorable Mention: Andrei Negut

The Morgan Prize Committee is pleased to award Honorable Mention for the 2009 Morgan Prize for Outstanding Research by an Undergraduate Student to Andrei Negut. The award recognizes his excellent Princeton senior thesis on "Laumon spaces and many-body systems", which establishes a large part of a conjecture of Braverman made at the 2006 International Congress of Mathematicians. In addition to this work, Negut has made important contributions to problems in very diverse fields: algebraic cobordism theory and dynamical systems. His recommenders consider Negut to be off to a "spectacular start" and look forward to future great achievements.

### Biographical Sketch: Andrei Negut

Andrei Negut was born and lived in Romania until the age of 18, by which time his passion for mathematics had been sparked. He attended Princeton University as an undergraduate, where contacts with some of the world's best mathematicians and teachers inspired his passion for the subject. At Princeton, he had the chance to pursue several research projects in different fields, honing his area of interest and broadening his appreciation of mathematics. After finishing his undergraduate studies, Negut spent a year in Europe, traveling between several research institutes (i.e., Institut des Hautes Etudes Scientifiques in France, Max-Planck-Institut für Mathematik in Germany, and Institute of Mathematics "Simion Stoilow" of the Romanian Academy), learning mathematics from various perspectives. Next year, he will pursue graduate studies at Harvard University. Apart from mathematics, he enjoys traveling the world, photography, and the Russian culture.

### Response: Andrei Negut

I am very honored to have been awarded this prize, which means very much to me on a personal basis. On a more global scale, it makes me very happy to see that the mathematical community carefully watches over young mathematicians and is always willing to offer them its support.

### About the Prize

The Morgan Prize is awarded annually for outstanding research in mathematics by an undergraduate student (or students having submitted joint work). Students in Canada, Mexico, or the United States or its possessions are eligible for consideration for the prize. Established in 1995, the prize was endowed by Mrs. Frank (Brennie) Morgan of Allentown, Pennsylvania, and carries the name of her late husband. The prize is given jointly by the AMS, the Mathematical Association of America (MAA), and the Society for Industrial and Applied Mathematics (SIAM) and carries a cash award of US$1,200.

Recipients of the Morgan Prize are chosen by a joint AMS-MAA-SIAM selection committee. For the 2009 prize, the members of the selection committee were: Georgia Benkart, James H. Curry, Maeve L. McCarthy, Michael E. Orrison, Kannan Soundararajan (chair), and Paul Zorn.

Previous recipients of the Morgan Prize are: Kannan Soundararajan (1995), Manjul Bhargava (1996), Jade Vinson (1997), Daniel Biss (1998), Sean McLaughlin (1999), Jacob Lurie (2000), Ciprian Manolescu (2001), Joshua Greene (2002), Melanie Wood (2003), Reid Barton (2005), Jacob Fox (2006), Daniel Kane (2007), and Nathan Kaplan (2008).

# Mathematics People

## Mirzakhani Receives 2009 Blumenthal Award

The Leonard M. and Eleanor B. Blumenthal Award for the Advancement of Research in Pure Mathematics has been presented to Maryam Mirzakhani of Princeton University. The award was presented at the Joint Mathematics Meetings in Washington, DC in January 2009.

### Citation

The Leonard M. and Eleanor B. Blumenthal Trust Award for the Advancement of Research in Pure Mathematics is awarded to Maryam Mirzakhani for her exceptionally creative, highly original thesis. This work combines tools as diverse as hyperbolic geometry, "classical methods" of automorphic forms, and symplectic reduction to obtain results on three different important questions. These results include a recursive formula for Weil-Petersson volumes of moduli spaces of Riemann surfaces, a determination of the asymptotics of the number of simple closed geodesics on a hyperbolic surface in terms of length, and a new proof of Witten's Conjecture (originally established by Kontsevich) establishing the KdV recursion for the intersection numbers on moduli space.

### Biographical Sketch

Maryam Mirzakhani obtained her B.Sc. in mathematics (1999) from the Sharif University of Technology in Tehran, Iran. She holds a Ph.D. from Harvard University (2004), where her advisor was Curtis McMullen. From 2004 to 2008 she was a Clay Mathematics Institute Research Fellow. She is a professor at Princeton University. Her research interests include Teichmüller theory, hyperbolic geometry, and ergodic theory.

### Response from Mirzakhani

I am deeply honored to be a recipient of the Leonard M. and Eleanor B. Blumenthal Award.

First, I would like to thank my Ph.D. advisor, Curt McMullen, for introducing me to many fascinating areas of mathematics and for his invaluable help and encouragement throughout all these years. I am also grateful to the math department at Harvard University and all my graduate school teachers for providing a great environment for graduate students. I want to express my gratitude to my teachers at Sharif University of Technology for showing me the beauty of mathematics. I am gratefully indebted to my many friends in the Boston area, especially Roya Beheshti, whose friendship has been a source of happiness and inspiration for me.

Finally, I thank my family for all their unceasing love and support.

### About the Award

The Leonard M. and Eleanor B. Blumenthal Trust for the Advancement of Mathematics was created for the purpose of assisting the Department of Mathematics of the University of Missouri at Columbia, where Leonard Blumenthal served as professor for many years. Its second purpose is to recognize distinguished achievements in the field of mathematics through the Leonard M. and Eleanor B. Blumenthal Award for the Advancement of Research in Pure Mathematics, which was originally funded from the Eleanor B. Blumenthal Trust (dated September 24, 1984) upon Mrs. Blumenthal's death on July 12, 1987.

The trust, which is administered by the Financial Management and Trust Services Division of Boone County National Bank in Columbia, Missouri, pays its net income to the recipient of the award each year for four years. The recipient is selected by a committee of five members, each of whom has made notable contributions to mathematics. The award is presented to the individual deemed to have made the most substantial contribution to research in the field of pure mathematics and who is deemed to have the potential for future production of distinguished research in the field. To fulfill these criteria, the prize committee has decided to grant the award for the most substantial Ph.D. thesis produced in the four-year interval between awards.

Previous recipients of the Blumenthal Award are Manjul Bhargava (2005), Stephen J. Bigelow and Elon B. Lindenstrauss (2001), Loïc Merel (1997), and Zhihong Xia (1993).

*—AMS Announcement*

## Gamburd Receives PECASE Award

Alexander Gamburd of the University of California, Santa Cruz, has been chosen to receive a 2007 Presidential Early Career Award for Scientists and Engineers (PECASE) for his work in the mathematical sciences. Gamburd was nominated by the Division of Mathematical Sciences of the National Science Foundation. He was one of sixty-eight young researchers to receive the award, the highest honor bestowed by the U.S. government on outstanding young scientists, mathematicians, and engineers who are in the early stages of establishing their independent research.

The recipients were selected from nominations made by eight participating federal agencies. Each awardee receives a five-year grant ranging from US$400,000 to nearly US$1 million to further his or her research and educational efforts.

*—From an NSF announcement*

# Klartag and Naor Awarded Salem Prize

Bo'az Klartag of Tel Aviv University and Assaf Naor of the Courant Institute of Mathematical Sciences, New York University, have been awarded the 2008 Salem Prize. Klartag was honored for his work in high-dimensional convexity and the local theory of Banach spaces. Naor was recognized for his contributions to the structural theory of metric spaces and its applications to computer science.

The Salem Prize is awarded every year to a young mathematician judged to have done outstanding work in the field of interest of Raphael Salem, primarily the theory of Fourier series.

*—Jean Bourgain, Institute for Advanced Study*

# AAAS Fellows Chosen

Six mathematicians have been elected as new fellows to the Section on Mathematics of the American Association for the Advancement of Science (AAAS). In addition, four researchers whose work involves the mathematical sciences have been elected to the Section on Information, Computing, and Communication. The new fellows in the Section on Mathematics are: Walter Craig, McMaster University; Robert J. Daverman, University of Tennessee, Knoxville; Richard Durrett, Cornell University; Alexander Nagel, University of Wisconsin; Jacob Rubinstein, Technion-Israel Institute of Technology; and William Y. Velez, University of Arizona. The new fellows in the Section on Information, Computing, and Communication are: Chandrajit Bajaj, University of Texas at Austin; Alan Kay, Viewpoints Research Institute; Daniel E. Koditschek, University of Pennsylvania; and Dexter Kozen, Cornell University.

*—From an AAAS announcement*

# A. O. L. Atkin (1923–2008)

A. O. L. (Oliver) Atkin was born in Liverpool, England. He attended Winchester College and the University of Cambridge. He spent the last year of the Second World War at Bletchley Park, where he was one of the many mathematicians and linguists who broke a variety of German ciphers. He returned to Cambridge in 1947 and received his doctorate in 1952. He moved to the United States in 1970 and joined the faculty of the University of Illinois at Chicago Circle (now the University of Illinois at Chicago) in 1972.

Atkin is especially well known for his paper with J. Lehner, "Hecke operators on $\Gamma_0(M)$", *Math. Annalen* **185**, pp. 134–160. This paper introduced the notion of "newform" in the theory of modular forms. As a result of that paper, Atkin's name is attached to the important $U$-operator in the Hecke theory of modular forms. He continued this work with Winnie Li in subsequent papers.

Atkin made a number of early observations about congruences among modular forms that were fundamental in the later development of the theory of $p$-adic modular forms. He did important work on partitions.

Atkin was a pioneer in the application of computers to mathematics. He spent several years in England at the Atlas Computer Laboratory. For background on his contributions during that period, see Bryan Birch's article "Atkin and the Atlas Lab" in *Computational Perspectives on Number Theory: Proceedings of a Conference in Honor of A. O. L. Atkin* (D. A. Buell and J. T. Teitelbaum, editors, AMS/IP Studies in Advanced Mathematics, Volume 7, 1998).

Many mathematicians relied on him for numerical data in support of their conjectures; he seemed to have a personal acquaintance with every modular form of relatively low weight and level.

His more recent work included taking an idea of René Schoof on an approach to computing points on elliptic curves mod $p$ and making it practical; after further refinements by Noam Elkies this algorithm is now known as SEA (for Schoof-Elkies-Atkin). He and Dan Bernstein found an improvement to the Sieve of Eratosthenes, now known as the "sieve of Atkin". Together with Morain, Atkin developed a powerful primality test using CM elliptic curves. In practical terms this test is arguably the most efficient currently available.

Especially later in his career, Atkin was not fond of publishing papers in journals and typically made his results known via the NMBRTHRY email list.

He was a fine pianist and organist and a champion duplicate bridge player.

He remained mathematically active until his death and was continuing to work on problems about modular forms for noncongruence subgroups with Winnie Li and her students. He first raised this topic with Swinnerton-Dyer thirty years ago.

He is survived by a son and daughter and five grandchildren.

*—Jeremy Teitelbaum, University of Connecticut*

# Mathematics Opportunities

## Call for Nominations for TWAS Prizes

The Academy of Sciences for the Developing World (TWAS) prizes will be awarded to individual scientists in developing countries in recognition of outstanding contributions to knowledge in eight fields of science.

The awards are given each year in each of the following fields: mathematics, medical sciences, biology, chemistry, physics, agricultural sciences, earth sciences, and engineering sciences. Each award consists of a prize of US$15,000 and a plaque. Candidates for the awards must be scientists who have been working and living in a developing country for at least ten years.

The deadline for nominations for the 2009 prizes is **March 31, 2009**. Nomination forms should be sent to: TWAS Prizes, c/o The Abdus Salam International Centre for Theoretical Physics (ICTP), Strada Costiera 11, 1-34014 Trieste, Italy; fax: 39 040 2240 698; email: `prizes@twas.org`. Further information is available on the World Wide Web at `http://www.twas.org/`.

*—From a TWAS announcement*

## NSF Program in Foundations of Data and Visual Analytics

The National Science Foundation (NSF) and the Department of Homeland Security (DHS) announce a new program, Foundations of Data and Visual Analytics (FODAVA). Research in data and visual analytics seeks to facilitate analytical reasoning through the use of interactive visual interfaces. To be successful, this research must extend beyond traditional scientific and information visualization to include statistics, mathematics, knowledge representation, management and discovery technologies, cognitive and perceptual sciences, decision sciences, and more.

Proposals should focus on creating fundamental research advances that will be widely applicable across scientific, engineering, commercial, and governmental domains that utilize visualization and analytics to gain insight and derive knowledge from massive, often streaming, dynamic, ambiguous, and possibly conflicting data sets. Research activities proposed should emphasize novel data transformations while also demonstrating research relevance to visual analytics systems by including a research component in areas such as, but not limited to, visualization, human-computer interaction, and cognitive psychology.

The deadline for full proposals is **April 2, 2009**. For more information and a list of cognizant program directors, see the website `http://www.nsf.gov/pubs/2009/nsf09525/nsf09525.htm?govDel=USNSF_25`.

*—From an NSF announcement*

## DMS Workforce Program

The Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) welcomes proposals for the Workforce Program in the Mathematical Sciences. The long-range goal of the program is to increase the number of well-prepared U.S. citizens, nationals, and permanent residents successfully pursuing careers in the mathematical sciences and in other NSF-supported disciplines. Of primary interest are activities centered on education that broaden participation in the mathematical sciences through research involvement for trainees at the undergraduate through postdoctoral educational levels. The program is particularly interested in activities that improve recruitment and retention, educational breadth, and professional development. The submission period for unsolicited proposals is **May 15–June 15, 2009**. For more information and a list of cognizant program directors, see the website `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503233`.

*—From a DMS announcement*

## Call for Proposals for 2010 NSF-CBMS Regional Conferences

To stimulate interest and activity in mathematical research, the National Science Foundation (NSF) intends to support up to seven NSF-CBMS Regional Research

Conferences in 2010. A panel chosen by the Conference Board of the Mathematical Sciences will make the selections from among the submitted proposals.

Each five-day conference features a distinguished lecturer who delivers ten lectures on a topic of important current research in one sharply focused area of the mathematical sciences. The lecturer subsequently prepares an expository monograph based on these lectures, which is normally published as a part of a regional conference series. Depending on the conference topic, the monograph will be published by the American Mathematical Society, by the Society for Industrial and Applied Mathematics, or jointly by the American Statistical Association and the Institute of Mathematical Statistics.

Support is provided for about thirty participants at each conference, and both established researchers and interested newcomers, including postdoctoral fellows and graduate students, are invited to attend. The proposal due date is **April 24, 2009**.

For further information on submitting a proposal, consult the CBMS website, `http://www.cbmsweb.org/NSF/2010_call.htm`, or contact: Conference Board of the Mathematical Sciences, 1529 Eighteenth Street, NW, Washington, DC 20036; telephone: 202-293-1170; fax: 202-293-3412; email: `lkolbe@maa.org` or `rosier@georgetown.edu`.

*—From a CBMS announcement*

# NSF-CBMS Regional Conferences, 2009

With funding from the National Science Foundation (NSF), the Conference Board of the Mathematical Sciences (CBMS) will hold four NSF-CBMS Regional Research Conferences during the summer of 2009.

These conferences are intended to stimulate interest and activity in mathematical research. Each five-day conference features a distinguished lecturer who delivers ten lectures on a topic of important current research in one sharply focused area of the mathematical sciences. The lecturer subsequently prepares an expository monograph based on these lectures.

Support for about thirty participants will be provided for each conference. Both established researchers and interested newcomers, including postdoctoral fellows and graduate students, are invited to attend.

Information about an individual conference may be obtained by contacting the conference organizer. The conferences to be held in 2009 are as follows.

*May 18–22, 2009: Topology, C*-Algebras, and String Duality.* Jonathan Rosenberg, lecturer. Texas Christian University. Organizers: Greg Friedman, 817-257-6343, email: `g.friedman@tcu.edu`; Robert Doran, 817-257-7335, email: `r.doran@tcu.edu`; conference website: `http://faculty.tcu.edu/gfriedman/CBMS`.

*May 18–22, 2009: Adaptive Finite Element Methods for Partial Differential Equations.* Rolf Rannacher, lecturer. Texas A&M University. Organizers: Guido Kanschat, 979-845-7632, email: `kanschat@tamu.edu`; Wolfgang Bangerth, 979-845-6393, email: `bangerth@math.tamu.edu`; conference website: `http://www.math.tamu.edu/~kanschat/cbms/`.

*July 20–24, 2009: Families of Riemann Surfaces and Weil-Petersson Geometry.* Scott A. Wolpert, lecturer. Central Connecticut State University. Organizers: Jeffrey K. McGowan, 860-832-2850, email: `jmcgowan@mac.com`; Eran Makover, 860-832-2843, `makovere@ccsu.edu`; conference website: `http://www.math.ccsu.edu/CBMS.html`.

*August 3-7, 2009: Algebraic Topology in Applied Mathematics.* Robert Ghrist, lecturer. Cleveland State University. Organizers: Peter Bubenik, 216-687-4688, email: `p.bubenik@csuohio.edu`; John Oprea, 216-687-4702, email: `j.oprea@csuohio.edu`; conference website: `http://academic.csuohio.edu/bubenik_p/cbms2009/`.

*—From a CBMS announcement*

# Project NExT: New Experiences in Teaching

Project NExT (New Experiences in Teaching) is a professional development program for new and recent Ph.D.'s in the mathematical sciences (including pure and applied mathematics, statistics, operations research, and mathematics education). It addresses all aspects of an academic career: improving the teaching and learning of mathematics, engaging in research and scholarship, and participating in professional activities. It also provides the participants with a network of peers and mentors as they assume these responsibilities. In 2009 about seventy faculty members from colleges and universities throughout the country will be selected to participate in a workshop preceding the Mathematical Association of America (MAA) summer meeting, in activities during the summer MAA meetings and the Joint Mathematics Meetings in January, and in an electronic discussion network. Faculty for whom the 2009–2010 academic year will be the first or second year of full-time teaching (post-Ph.D.) at the college or university level are invited to apply to become Project NExT Fellows.

The application deadline is **April 17, 2009**. For more information see the Project NExT website, `http://archives.math.utk.edu/projnext/`, or contact Christine Stevens, director, at `stevensc@slu.edu`. Project NExT is a program of the MAA. It receives major funding from the ExxonMobil Foundation, with additional funding from the Dolciani-Halloran Foundation, the Educational Advancement Foundation, the American Mathematical Society, the American Statistical Association, the National Council of Teachers of Mathematics, Texas Instruments, the American Institute of Mathematics, the Association of Mathematics Teacher Educators, the Association for Symbolic Logic, W. H. Freeman Publishing Company, Maplesoft, John Wiley & Sons, MAA Sections, and the Greater MAA Fund.

*—From a Project NExT announcement*

# Inside the AMS

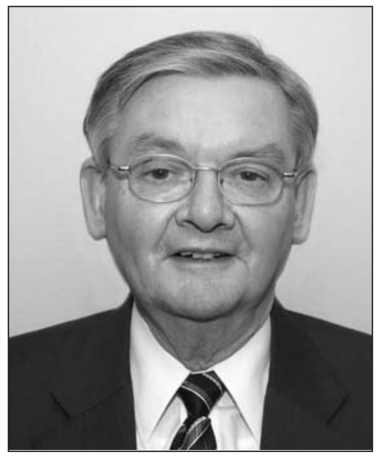
## Fairweather Named *MR* Executive Editor

In 1966, shortly after finishing his Ph.D. at the University of St. Andrews in his native country of Scotland, Graeme Fairweather boarded a plane for Houston, where he was to take up a visiting position at Rice University. During the flight he was suddenly gripped by a worry. Rice mathematics chair Mort Curtis was to meet him at the airport, but how would Fairweather recognize him? In fact, Curtis had already anticipated and solved the problem. He simply showed up carrying an issue of *Mathematical Reviews*, with the unmistakable orange cover. "I came from a small department in Scotland," Fairweather remarked, "but of course I recognized *Math Reviews*."

Fairweather could not have known that more than forty years later, when the orange covers would be superseded by its Web logo as an international icon of mathematics, *MR* would welcome him as its executive editor. He is retired from the Colorado School of Mines and succeeds Kevin Clancey, who served as executive editor for four years until his retirement. The two overlapped for two months in the fall of 2008 to provide an orderly transition, and Fairweather formally took up the position of executive editor in November. He brings to *MR* a wealth of administrative experience and an abundance of enthusiasm for the crucial role *MR* plays in the mathematical community.

When he first visited the *MR* office in Ann Arbor, Michigan, to find out more about what the executive editor position entailed, Fairweather was "absolutely amazed at the organization", he said. "When you step in the door, you find a very collegial and congenial operation. That was the atmosphere I detected, so it was easy to get to know people and how things work." He was impressed by the intricacy of the process, which begins with receipt of journals and continues through to finished reviews and their entry into the *MR* database, which nowadays most people access through the Web interface MathSciNet. The AMS and *MR* staff must also have been impressed: Fairweather was offered the position on the spot.

Now a few months into the job, Fairweather said that he is still learning details of the *MR* operation. He reported that, thanks to the efforts of Clancey and Clancey's predecessor, Jane Kister, as well as former AMS executive director John Ewing, the *MR* operation is in excellent shape. "I don't have firm plans to make significant changes, as everything is running very smoothly," said Fairweather. "*MR* has a loyal, dedicated staff with decades of experience who keep everything working well."



**Graeme Fairweather**

Nevertheless, there are always new challenges in the fast-changing world of electronic communications. For example, *MR* has been negotiating with publishers to allow *MR* electronic access to articles for review. Another challenge is keeping up with the increase in the number of journals, an increase made possible in part by the ease of electronic publishing. "There is a growing number of journals, but little increase in resources," Fairweather said. "So we have to be more efficient." He noted that the *MR* systems support department has an excellent track record in developing tools to improve the efficiency of the editing and processing of the volume of material published on MathSciNet.

The *MR* executive editor must handle a diverse and complex set of tasks, from dealing with high-level publishing policy issues, to working with the *MR* Editorial Committee on deciding which journals to review, to managing the *MR* staff of about eighty people. And then there are inquiries from *MR* users. Fairweather said that about 90 percent of these can be dealt with quickly and easily by the *MR* editors; the other, thornier, 10 percent land on his desk. The executive editor must handle these with care and consistency.

Aside from publishing papers in his research area of numerical analysis, Fairweather had not previously been involved in a publishing enterprise. But he has always been interested in good, clear communication and was known for using a red pen to correct students' theses at the Colorado School of Mines. He took a position there as head of the Department of Mathematical and Computer Sciences fourteen years ago, when several retirements were imminent. "I went there because of the opportunity to grow the department," he said. Before his move to Colorado, Fairweather spent twenty-three years at the University of Kentucky, where he was involved in building up the university's Center for Computational Sciences, funded by the National Science Foundation. Fairweather served as associate director of the center, whose initial focal point was an IBM supercomputer that was used by a wide range of groups on campus, from engineers to physicists to an English professor. The center also provided support for graduate students and postdocs and held a colloquium series and occasional workshops.

*"MR has a loyal, dedicated staff with decades of experience who keep everything working well."*

Fairweather is looking forward to continuing to learn about *MR* and to keeping it running in top shape. He said he is especially grateful to Clancey for the two months they spent together in the *MR* office so that Fairweather could learn the ropes. "That was one of the most enjoyable experiences of my career," he said. The enjoyment did not stop there, and Fairweather is very happy working in the *MR* office in Ann Arbor. He recalled the saying of Andrew Carnegie, a fellow Scot, that where there is little success, there is little laughter. "*Math Reviews* is very successful, and there is a lot of good humor in the building amongst the staff," he said. "I am absolutely thrilled to have this opportunity, as the AMS has such a great reputation, and *MR* is truly unique."

—*Allyn Jackson*

# From the AMS Public Awareness Office

**Mathematics Awareness Month—April 2009.** Visit the Mathematics Awareness Month website to download the "Mathematics and Climate" theme poster, read the theme essays, use the sample press release, and link to related resources, at `http://www.mathaware.org`.

**Highlights of the Joint Mathematics Meetings.** See photos and read about some of the highlights of the


Joint Mathematics Meetings in Washington DC, including prizewinners, invited addresses and sessions, exhibits, Graduate School Fair, Mathematical Art Exhibition, *Who Wants to Be a Mathematician* game, AMS Member Banquet, Employment Center, and more, at `http://www.ams.org/ams/jmm09-highlights.html`.

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

# Deaths of AMS Members

Leon Brown, from Livonia, MI, died on October 19, 2004. Born on September 25, 1927, he was a member of the Society for 51 years.

Sidney James Drouilhet II, professor of mathematics at Minnesota State University Moorhead, died on January 23, 2009. Born on August 24, 1949, he was a member of the Society for 36 years.

Alexander S. Elder, retired, from Aberdeen, MD, died on December 31, 2008. Born on July 29, 1915, he was a member of the Society for 48 years.

Michel Eytan, professor emeritus, from Strasbourg, France, died on January 4, 2009. Born on January 20, 1936, he was a member of the Society for 41 years.

Joe R. Foote, from Hot Springs, AR, died on December 26, 2004. Born on August 17, 1919, he was a member of the Society for 37 years.

William O. J. Moser, from Montreal, Canada, died on January 28, 2009. Born on September 5, 1927, he was a member of the Society for 58 years.

Ilya Piatetski-Shapiro, professor, Yale University, died on February 21, 2009. Born on March 30, 1929, he was a member of the Society for 25 years.

Jacob Towber, professor emeritus, from Evanston, IL, died on January 3, 2008. Born on October 17, 1933, he was a member of the Society for 28 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.ou.edu` in the case of the editor and `notices@ams.org` in the case of the managing editor. The fax numbers are 405-325-7484 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

### Upcoming Deadlines

**March 31, 2009:** Nominations for prizes of the Academy of Sciences for the Developing World. See "Mathematics Opportunities" in this issue.

**March 31, 2009:** Submissions for *Plus* Magazine New Writers Award. See the website `http://plus.maths.org/competition/`.

**April 2, 2009:** Full proposals for NSF Program in Foundations of Data and Visual Analytics (FODAVA). See "Mathematics Opportunities" in this issue.

**April 15, 2009:** Applications for fall 2009 semester of Math in Moscow. See `http://www.mccme.ru/mathinmoscow` or write to: Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax: +7095-291-65-01; email: `mim@mccme.ru`. For information on AMS scholarships see `http://www.ams.org/outreach/mimoscow.html` or write to: Math in Moscow Program, Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence RI 02904-2294; email: `student-serv@ams.org`.

**April 17, 2009:** Applications for Project NexT: New Experiences in Teaching. See "Mathematics Opportunities" in this issue.

**April 24, 2009:** Proposals for 2010 NSF-CBMS Regional Conferences. See "Mathematics Opportunities" in this issue.

**May 8, 2009:** Applications for AWM Travel Grants. See `http://www.awm-math.org/travelgrants.html`; telephone: 703-934-0163; email: `awm@awm-math.edu`. The postal address is: Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

**May 15-June 15, 2009:** Proposals for DMS Workforce Program in the Mathematical Sciences. See "Mathematics Opportunities" in this issue.

**May 15, 2009:** Applications for National Academies Research Associateship Programs. See `http://www7.nationalacademies.org/rap/` or

#### Where to Find It

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

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.

**June 1, 2009:** Applications for the September program of the Christine Mirzayan Science and Technology Policy Graduate Fellowship Program of the National Academies. See http://www7.nationalacademies.org/policyfellows; or contact The National Academies Christine Mirzayan Science and Technology Policy Graduate Fellowship Program, 500 Fifth Street, NW, Room 508, Washington, DC 20001; telephone: 202-334-2455; fax: 202-334-1667; email: policyfellows@nas.edu.

**June 1, 2009:** Applications for the Math for America Foundation (MfA) Fellowship Program in San Diego. See http://www.mathforamerica.org/.

**June 2, 2009:** Proposals for NSF's Enhancing the Mathematical Sciences Workforce in the Twenty-First Century program. See http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf05595.

**June 30, 2009:** Applications for Fermat Prize for Mathematics Research. Contact Prix Fermat de Recherche en Mathématiques, Service Relations Publiques, Université Paul Sabatier, 31062 Toulouse Cedex 9, France, or see the website http://www.math.ups-tlse.fr/Fermat/.

**August 4, 2009:** Letters of intent for NSF Project ADVANCE Institutional Transformation (IT) and Institutional Transformation Catalyst (IT-Catalyst) awards. See http://www.nsf.gov/pubs/2009/nsf09504/nsf09504.htm?govDel=USNSF_25.

**August 4, 2009:** Full proposals (by invitation only) for NSF Partnerships for International Research and Education (PIRE). See http://www.nsf.gov/pubs/2009/nsf09505/nsf09505.htm?govDel=USNSF_25#awd_info.

**August 15, 2009:** Applications for National Academies Research Associateship Programs. See http://www7.nationalacademies.org/rap/ or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; email: rap@nas.edu.

**September 14, 2009:** Full proposals for NSF Integrative Graduate Education and Research Training (IGERT). See http://www.nsf.gov/pubs/2009/nsf09519/nsf09519.htm?govDel=USNSF_25.

**October 1, 2009:** Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html; telephone: 703-934-0163; email: awm@awm-math.edu. The postal address is: Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

**November 1, 2009:** Applications for the January program of the Christine Mirzayan Science and Technology Policy Graduate Fellowship Program of the National Academies. See http://www7.nationalacademies.org/policyfellows; or contact The National Academies Christine Mirzayan Science and Technology Policy Graduate Fellowship Program, 500 Fifth Street, NW, Room 508, Washington, DC 20001; telephone: 202-334-2455; fax: 202-334-1667; email: policyfellows@nas.edu.

**November 12, 2009:** Full proposals for NSF Project ADVANCE Institutional Transformation (IT) and Institutional Transformation Catalyst (IT-Catalyst) awards. See http://www.nsf.gov/pubs/2009/nsf09504/nsf09504.htm?govDel=USNSF_25.

**November 15, 2009:** Applications for National Academies Research Associateship Programs. See http://www7.nationalacademies.org/rap/ 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.

## Mathematical Sciences Education Board, National Research Council

*Jan de Lange*, Freudenthal Institute, The Netherlands

*Keisha M. Ferguson*, Pattengill Elementary School, Ann Arbor, MI

*Louis Gomez*, Northwestern University

*Javier Gonzalez*, Pioneer High School, Whittier, CA

*Sharon Griffin*, Clark University

*Phillip A. Griffiths* (chair), Institute for Advanced Study

*Arthur Jaffe*, Harvard University

*Jeremy Kilpatrick*, University of Georgia

*Julie Legler*, St. Olaf College

*W. James Lewis*, University of Nebraska, Lincoln

*Kevin F. Miller*, University of Michigan, Ann Arbor

*Marge Petit* (vice chair), Consultant, Fayston, VT

*Donald Saari*, University of California, Irvine

*Nancy J. Sattler*, Terra State Community College, Freemont, OH

*Richard J. Schaar*, Texas Instruments

*Frank Wang*, Oklahoma School of Science and Mathematics

**MSEB Staff**

*David R. Mandel*, Director

The contact information is: Mathematical Sciences Education Board, National Academy of Sciences, 500 Fifth Street, NW, 11th Floor, Washington, DC 20001; telephone 202-334-2353; fax 202-344-2210; email: mseb@nas.edu; World Wide Web http://www7.nationalacademies.org/MSEB/.

## Book List

*The Book List highlights books that have mathematical themes and are aimed at a broad audience potentially including mathematicians, students, and the general public. When a book has been reviewed in the* Notices, *a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. 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 Abundance of Katherines*, by John Green. Dutton Juvenile Books, September 2006. ISBN-13:978-0-5254-7688-7. (Reviewed October 2008.)

*The Annotated Turing: A Guided Tour Through Alan Turing's Historic Paper on Computability and the Turing Machine*, by Charles Petzold. Wiley, June 2008. ISBN-13: 978-04702-290-57.

*The Archimedes Codex*, by Reviel Netz and William Noel. Weidenfeld and Nicolson, May 2007. ISBN-13: 978-0-29764-547-4. (Reviewed September 2008.)

*The Best of All Possible Worlds: Mathematics and Destiny*, by Ivar Ekeland. University Of Chicago Press, October 2006. ISBN-13: 978-0-226-19994-8. (Reviewed March 2009.)

*The Book of Numbers: The Secret of Numbers and How They Changed the World*, by Peter J. Bentley. Firefly Books, February 2008. ISBN-13: 978-15540-736-10.

*The Cat in Numberland*, by Ivar Ekeland. Cricket Books, April 2006. ISBN-13: 978-0-812-62744-2. (Reviewed January 2009.)

*Crossing the Equal Sign*, by Marion D. Cohen. Plain View Press, January 2007. ISBN-13: 978-18913-866-95.

*Digital Dice*, by Paul J. Nahin. Princeton University Press, March 2008. ISBN-13: 978-06911-269-82.

*Dimensions*, by Jos Leys, Etienne Ghys, and Aurélien Alvarez. DVD, 117 minutes. Available at `http://www.dimensions-math.org`.

*Discovering Patterns in Mathematics and Poetry*, by Marcia Birken and Anne C. Coon. Rodopi, February 2008. ISBN-13: 978-9-0420-2370-3.

*The Drunkard's Walk: How Randomness Rules Our Lives*, by Leonard Mlodinow. Pantheon, May 2008. ISBN-13: 978-03754-240-45.

*Einstein's Mistakes: The Human Failings of Genius*, by Hans C. Ohanian. W. W. Norton, September 2008. ISBN-13: 978-0393062939.

**Embracing the Wide Sky: A Tour Across the Horizons of the Human Mind*, by Daniel Tammet. Free Press, January 2009. ISBN-13: 978-14165-696-95.

*Emmy Noether: The Mother of Modern Algebra*, by M. B. W. Tent. A K Peters, October 2008. ISBN-13: 978-15688-143-08.

*Euclidean and Non-Euclidean Geometries: Development and History*, fourth revised and expanded edition, by Marvin Jay Greenberg. W. H. Freeman, September 2007. ISBN-13: 978-0-7167-9948-1.

*Euler's Gem: The Polyhedron Formula and the Birth of Topology*, by David S. Richeson. Princeton University Press, September 2008. ISBN-13: 97-80691-1267-77.

*Fifty Mathematical Ideas You Really Need to Know*, by Tony Crilly. Quercus, 2007. ISBN-13: 978-18472-400-88.

*Fighting Terror Online: The Convergence of Security, Technology and the Law*, by Martin Charles Golumbic. Springer, 2008. ISBN: 978-0-387-73577-1.

*Five-Minute Mathematics*, by Ehrhard Behrends (translated by David Kramer). AMS, May 2008. ISBN-13: 978-08218-434-82.

*Geekspeak: How Life + Mathematics = Happiness*, by Graham Tattersall. Collins, September 2008. ISBN-13: 978-00616-292-42.

*Geometric Folding Algorithms: Linkages, Origami, Polyhedra*, by Erik D. Demaine and Joseph O'Rourke. Cambridge University Press, July 2007. ISBN-13: 978-05218-57574.

*Geometric Origami*, by Robert Geretschläger. Arbelos, October 2008. ISBN-13: 978-09555-477-13.

*The Golden Section: Nature's Greatest Secret (Wooden Books)*, by Scott Olsen. Walker and Company, October 2006. ISBN-13: 978-08027-153-95.

*Group Theory in the Bedroom, and Other Mathematical Diversions*, by Brian Hayes. Hill and Wang, April 2008. ISBN-13: 978-08090-521-96. (Reviewed February 2009.)

*Guesstimation: Solving the World's Problems on the Back of a Cocktail Napkin*, by Lawrence Weinstein and John A. Adam. Princeton University Press, April 2008. ISBN-13: 978-0-6911-2949-5.

*Hexaflexagons, Probability Paradoxes, and the Tower of Hanoi: Martin Gardner's First Book of Mathematical Puzzles and Games*, by Martin Gardner. Cambridge University Press, September 2008. ISBN-13: 978-0-521-73525-4.

*How Math Explains the World: A Guide to the Power of Numbers, from Car Repair to Modern Physics*, by James D. Stein. Collins, April 2008. ISBN-13: 978-00612-417-65.

*How Round Is Your Circle*, by John Bryant and Chris Sangwin. Princeton University Press, January 2008. ISBN-13: 978-0-6911-3118-4.

*Impossible?: Surprising Solutions to Counterintuitive Conundrums*, by Julian Havil. Princeton University Press, April 2008. ISBN-13: 978-0-6911-3131-3.

*The Indian Clerk*, by David Leavitt. Bloomsbury USA, September 2007. ISBN-13: 978-15969-1040-9. (Reviewed September 2008.)

*Irreligion: A Mathematician Explains Why the Arguments for God Just Don't Add Up*, by John Allen Paulos. Hill and Wang, December 2007. ISBN-13: 978-0-8090-591-95. (Reviewed August 2008.)

*Is God a Mathematician?* by Mario Livio. Simon & Schuster, January 2009. ISBN-13: 978-07432-940-58.

*Kiss My Math: Showing Pre-Algebra Who's Boss*, by Danica McKellar. Hudson Street Press, August 2008. ISBN-13: 978-1594630491.

*The Last Theorem*, by Arthur C. Clarke and Frederik Pohl. Del Rey, August 2008. ISBN-13: 978-0345470218.

*Logic's Lost Genius: The Life of Gerhard Gentzen*, by Eckart Menzler-Trott, Craig Smorynski (translator), Edward R. Griffor (translator). AMS-LMS, November 2007. ISBN-13: 978-0-8218-3550-0.

*Making Mathematics Work with Needlework: Ten Papers and Ten Projects*, edited by Sarah-Marie Belcastro and Carolyn Yackel. A K Peters, September 2007. ISBN-13: 978-1-5688-1331-8.

*The Map of My Life*, by Goro Shimura. Springer, September 2008. ISBN-13: 978-03877-971-44.

*Mathematical Omnibus: Thirty Lectures on Classic Mathematics*, by Dmitry Fuchs and Serge Tabachnikov. AMS, October 2007. ISBN-13: 978-08218-431-61. (Reviewed December 2008).

*The Mathematician's Brain*, by David Ruelle. Princeton University Press, July 2007. ISBN-13 978-0-691-12982-2. (Reviewed November 2008.)

*Mathematics and the Aesthetic: New Approaches to an Ancient Affinity*, edited by Nathalie Sinclair, David Pimm, and William Higginson. Springer, November 2006. ISBN-13: 978-03873-052-64. (Reviewed February 2009.)

*Mathematics and Democracy: Designing Better Voting and Fair-Division Procedures*, by Steven J. Brams. Princeton University Press, December 2007. ISBN-13: 978-0691-1332-01.

*Mathematics at Berkeley: A History*, by Calvin C. Moore. A K Peters, February 2007. ISBN-13: 978-1-5688-1302-8. (Reviewed November 2008.)

*Mathematics in Ancient Iraq: A Social History*, by Eleanor Robson. Princeton University Press, August 2008. ISBN13: 978-06910-918-22.

*The Mathematics of Egypt, Mesopotamia, China, India, and Islam: A Sourcebook*, by Victor J. Katz et al. Princeton University Press, July 2007. ISBN-13: 978-0-6911-2745-3.

*Measuring the World*, by Daniel Kehlmann. Pantheon, November 2006. ISBN 0-375-42446-6. (Reviewed June/July 2008.)

*More Mathematical Astronomy Morsels*, by Jean Meeus. Willmann-Bell, 2002. ISBN 0-943396743.

*More Sex Is Safer Sex: The Unconventional Wisdom of Economics*, by Steven E. Landsburg. Free Press, April 2007. ISBN-13: 978-1-416-53221-7. (Reviewed June/July 2008.)

*Number and Numbers*, by Alain Badiou. Polity, June 2008. ISBN-13: 978-07456-387-82.

*Number Story: From Counting to Cryptography*, by Peter M. Higgins. Springer, February 2008. ISBN-13: 978-1-8480-0000-1.

*The Numbers Behind NUMB3RS: Solving Crime with Mathematics*, by Keith Devlin and Gary Lorden. Plume, August 2007. ISBN-13: 978-04522-8857-7. (Reviewed March 2009.)

*The Numerati*, by Stephen Baker. Houghton Mifflin, August 2008. ISBN-13: 978-06187-846-08.

*One to Nine: The Inner Life of Numbers*, by Andrew Hodges. W. W. Norton, May 2008. ISBN-13: 978-03930-664-18.

*Origami, Eleusis, and the Soma Cube: Martin Gardner's Mathematical Diversions*, by Martin Gardner. Cambridge University Press, September 2008. ISBN-13: 978-0-521-73524-7.

*Our Days Are Numbered: How Mathematics Orders Our Lives*, by Jason Brown. McClelland and Stewart, to appear April 2009. ISBN-13: 978-07710-169-67.

*A Passion for Discovery*, by Peter Freund. World Scientific, August 2007. ISBN-13: 978-9-8127-7214-5.

*Plato's Ghost: The Modernist Transformation of Mathematics*, by Jeremy Gray. Princeton University Press, September 2008. ISBN-13: 978-06911-361-03.

*The Presidential Election Game*, by Steven J. Brams. A K Peters, December 2007. ISBN-13: 978-1-5688-1348-6.

*The Princeton Companion to Mathematics*, edited by Timothy Gowers (June Barrow-Green and Imre Leader, associate editors). Princeton University Press, November 2008. ISBN-13: 978-06911-188-02.

*Professor Stewart's Cabinet of Mathematical Curiosities*, by Ian Stewart. Basic Books, December 2008. ISBN-13: 978-0-465-01302-9.

*Pursuit of Genius: Flexner, Einstein, and the Early Faculty at the Institute for Advanced Study*, by Steve Batterson. A K Peters, June 2006. ISBN 1-56881-259-0. (Reviewed August 2008.)

*Pythagorean Crimes*, by Tefcros Michalides. Parmenides Publishing, September 2008. ISBN-13: 978-19309-722-78. (Reviewed January 2009.)

*Random Curves: Journeys of a Mathematician*, by Neal Koblitz. Springer, December 2007. ISBN-13: 978-3-5407-4077-3.

*Reminiscences of a Statistician: The Company I Kept*, by Erich Lehmann. Springer, November 2007. ISBN-13: 978-0-387-71596-4.

*Rock, Paper, Scissors: Game Theory in Everyday Life*, by Len Fisher. Basic Books, November 2008. ISBN-13: 978-04650-093-81.

*Roots to Research: A Vertical Development of Mathematical Problems*, by Judith D. Sally and Paul J. Sally Jr. AMS, November 2007. ISBN-13: 978-08218-440-38. (Reviewed December 2008.)

*Sacred Mathematics: Japanese Temple Geometry*, by Fukagawa Hidetoshi and Tony Rothman. Princeton University Press, July 2008. ISBN-13: 978-0-6911-2745-3.

*The Shape of Content: An Anthology of Creative Writing in Mathematics and Science*, edited by Chandler Davis, Marjorie Wikler Senechal, and Jan Zwicky. A K Peters, November 2008. ISBN-13: 978-15688-144-45.

*Souvenirs sur Sofia Kovalevskaya* (French), by Michèle Audin. Calvage et Mounet, October 2008. ISBN-13: 978-29163-520-53.

*Strange Attractors: Poems of Love and Mathematics*, edited by Sarah Glaz and JoAnne Growney. A K Peters, November 2008. ISBN-13: 978-15688-134-17.

*Super Crunchers: Why Thinking-by-Numbers Is the New Way to Be Smart*, by Ian Ayres. Bantam, August 2007. ISBN-13: 978-05538-054-06. (Reviewed in this issue.)

*The Symmetries of Things*, by John H. Conway, Heidi Burgiel, and Chaim Goodman-Strauss. A K Peters, May 2008. ISBN-13: 978-1-5688-1220-5.

*Symmetry: A Journey into the Patterns of Nature*, by Marcus du Sautoy. Harper, March 2008. ISBN-13: 978-0-0607-8940-4.

*Symmetry: The Ordering Principle (Wooden Books)*, by David Wade. Walker and Company, October 2006. ISBN-13: 978-08027-153-88.

*Tools of American Math Teaching, 1800–2000*, by Peggy Aldrich Kidwell, Amy Ackerberg-Hastings, and David Lindsay Roberts. Johns Hopkins University Press, July 2008. ISBN-13: 978-0801888144.

*The Unfinished Game: Pascal, Fermat, and the Seventeenth-Century Letter That Made the World Modern*, by Keith Devlin. Basic Books, September 2008. ISBN-13: 978-0-4650-0910-7.

*The Unimaginable Mathematics of Borges' Library of Babel*, by William Goldbloom Bloch. Oxford University Press, August 2008. ISBN-13: 978-01953-345-79.

*Unknown Quantity: A Real and Imaginary History of Algebra*, by John Derbyshire. Joseph Henry Press, May 2006. ISBN 0-309-09657-X. (Reviewed May 2008.)

**What's Happening in the Mathematical Sciences*, by Dana Mackenzie. AMS, 2009. ISBN-13: 978-08218-447-86.

*The Wraparound Universe*, by Jean-Pierre Luminet. A K Peters, March 2008. ISBN 978-15688-130-97. (Reviewed December 2008.)

*Zeno's Paradox: Unraveling the Ancient Mystery behind the Science of Space and Time*, by Joseph Mazur. Plume, March 2008 (reprint edition). ISBN-13: 978-0-4522-8917-8.

AMERICAN MATHEMATICAL SOCIETY

# Leroy P. Steele Prizes

## Call for Nominations

The selection committee for these prizes requests nominations for consideration for the 2010 awards. Further information about the prizes can be found in the November 2007 *Notices*, pp. 1372–1390 (also available at http://www.ams.org/prizes-awards).

Three Leroy P. Steele Prizes are awarded each year in the following categories: (1) the Steele Prize for Lifetime Achievement: 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) the Steele Prize for Mathematical Exposition: for a book or substantial survey or expository-research paper; and (3) the Steele Prize for Seminal Contribution to Research: 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 2010 the prize for Seminal Contribution to Research will be awarded for a paper in algebra.

Nominations with supporting information should be submitted to the Secretary, Robert J. Daverman, American Mathematical Society, 302A Aconda Court, Department of Mathematics, University of Tennessee, Knoxville TN 37996-0612. Include a short description of the work that is the basis of the nomination, including complete bibliographic citations. A curriculum vitae should be included. The nominations will be forwarded by the Secretary to the prize selection committee, which will make final decisions on the awarding of prizes.

**Deadline for nominations is May 31, 2009.**

AMS
American Mathematical Society
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AMERICAN MATHEMATICAL SOCIETY

# Call for NOMINATIONS

The selection committees for these prizes request nominations for consideration for the 2010 awards, which will be presented at the Joint Mathematics Meetings in San Francisco, CA, in January 2010. Information about past recepients of these prizes may be found in the November 2007 issue of the *Notices*, pp. 1372-1390 and at http://www.ams.org/prizes-awards.

## LEVI L. CONANT PRIZE

This prize was established in 2000 in honor of Levi L. Conant to recognize an outstanding expository paper published in either the *Notices of the AMS* or the *Bulletin of the AMS* during 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.

## DISTINGUISHED PUBLIC SERVICE AWARD

This award was established by the AMS Council in response to a recommendation from its Committee on Science Policy. The award is presented to a research mathematician who made a distinguished contribution to the profession in the preceding five years. The US$4,000 prize is awarded every two years.

## E. H. MOORE RESEARCH ARTICLE PRIZE

Among other activities, E. H. Moore founded the Chicago branch of the AMS, served as the Society's sixth president (1901–2), delivered the Colloquium Lectures in 1906 and founded and nurtured the *Transactions of the AMS*. This prize was established in 2002 to honor his extensive contributions to the discipline and to the Society. It is awarded for an outstanding research article published in one of the AMS primary research journals (namely, the *Journal of the AMS*, *Proceedings of the AMS*, *Transactions of the AMS*, *Memoirs of the AMS*, *Mathematics of Computation*, *Electronic Journal of Conformal Geometry and Dynamics*, and the *Electronic Journal of Representation Theory*) during the calendar years 2004–2009. The US$5000 prize is awarded every three years.

Nominations should be submitted to the Secretary, Robert J. Daverman, American Mathematical Society, 302A Aconda Court, Department of Mathematics, University of Tennessee, Knoxville TN 37996-0612. Include a short description of the work that is the basis of the nomination, with complete bibliographic citations when appropriate. A brief curriculum vita of the nominee also should be included. The nominations will be forwarded by the Secretary to the appropriate prize selection committee, which will make final decisions on the awarding of these prizes.

**Deadline for nominations is June 30, 2009.**

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# *Call for* NOMINATIONS

The selection committees for these prizes request nominations for consideration for the 2010 awards, which will be presented at the Joint Mathematics Meetings in San Francisco, CA, in January 2010. Information about past recipients of these prizes may be found in the November 2007 issue of the *Notices*, pp. 1372–1390 and at http://www.ams.org/prizes-awards. Each of these US$5,000 prizes is awarded every three years.

## DAVID P. ROBBINS PRIZE

This prize was established in 2005 in memory of David P. Robbins by members of his family. Robbins 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; it shall be on a topic which is broadly accessible and shall provide both a clear statement of the problem and clear exposition of the work. The nomination should include a complete bibliographic citation for that work, supplemented with brief remarks explaining what aspects make it particularly suited for this prize.

## OSWALD VEBLEN PRIZE IN GEOMETRY

The Oswald Veblen Prize in Geometry, which was established in 1961 in honor of Professor Veblen, 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 North American journal.

## NORBERT WIENER PRIZE IN APPLIED MATHEMATICS

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

Nominations should be submitted to the Secretary, Robert J. Daverman, American Mathematical Society, 302A Aconda Court, Department of Mathematics, University of Tennessee, Knoxville TN 37996-0612. Include a short description of the work that is the basis of the nomination, with complete bibliographic citations when appropriate. A brief curriculum vita of the nominee also should be included. The nominations will be forwarded by the Secretary to the appropriate prize selection committee, which will make final decisions on the awarding of these prizes.

**Deadline for nominations is June 30, 2009.**

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# Call for Nominations

2010

## Frank and Brennie Morgan AMS-MAA-SIAM Prize

### for Outstanding Research in Mathematics by an Undergraduate Student

The prize is awarded each year to an undergraduate student (or students having submitted joint work) for outstanding research in mathematics. Any student who is an undergraduate in a college or university in the United States or its possessions, or Canada or Mexico, is eligible to be considered for this prize.

The prize recipient's research need not be confined to a single paper; it may be contained in several papers. However, the paper (or papers) to be considered for the prize must be submitted while the student is an undergraduate; they cannot be submitted after the student's graduation. The research paper (or papers) may be submitted for consideration by the student or a nominator. All submissions for the prize must include at least one letter of support from a person, usually a faculty member, familiar with the student's research. Publication of research is not required.

The recipients of the prize are to be selected by a standing joint committee of the AMS, MAA, and SIAM. The decisions of this committee are final. The 2010 prize will be awarded for papers submitted for consideration no later than June 30, 2009, by (or on behalf of) students who were undergraduates in December 2008.

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Questions may be directed to:

Dr. Martha J. Siegel, MAA Secretary
Mathematics Department
YR 339
Towson University
8000 York Road
Towson, MD 21252-0001
telephone: 410-704-2980
e-mail: msiegel@towson.edu

Nominations and submissions should be sent to:

Morgan Prize Committee
c/o Robert J. Daverman, Secretary
American Mathematical Society
302A Aconda Court
Department of Mathematics
University of Tennessee
Knoxville, TN 37996-0612

THE MATHEMATICAL ASSOCIATION OF AMERICA

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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/`.

## April 2009

* 2–4 **IMA Special Workshop: Career Options for Women in Mathematical Sciences**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
**Description:** This workshop aims to familiarize women in the mathematical sciences with professional opportunities in industry and government labs and to help them thrive in these fields. There will also be a special session to discuss principles of negotiation, developing "best alternatives to a negotiated agreement", and understanding your negotiating style. Case practices, particularly job interview scenarios will be used to illustrate the principles presented in the workshop. The audience is graduate students and Ph.D.'s in the early stages of their post-graduate careers. Researchers at any stage of their careers will also find it valuable. Speakers, panelists, and discussion leaders are women in research and management positions in industry and government labs as well as women in academia who have strong ties with industry. Participants are encouraged to present a poster on their research. Sponsored by the at the University of Minnesota and the Association for Women in Mathematics (AWM).
**Information:** `http://www.ima.umn.edu/2008-2009/SW4.2-4.09/`.

* 8–12 **Polynomial Computer Algebra '2009**, The Euler International Mathematical Institute, St. Petersburg, Russia.
**Description:** The Conference will be devoted to modern polynomial algorithms in computer algebra which are gaining importance in various applications of science as well as in fundamental researches. The following topics are in the scope of the Conference: Groebner bases, Combinatorics of monomial orderings, Differential bases, Involutive algorithms, Computational algebraic geometry, D-modules, Polynomial differential operators, Parallelization of algorithms, Quantum computing, Cryptography, Tropical manifolds, Matrix algorithms, Complexity of algorithms and others.
**Information:** `http://www.pdmi.ras.ru/EIMI/2009/pca/`.

* 27–May 2 **Master-class in Geometry (Surface group representations, hyperbolic geometry, and Teichmüller theory)**, Institut de Recherche Mathématique Avancée, University of Strasbourg, France.
**Description:** The master-class consists of 5 courses of 5 hours each, given by Vladimir Fock, Frank Herrlich, Juien Marché, Sergei Matveev, and Carlo Petronio. The subject is geometry and topology in low dimensions, with particular attention given to surface group representations, hyperbolic geometry, and Teichmüller theory. The master-class is addressed to graduate students and [Dresearchers in Geometry and topology. In addition to the courses, there will be a series of survey talks on geometry and topology in low-dimensions. Graduate students are welcome. Registration is required, and it is free of charge. It can be done through through the URL link. Room reservation can be asked through the same link.
**Information:** `http://www-irma.u-strasbg.fr/article770.html`.

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**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/`.

* 29–May 1 **Simons Lectures in Mathematics**, Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts.
**Lecturer:** Étienne Ghys (CNRS-École Normale Supérieure de Lyon) will give 3 lectures on "Dynamics in Dimension 3": Asymptotic invariants for flows, Right-handed vector fields, and The Rademacher function. Lectures at 4:30 p.m., each preceded by a reception at 4:00 p.m.

## May 2009

* 4–6 **Simons Lectures in Mathematics**, Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts.
**Lecturer:** Robert Schapire (Princeton University) will give 3 lectures on "The Boosting Approach to Machine Learning: Foundations, Perspectives, Applications" (The AdaBoost algorithm its analysis; Boosting and how to play repeated games; and Boosting, optimization and maximum entropy). Lectures at 4:30 p.m., each preceded by a reception at 4:00 p.m.

* 14–16 **Variational and Topological Methods and Water Waves**, University of Bath, Bath, United Kingdom.
**Description:** This workshop addresses nonlinear aspects of PDE theory using variational and topological methods. While there are manifold applications of these modern analytical tools, the topic of water waves will provide a focus, and present an opportunity for mathematicians with a variety of backgrounds, including nonlinear functional analysis, topological degree theory, bifurcation theory, and Hamiltonian systems, to meet and review developments. Participants at all levels are welcome, including research students.
**Speakers:** Boris Buoni (Lausanne), Walter Craig (Hamilton), Norman Dancer (Sydney), Gerard Iooss (Nice), Bryce McLeod (Oxford), Louis Nirenberg (New York), Pavel Plotnikov (Novosibirsk), Eugene Shargorodsky (London), Paul Rabinowitz (Madison), Charles Stuart (Lausanne), Neil Trudinger (Canberra), David Williams (Swansea). This is an EPSRC-funded workshop celebrating the 60th birthday of John Toland.
**Information:** `http://www.bath.ac.uk/math-sci/events/waves2009`.

* 18–21 **Mathematical Modeling in the Medical Sciences, in conjunction with the 24th Annual Shanks Lecture**, Department of Mathematics, Vanderbilt University, Nashville, Tennessee.
**Description:** Biomathematics encompasses the application of mathematical methods to the study of living organisms. Mathematics plays an essential role in understanding biological systems on many different scales of both size and time. For example, we can model biological processes at various scales: (1) molecular, sub-cellular, cellular, tissue, organism, and population; and (2) milliseconds, seconds, minutes, hours, days, and years. Mathematics has a rich history as a tool for biologists. More recently, mathematics has found applications in the medical sciences, both in the basic sciences of medicine and in patient care. The 24th Shanks Conference is a forum for all areas of biomathematics, but speakers have been invited from the special interest areas: Models of cancer growth; models of epidemics and infection; models of physiologic systems and clinical practice; and medical imaging. The featured Shanks Lecturer is Nicola Bellomo of Politecnico Torino.
**Information:** `http://www.math.vanderbilt.edu/~shanks2009`.

* 18–22 **IMA Workshop: Molecular Simulations: Algorithms, Analysis, and Applications**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
**Description:** This workshop will bring together mathematicans, chemists, physicists, biologists and researchers from other disciplines whose work pertains to statistical mechanics and molecular dynamics used in simulations of biomolecular, chemical, and liquid or solid state systems. We will consider key aspects of molecular simulations: numerical algorithms, mathematical analysis and applications—paying special attention to problems that call for new methodologies or mathematics. Relevant topics include sampling methods, methods for free energy calculation, reaction pathways and reaction rates, long-time integration, geometric integrators, trajectory analysis, stochastic and Monte Carlo methods, and Car-Parrinello dynamics. Numerical methodologies, mathematical theory, and applications will be discussed.
**Information:** `http://www.ima.umn.edu/2008-2009/W5.18-22.09/`.

* 23–26 **IMST 2009/FIM 17**, University of West Bohemia, Plzen, Czech Republic.
**Description:** Department of Mathematics, University of West Bohemia will be hosting the 17th annual conference of the Forum for Interdisciplinary Mathematics (FIM) titled "International Conference on Interdisciplinary Mathematical & Statistical Techniques". Earlier recent conferences have been held in Australia, China, Portugal, India, and various universities in the USA. The academic activities of the conference will primarily focus on the following areas of mathematical and statistical sciences: combinatorics and graph theory, functional analysis, differential equations, Bayesian statistics, bioinformatics, biostatistics, design and analysis of experiments, and multivariate analysis. However, presentations in other areas of mathematical and statistical sciences are also welcome. Special section devoted to undergraduates is planned.
**Information:** `http://www.kma.zcu.cz/IMST2009`.

* 24–25 **The Second Graduate Research Conference in Algebra and Representation Theory**, Kansas State University, Manhattan, Kansas.
**Description:** Graduate students are invited to participate in The Second Graduate Research Conference in Algebra and Representation Theory. The conference will feature two invited lectures given by the world renowned experts: Alexandre Kirillov (University of Pennsylvania); York Sommerhauser (University of South Alabama). We expect to provide partial support for travel and accommodation. Detailed information about support, speakers, and participants will be announced soon on the conference homepage. Women and minorities are especially encouraged to apply for participation.
**Information:** `http://www.math.ksu.edu/main/events/grad_conf_2009`.

* 25–27 **Young Scientists Conference: Actual Problems of Mechanics and Mathematics in memory of academician Ya. S. Pidstryhach**, Pidstryhach Institute for Applied Problems of Mechanics and Mathematics, Lviv, Ukraine.
**Description:** The objective of the conference is to provide a forum of distinguished and young researchers, who are involved in applied mathematics and mechanics in order to stimulate the development of young scientists and to increase their level by means of live communication, listening to lectures of senior colleagues, and presenting their own results. The scientific program will consist of plenary sessions featuring invited lectures by distinguished speakers and sectional sessions with oral presentation of the contributed papers mainly by young scientists.
**Information:** `http://www.iapmm.lviv.ua/chyt2009`.

* 25–29 **Conference on Topological Field Theory**, Northwestern University, Evanston, Illinois.
**Description:** There will be a workshop intended primarily for graduate students and others new to the field during the preceding week. The speaker list is on the conference web site and will be updated there. The organizers are Kevin Costello, Ezra Getzler, and Paul Goerss. Both the conference and the workshop will be supported by the National Science Foundation and Northwestern University. If you'd like support, please contact the organizers by February 20, 2009. Priority will go to those who respond early.
**Information:** `http://www.math.northwestern.edu/~pgoerss/tftemphasis/`.

* 25–29 **Eigenvalue and Saturation Problems for Reductive Groups**, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.

**Description:** There were be survey talks (morning sessions) and research talks (afternoons) to consider recent advances in the eigenvalue and saturation problems for reductive groups and its relations to invariant theory and combinatorics; generalizations of the Horn and saturation conjectures; quiver theory and generalized theta functions on algebraic curves.

**Speakers:** P. Belkale, M. Kapovich, S. Kumar, K. Purbhoo, N. Ressayre, T. Abe, A. Boysal, C. Chindris, T. Haines, L, Mihalcea, J. Millson, R. Sjamaar.

**Conference Support:** The conference is supported through the FRG project 0554247 from the NSF. There will be some funds available for graduate students and post docs. To ask for support, send your request along with your vitae to the conference secretary Lee Trimble (trimble@email.unc.edu).

* 27–29 **Dynamical System Modeling and Stability Investigation**, The Department of Complex System Modeling, Faculty of Cybernetics, Kyiv Taras Shevchenko National University, Kyiv, Ukraine.

**Description:** 1. Mathematical methods of system investigation 2. Mathematical modeling of processes 3. Modeling and investigation of processes in mechanics 4. Mathematical methods of control and optimization 5. Logic-mathematical methods of modeling.

**Information:** http://dsmsi.univ.kiev.ua.

* 27–31 **Fields Institute Workshop on Geometry Related to the Langlands Programme**, University of Ottawa, Ottawa, Canada.

**Description:** The theme of this workshop is the exploration of some of the geometric ideas appearing in recent advances in the Langlands programme, with an emphasis on results which apply to both function fields and number fields. The workshop begins with three mini-courses, aimed towards advanced graduate students and non-specialists: on perverse sheaves and character sheaves (by Anne-Marie Aubert, CNRS), on the Jacquet-Langlands correspondence (by Ioan Badulescu, Montpellier II), and on recent successful approaches to the Fundamental Lemma (by Pierre-Henri Chaudouard, CNRS). The workshop will conclude with a two-day conference, featuring research talks picking up on the themes of the mini-courses.

**Information:** http://www.fields.utoronto.ca/programs/scientific/08-09/Langlands/.

## June 2009

* 1–5 **i-MATH School on Derived Algebraic Geometry**, University Institute for Fundamental Physics and Mathematics (IUFFyM), University of Salamanca, Spain.

**Description:** The workshop is devoted to a brand new geometry which includes aspects of the traditional algebraic geometry of schemes and stacks, higher homotopy theory, and derived and infinity categories. Important applications of derived algebraic geometry to intersection theory and integral functors will be also considered, keeping an eye on their influence in string theory.

**Information:** http://mukai.fis.usal.es/~ruiperez/Workshop09/Welcome.html.

* 1–October 31 **i-MATH Trimester on Derived Algebraic Geometry**, University Institute for Fundamental Physics and Mathematics (IUFFyM), University of Salamanca, Spain.

**Description:** This is a special trimester (June to October 2009) devoted to Derived Algebraic Geometry, applications and related fields, which will take place in the University Institute for Fundamental Physics and Mathematics, IUFFyM (University of Salamanca). Among the activities, there will be visits (one week to one month) of researchers in the field and a School (June 1–5).

**Information:** http://mukai.fis.usal.es/~ruiperez/Workshop09/i-MATH_Trimester_on_DGA.html.

* 8–12 **Recursion structures in topological string theory and enumerative geometry**, American Institute of Mathematics, Palo Alto, California.

**Description:** This workshop, sponsored by AIM and the NSF, will be devoted to the study of a newly discovered recursion structure in topological string theory and its applications to Gromov-Witten theory and enumerative geometry.

**Information:** http://www.aimath.org/ARCC/workshops/recursionstruct.html.

* 8–13 **Disordered Systems: Spin Glasses**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, 2920, Chemin de la tour, 5th floor, Montréal, Québec, H3T 1J4, Canada.

**Description:** The modelling and mathematical analysis of disordered spin systems has proven to be among the most fascinating fields of statistical mechanics over the last 25 years. A fundamental difficulty in these models is the extremely complicated many-valley structure of the energy landscape. Even the seemingly simple mean-field model, introduced by Sherrington and Kirkpatrick, turned out to have an amazingly rich mathematical structure. Only recently, there has been a growing mathematical understanding of mean-field spin glasses, but many questions—some of which transcend the original physical questions—remain unsolved.

**Information:** http://www.crm.umontreal.ca/Spin09/index_e.shtml.

* 14–18 **QTRF5 - Quantum Theory: Reconsideration of Foundations-5**, Vaxjo University, Vaxjo, Sweden.

**Description:** This conference is devoted to quantum foundations, probability, geometry, gravity and applications of the mathematical formalism of QM to macroscopic phenomena—cognitive science, psychology, economy. During previous conferences we were fortunate to have physicists (theorists as well as experimentalists), mathematicians, and several philosophers interested in foundations of quantum theory. Fundamental questions of quantum mechanics, especially information theory, quantum computing, cryptography, and teleportation have continued to be central topics this year.

**Information:** http://www.vxu.se/msi/konferens/QTRF5/.

* 14–20 **The Interplay of Algebra and Geometry**, Cortona, Italy.

**Description:** The one-week conference “The Interplay of Algebra and Geometry”, which is being organized to honor the 60th birthday of Prof. Corrado De Concini, intends to present some of the most important and recent developments in the following fields: Complete symmetric varieties and wonderful compactifications; Models of subspace arrangements and box splines; Quantum groups; Representation theory and Invariant theory; Cohomology of Artin and braid groups.

**Scientific Committee:** Enrico Arbarello, Sapienza Università di Roma; Victor Kac, MIT; Claudio Procesi, Sapienza Università di Roma; Marc Rosso, ENS, Paris; Mario Salvetti, Università di Pisa.

**Organizing Committee:** Nicoletta Cantarini, Università di Padova; Giovanni Gaiffi, Università di Pisa; Paolo Papi, Sapienza Università di Roma.

**Information:** http://www.dm.unipi.it/cortona2009.

* 15–18 **Workshop on Electromagnetic Inverse Problems**, University of Manchester, Manchester, United Kingdom.

**Description:** This workshop on electromagnetic inverse problems coincides with the annual meeting on Biomedical Applications of Electrical Impedance Tomography, and is intended to bring together specialists in the mathematics of EIT and related inverse problems with those working not only on medical applications but also other areas including geophysics, process monitoring, archaeology, landmine detection and non-destructive testing. We will also aim to promote collaboration with those working in electosensing in the animal kingdom (notably weakly electric fish).

**Speakers include:** Gunther Uhlmann, Victor Isakov, Habib Ammari and Mike Nelson.

**Information:** `http://www.maths.manchester.ac.uk/eit2009/`.

* 15–20 **Strobl09 Conference on Time-Frequency**, Conference center "BIFEB" Strobl, Salzburg, Austria.
**Description:** This is a general conference on mathematical and computational aspects of harmonic analysis and time-frequency analysis and will take place in the congenial and productive atmosphere of the town of Strobl near Salzburg, Austria.
**Topics:** Time-frequency analysis, pseudodifferential operators, wireless communications and time-varying systems, compressed sensing and sparsity, sampling theory, signal transforms and wavelet theory, functions spaces.
**Organizers:** Hans G. Feichtinger, K. Groechenig.
**Deadline for registration and submission of abstracts:** April 15, 2009.
**Information:** `http://nuhag.eu/strobl09`.

* 15–26 **IMA New Directions Short Course: Applied Algebraic Topology**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
**Description:** IMA will host an intensive short course designed to efficiently provide researchers in the mathematical sciences and related disciplines; the basic knowledge prerequisite to undertake research in applied algebraic topology. The course will be taught by Gunnar Carlsson, Department of Mathematics, Stanford University, and Robert Ghrist, Department of Electrical and Systems Engineering, Department of Mathematics, University of Pennsylvania. The primary audience for the course is mathematics faculty. No prior background in applied algebraic topology is expected.
**Information:** `http://www.ima.umn.edu/2008-2009/ND6.15-26.09/`.

* 15–July 3 **IMA PI Summer Program for Graduate Students: The Mathematics of Inverse Problems**, University of Delaware, Newark, Delaware.
**Description:** The course will concentrate on The Mathematics of Inverse Problems. Inverse problems is a fast-growing area involving a broad range of disciplines from the most abstract and pure mathematics to practical engineering. The 2009 summer program on inverse problems covers three different types of inverse problems: inverse problems for hyperbolic PDE's, inverse scattering in the frequency domain, and variational inverse problems. The program will cover the techniques used to tackle problems at the cutting edge of mathematical research in each of these areas. This is a unique and timely synthesis of disciplines that will position future researchers for the next step in inverse scattering from waves that, we believe, will combine variational methods with direct qualitative techniques.
**Information:** `http://www.ima.umn.edu/2008-2009/PISG6.15-7.3.09/`.

* 22–26 **Topology of Algebraic Varieties**, Jaca, Spain.
**Description:** This five day conference is in honor of Anatoly Libgober's 60th birthday. Main topics are: the topology of algebraic varieties, and relations between knot theory, algebraic geometry and mathematical physics. In addition to the 26 invited plenary speakers, we are soliciting applications for posters and short communications. Deadlines and further information can be found on the conference homepage. Students and postdocs may request NSF travel support by writing to one of the organizers.
**Information:** `http://www.math.uic.edu/~jaca2009/`.

* 22–29 **The Poetry of Analysis (Conference in honour of Antonio CÛrdoba on the occasion of his 60th birthday)**, Colegio Mayor Juan Luis Vives, Madrid, Spain.
**Description:** This international meeting is a celebration both of the outstanding mathematical career of Prof. Antonio Córdoba and of his contribution to the development of mathematics in Spain. As an expresion of our gratitude to Prof. Córdoba we have organized a group of exceptional speakers for this conference. The talks will focus on the latest advances in several areas emphasizing "multidisciplinarity", the art which Antonio mastered when there was not even a term for it, to the great benefit of his students and collaborators. On behalf of all of them: Thank you, Antonio!
**Information:** `http://www.uam.es/gruposinv/ntatuam/cordoba/index.html`.

* 23–26 **Sixth Annual International Symposium on Voronoi Diagrams in Science and Engineering (ISVD 2009)**, Technical University of Denmark, Kongens Lyngby, Denmark.
**Description:** The International Symposium on Voronoi Diagrams in Science and Engineering (ISVD) is the premier conference on Voronoi diagrams and their applications to many different scientific and engineering disciplines to solve real-world problems. Authors are invited to submit papers (up to 10 pages) describing original research related to the following topics: Mathematical aspects of Voronoi diagrams and Delaunay graphs, Generalizations of Voronoi diagrams and Delaunay graphs, Algorithms and implementation of Voronoi diagrams/Delaunay graphs, Applications of Voronoi Diagrams in bioinformatics; biology/ecology; computer science: computer graphics, image reconstruction and analysis, surface reconstruction, robotics and spatial databases; crystallography/material science; electronics (VLSI); geography; geomatics: geographic information systems, photogrammetry, and remote sensing; physics, chemistry and sustainable energies. There will be a special session devoted to bioinformatics.
**Information:** `http://www.imm.dtu.dk/ISVD`.

* 28–July 3 **Affine Isometric Actions of Discrete Groups**, The Centro Stefano Franscini, Zurich, Switzerland.
**Description:** The study of affine isometric actions of groups on Hilbert or Banach spaces opens a new chapter in the theory of group representations, with connections to rigidity, ergodic theory, geometric group theory, and metric geometry. The aim of this conference, the first ever dedicated to this young subject, is to bring together young and confirmed experts in order to present new results and methods, isolate key problems in the field, and discuss future applications (e.g., possibly in theoretical computer science).
**Information:** `http://www.unige.ch/math/folks/arjantse/ascona09/`.

* 29–July 3 **Workshop on Stochastic Analysis and Finance**, City University of Hong Kong, Kowloon, Hong Kong.
**Description:** The workshop aims to foster communication and dissemination or recent results among researchers in stochastic analysis and mathematical finance.
**Information:** `http://www6.cityu.edu.hk/ma/wsaf09/`.

* 29–July 31 **Special Program: IMA Interdisciplinary Research Experience for Undergraduates**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
**Description:** The IMA summer REU gives students an experience in working on an interdisciplinary project involving mathematics. Students will work in teams of three with a faculty advisor and a postdoctoral mentor. This is a hands-on experience. There will be a few formal lectures. However, students will spend most of their time doing actual research. Students are expected to produce a poster and a publication-quality written report, and to give an oral presentation by the end of the 5-week period.
**Information:** `http://www.ima.umn.edu/2008-2009/SW6.29-7.31.09/`.

## July 2009

* 1–3 **International Conference on Design Theory and Applications**, National University of Ireland, Galway, Ireland.
**Description:** The conference will celebrate the 50th birthday of Dr. Warwick de Launey, and his many achievements in design theory. The broad theme of the conference is all areas of design theory, especially Hadamard matrices and their generalizations. Talks dealing with (i) applications of design theory, and (ii) computational aspects

of design theory, are particularly encouraged and welcome. Refereed articles will be published post-proceedings in a special issue of Cryptography and Communications: Discrete structures, Boolean functions and sequences.

**Organizing Committee:** Víictor Álvarez, Universidad de Sevilla, Spain; Dane Flannery, National University of Ireland, Galway; Kathy Horadam, RMIT University, Australia.

**Information:** `http://larmor.nuigalway.ie/~detinko/DeSign.htm`

* 10–12 **Ninth International Conference on Mathematical Knowledge Management**, Grand Bend, Ontario, Canada.

**Description:** Mathematical Knowledge Management is the field at the intersection of mathematics, computer science, library science and scientific publishing. Its development is driven by on the one hand new technological possibilities which computer science, the Internet, and intelligent knowledge processing offer, and on the other hand the increasing demand by engineers and scientists for new techniques for producing, transmitting, consuming, and managing sophisticated mathematical knowledge.

**Information:** `http://www.orcca.on.ca/conferences/cicm09/mkm09`.

* 13–31 **IMA Summer Program: Nonlinear Conservation Laws and Applications**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.

**Description:** The first week of the program will be largely devoted to tutorial sessions and general survey lectures. These will be targeted at young researchers and Ph.D. students who know only some basic facts on the subject and want to get familiar with the main lines of current research. The following two weeks will contain more specialized research talks with one or two themes each day. These talks will be intermixed with discussions, pointing out the most promising areas for further research. We plan to overlap themes in several areas to stimulate interaction between different groups. The second week will focus more on the theoretical aspects, and the third week on applications and numerical methods.

**Information:** `http://www.ima.umn.edu/2008-2009/SP7.13-31.09/`.

## August 2009

* 3–7 **Chern-Simons Gauge Theory: 20 years after**, Max Planck Institute for Mathematics, Bonn, Germany.

**Description:** Chern-Simons theory has developed in several different directions since its relation to knot theory was discovered by Witten 20 years ago. On the one hand, there have been several advances in understanding the TQFT approach to his 3-manifold invariants and the semiclassical approximation, as well as in treating the Feynman path integral version rigorously using stochastic analysis. On the other hand, Witten's seminal work initiated lots of interesting questions and results in knot theory and geometric topology, as well as the development of entirely new fields. The workshop will bring together researchers working in geometric topology, stochastic analysis and mathematical physics with a particular interest in Chern-Simons theory. The schedule will include a limited number of one-hour talks, as well as additional time for problem sessions, informal discussion, and social events. The final schedule will be announced in advance of the workshop and posted on this website.

**Information:** `http://www.hausdorff-center.uni-bonn.de/event/2009/gauge_theory/`.

* 3–8 **7th Pan African Congress of Mathematicians (PACOM) 2009**, Yamoussoukro, Ivory Coast.

**Description:** All interested mathematicians are invited and will find attached here the First Announcement. The Local Organizing Committee of PACOM 2009 would be grateful to you if you could widely circulate this information through the universities and institutions of high education in your respective countries.

**Information:** Professor Etienne Desquith; email: `desquith@hotmail.com`; phone: (+225) 01 33 78 28.

* 4–10 **International Conference of Mathematical Sciences (ICMS Istanbul 2009)**, Maltepe University, Marmara Egitim Koyu, TR 34857 Maltepe, Istanbul, Turkey.

**Description:** The aim of this conference to see ongoing developments in mathematical sciences and computer sciences, and make scientists get together to discuss relevant subjects to have new ideas, present current published or unpublished results, and prepare new manuscripts.

**Information:** `http://mathsciencesconf.maltepe.edu.tr/`.

* 9–14 **Model Theory: ESF Mathematics Conference in Partnership with EMS and ERCOM**, Mathematical Research and Conference Center, Bedlewo, Poland.

**Description:** Model theory is a branch of mathematical logic dealing with mathematical structures (models). Model theory is traditionally divided into two—parts pure and applied. Pure model theory studies abstract properties of first order theories, and derives structure theorems for their models. Originally, a good description of models was available only for so-called superstable theories, which is quite a restricted class. Nowadays, there is a great progress in extending the methods and results of pure model theory to wider and wider classes of theories (e.g., dependent, simple). There are also interesting new connections between pure model theory and descriptive set theory.

**Information:** Learn more at: `http://www.esf.org/conferences/09305`.

* 9–22 **Summer School: Structures in Lie Representation Theory, Crystals, Derived Functors, Harish-Chandra Modules, Invariants, Quivers**, Jacobs University, Bremen, Germany.

**Description:** The root system of E6 projected from 6 dimensions down to 2—courtesy of J. Stembridge. Root diagram of B5 given a weight triangularization—courtesy of A. Joseph. Root diagram of A6 given a weight triangularization cocourtesy of A. Joseph.

**Courses:** Mini-courses are given by Michel Brion (Grenoble), Maria Gorelik (Rehovot), Anthony Joseph (Rehovot), Alexander Premet (Manchester), Claus Michael Ringel (Bielefeld), Vera Serganova (Berkeley), Wolfgang Soergel (Freiburg), Gregg Zuckerman (New Haven).

**Information:** Additional information can be obtained from Ivan Penkov, School of Engineering and Science, Jacobs University, Bremen, Germany; email: `i.penkov@jacobs-university.de`. The Summer School is funded by the Volkswagen Foundation.

* 15 **Workshop on Logical Aspects of Fault Tolerance (LAFT) co-located with LICS 2009**, University of California, Los Angeles, California.

**Description:** We are soliciting papers on logical aspects of fault tolerance. The concept of "fault" underlies essentially all computational systems that have any goal. Loosely speaking, a fault is an unintended event that can have an unintended effect on the attainment of that goal. "Fault tolerance" is the term given to a system's ability to cope in some way with a fault, either inherently or through design. Fault tolerance has been studied for its application to circuits, and then branching out to distributed systems and more recently to quantum computers, where the concern with fault tolerance is almost the paramount issue. The relevance to biological computation is also obvious. Papers must be concerned with the logic of fault tolerance, not simply fault tolerance.

**Important Dates:** Papers due: April 17, 2009. Notification: May 22, 2009. Final papers: July 10, 2009. Workshop: August 15, 2009. Please send all workshop correspondence, including submissions, to: `marcus@aero.org`.

**Information:** `http://www.aero.org/support/laft`.

* 31–September 4 **GF2009 International Conference on Generalized Functions**, University of Vienna, Vienna, Austria.

**Description:** This conference continues a long-standing tradition of international conferences on generalized functions gathering

researchers working in all branches of "generalized functions". As seen with the past few conferences held in Guadeloupe (France, 2000), Novi Sad (Serbia, 2004) and Bedlewo (Poland, 2007) the spectrum of interrelations with other fields of mathematics and applications has been steadily increasing. Following this development, GF2009 aims at a broad coverage of research in generalized functions (distribution theory, algebras of generalized functions), linear and nonlinear PDE (solvability, regularity, applied analysis), harmonic analysis (modulation spaces, time-frequency analysis and pseudodifferential operators), and applications in geometry ((non-)linear distributional geometry) and mathematical physics (general relativity, mathematical geophysics).
**Information:** `http://www.mat.univie.ac.at/~gf2009/`.

* 31–September 6 **International School on Geometry and Quantization**, Mathematics Research Unit, University of Luxembourg, Luxembourg.
**Topics:** Topics concentrate on algebraic-geometric and complex-analytic-geometric aspects of quantization. Leading experts in the field will give introductory courses on: Quantization of moduli spaces of bundles and the mapping class group, Stratified Kähler spaces, Quantization of universal Teichmüller space, Geometry of loop spaces, Quantum integrable systems and Langlands program, Introduction to geometric asymptotic analysis, and Geometric quantization and heat kernel methods. The school is aiming for young reseachers intending to enter these exciting fields of research. Immediately after the school there will be a one week international conference GEOQUANT on the same topics.
**Lecturers:** Andersen, Jorgen, Aarhus, Denmark; Huebschmann, Johannes, Lille, France; Sergeev, Armen, Moscow, Russia; Talalaev, Dmitry, Moscow, Russia; Tate, Tatsuja, Nagoya; Japan; Wurzbacher, Tilmann, Metz, France; Zhang, Weiping, Nankai, China.
**Information:** `http://math.uni.lu/geoquant/school`.

## September 2009

* 7–8 **CETL-MSOR Conference 2009**, Open University, Milton Keynes, England.
**Description:** The Maths, Stats & OR Network will be running its fourth annual learning and teaching conference in conjunction with the related Centres of Excellence in Teaching and Learning (CETLs). The 2009 conference will be hosted by the Centre for Open Learning of Mathematics, Science, Computing and Technology (COLMSCT). The aim of this conference is to promote, explore, and disseminate emerging good practice and research findings in mathematics and statistics support, teaching, learning, and assessment.
**Information:** `http://mathstore.ac.uk/index.php?pid=253`.

* 7–11 **Third International Conference on Geometry and Quantization GEOQUANT**, Mathematics Research Unit, University of Luxembourg, Luxembourg.
**Topics:** The scientific program of the conference is concentrated around the following main topics: algebraic-geometric and complex-analytic-geometric aspects of quantization; geometric quantization and moduli space problems; asymptotic geometric analysis; infinite-dimensional geometry; relations with modern theoretical physics.
**Speakers (preliminary list):** Andersen, Jorgen, Aarhus (TBC); Charles, Laurent, Paris; Domrin, Andrei, Moscow; Englis, Mirek, Prague; Foth, Tatyana, Western Ontario; Fujita, Hajime, Tokyo; Gorodentsev, Alexey, Moscow; Huebschmann, Johannes, Lille; Kaledin, Dmitry, Moscow (TBC); Karabegov, Alexander, Abilene; Kobayashi, Ryoishi, Nagoya; Mano, Toshiyuki, Kyoto; Marinescu, George, Kˆln; Natanzon, Sergey, Moscow; Nohara, Yuichi, Nagoya; Osipov, Denis, Moscow; Paoletti, Robert, Milano; Talalaev, Dmitry, Moscow; Tate, Tatsuja, Nagoya; Trechev, Dmitry, Moscow; Tyurin, Nikolai, Dubna; Ueno, Kenji, Kyoto; Upmeier, Harald, Marburg; Zhang, Weiping, Nankai, China.
**Information:** `http://math.uni.lu/geoquant`.

* 14–18 **IMA Workshop: Flowing Complex Fluids: Rheological Measurements and Constitutive Modeling**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
**Description:** Fluids with nontrivial small-scale inhomogeneities (microstructure) include suspensions, emulsions, foams, polymer melts and solutions, surfactant solutions and liquid crystals. Flows of these complex fluids display features that are not found in simple fluids, including interfacial and bulk instabilities, texture formation and evolution and other novel flow phenomena that all can be traced back to the influence the fluid microstructure has on the stresses that develop within the flow. This workshop will focus on the experimental motivation and the constitutive modeling of complex fluids at all scales. Topics to be discussed include modeling from microscopic to mesoscopic to macroscopic, closures, constitutive model predictions including shear thinning and thickening regimes, inhomogeneities in flow including transient and steady state shearbanding, and shear induced phase transitions.
**Information:** `http://www.ima.umn.edu/2009-2010/W9.14-18.09/`.

* 21–25 **Convex algebraic geometry, optimization and applications**, American Institute of Mathematics, Palo Alto, California.
**Description:** This workshop, sponsored by AIM and the NSF, will be devoted to the study of "Convex Algebraic Geometry" and some of its numerous applications.
**Information:** `http://aimath.org/ARCC/workshops/convexalggeom.html`.

* 24–30 **6th International Conference on Functional Analysis and Approximation Theory -FAAT 2009**, Acquafredda di Maratea, Italy.
**Description:** The meeting will be devoted to some significant aspects of contemporary mathematical research on functional analysis, operator theory and approximation theory including the applications of these fields in other areas such as partial differential equations, integral equations, numerical analysis. It is expected that the Proceedings of the Conference will be published.
**Plenary speakers:** J. Appell (Würzburg), G. Godefroy (Paris), N. Jacob (Swansea), M. Kato (Kitakyushu), L. Maligranda (Lulea), F. Marcellan (Madrid), G. Milovanovic (Serbia), G. Monegato (Torino), B. de Pagter (Delft), L.E. Persson (Lulea), D. Potts (Chemnitz), I. Raaa (Cluj-Napoca), B. Silbermann (Chemnitz), V. Totik (Szeged), J. Szabados (Budapest), P. Vertesi (Budapest).
**Organizing Committee:** F. Altomare, A. Attalienti, M. Campiti, M. Cappelletti Montano, L. D'Ambrosio, M. C. De Bonis, S. Diomede, V.Leonessa, G. Mastroianni, D. Occorsio, M. G. Russo.
**Information:** `http://www.dm.uniba.it/faat2009`; email: `faat2009@dm.uniba.it`.

## October 2009

* 12–16 **IMA Workshop: Flowing Complex Fluids: Fluid Mechanics-Interaction of Microstructure and Flow**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
**Description:** Fluids with nontrivial small-scale inhomogeneities (microstructure) include suspensions, emulsions, foams, polymer melts and solutions, surfactant solutions and liquid crystals. Flows of these complex fluids display features that are not found in simple fluids, including interfacial and bulk instabilities, texture formation and evolution and other novel flow phenomena that all can be traced back to the influence the fluid microstructure has on the stresses that develop within the flow. This workshop focuses on these fluid mechanical phenomena and their origins in the complex nature of the fluid. Topics include free surface flows and extensional rheometry, instabilities and flow induced phase transitions, turbulence and drag reduction in polymer and surfactant solutions, coating and extrusion, some microfluidic flows of complex fluids, and multiscale computational methods.

**Information:** `http://www.ima.umn.edu/2009-2010/W10.12-16.09/`.

* 14–17 **Integers Conference 2009**, University of West Georgia, Carrollton, Georgia.

**Description:** The Editors of *Integers: Electronic Journal of Combinatorial Number Theory* are pleased to announce the Integers Conference 2009. The Integers conferences are international conferences in combinatorial number theory, held for the purpose of bringing together mathematicians, students, and others interested in combinatorics and number theory. The Integers Conference 2009 will also be honoring Professors Melvyn Nathanson and Carl Pomerance on the occasions of their 65th birthdays. The proceedings of the conference will be published as a special volume of the Integers journal. The conference will feature six plenary speakers and many other invited talks.

**Information:** `http://www.westga.edu/~math/IntegersConference2009`.

* 21–23 **The 4th International Conference on Research and Education in Mathematics 2009 (ICREM09)**, Kuala Lumpur, Malaysia.

**Description:** Mathematics, applications of mathematics, statistics, operations research, innovation in teaching mathematics, mathematics education and other related to mathematics and statistics.

**Information:** `http://www.inform.upm.edu.my`.

* 22–24 **Partial Differential Equations and Applications International Workshop for the 60th birthday of Michel Pierre**, Club Med, Vittel, France.

**Description:** The scope of this meeting is to gather international scientists to discuss recent advances in the fields studied by Michel Pierre, professor at ENS Cachan O'Antenne de Bretagne. His contributions are very important in non-linear analysis and applications to partial differential equations. More precisely, he is interested in one of the following topics : non-linear semi-groups, non-linear parabolic and elliptic partial differential equations with L1 or measure data, global existence for reaction-diffusion systems, shape optimization problem, in particular regularity of optimal shapes, control of PDE.

**Information:** `http://edpa2009.iecn.u-nancy.fr/`.

## November 2009

* 2–6 **The Cuntz Semigroup**, American Institute of Mathematics, Palo Alto, California.

**Description:** This workshop, sponsored by AIM and the NSF, will explore the Cuntz semigroup; an invariant of $C*$-algebras inspired by $K$-theory and recently shown to be important for classification.

**Information:** `http://aimath.org/ARCC/workshops/cuntzsemigroup.html`.

* 9–13 **Cyclic homology and symplectic topology**, American Institute of Mathematics, Palo Alto, California.

**Description:** This workshop, sponsored by AIM and the NSF, will be devoted to the incarnations of cyclic homology in symplectic topology.

**Information:** `http://aimath.org/ARCC/workshops/cyclichomology.html`.

## December 2009

* 7–11 **IMA Workshop: Microfluidics: Electrokinetic and Interfacial Phenomena**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.

**Description:** Microfluidics is the science of fluid motion on microscopic scales, roughly 100 nanometers to 100 microns. In this regime inertial effects are negligible and interfacial effects, i.e., surface tension, capillarity, electrostatic charge, etc. dominate. The subject has emerged as an area of intense interest in the applied sciences because of applications in nanotechnology and bio-analytical chemistry. The workshop will focus on topics in the basic science of ionic fluids: zeta potentials, Debye Layers, electroosmosis and electrophoresis; interfacial effects and applications such as controlled droplet motion by electrowetting, and the Brownian hydrodynamics of macromolecules and polymers.

**Information:** `http://www.ima.umn.edu/2009-2010/W12.7-11.09/`.

* 14–18 **Brownian motion and random matrices**, American Institute of Mathematics, Palo Alto, California.

**Description:** This workshop, sponsored by AIM and the NSF, will be devoted to beta-generalizations of the classical ensembles in random matrix theory. These are certain tridiagonal and unitary Hessenberg matrices, with an eigenvalue p.d.f. generalizing that of Gaussian Hermitian matrices and Haar distributed unitary matrices.

**Information:** `http://aimath.org/ARCC/workshops/brownianrmt.html`.

* 17–21 **The 14th Asian Technology Conference in Mathematics (ATCM 2009)**, Beijing Normal University, Beijing, China.

**Description:** Conference Theme "Journey to discover more mathematics". The ATCM 2009 is an international conference to be held in China that will continue addressing technology-based issues in all mathematical sciences. The aim of this conference is to provide a forum for educators, researchers, teachers and experts in exchanging information regarding enhancing technology to enrich mathematics learning, teaching and research at all levels. English is the official language of the conference. There will be over 400 participants coming from over 33 countries around the world. Deadlines for abstract and full paper are June 15 and July 30 respectively.

**Information:** `http://atcm.mathandtech.org`.

## January 2010

* 17–19 **ACM-SIAM Symposium on Discrete Algorithms (SODA10)**, Hyatt Regency Austin, Austin, Texas.

**Description:** This symposium focuses on research topics related to efficient algorithms and data structures for discrete problems. In addition to the design of such methods and structures, the scope also includes their use, performance analysis, and the mathematical problems related to their development or limitations. Performance analyses may be analytical or experimental and may address worst-case or expected-case performance. Studies can be theoretical or based on data sets that have arisen in practice and may address methodological issues involved in performance analysis.

**Information:** `http://www.siam.org/meetings/da10/`.

## February 2010

* 22–26 **IMA Workshop: Analysis and Computation of Incompressible Fluid Flow**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.

**Description:** The mathematical and numerical analysis of incompressible flows is of paramount importance for understanding basic nonlinear phenomena in science and engineering. The subject contains some of the most challenging nonlinear partial differential equations of mathematical physics, posing problems for both analysis and computation. This workshop will address modern developments in the core analytical issues of existence and uniqueness of smooth solutions, as well as of weak solutions and statistical solutions. Additional topics will include geophysical flows, analysis of complex fluid models, free surface problems, vanishing viscosity limits, and numerical methods for scientific computation of complex flows.

**Information:** `http://www.ima.umn.edu/2009-2010/W2.22-26.10/`.

* 24–26 **SIAM Conference on Parallel Processing and Scientific Computing (PP10)**, Hyatt Regency Seattle, Seattle, Washington.

**Description:** This conference organized by the SIAM Activity on Supercomputing.

**Information:** `http://www.siam.org/meetings/pp10/index.php`.

## March 2010

* 8–June 11 **Long Program: Model and Data Hierarchies for Simulating and Understanding Climate**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
**Overview:** Simulation has advanced climate science, but not sufficiently to the profit of theory and understanding. Our hypothesis is that the development of climate science will be best served by focusing computational and intellectual resources on model and data hierarchies. By bringing together physicists, mathematicians, statisticians, engineers, and climate-scientists to focus on themes across scales and scientific methodologies, our program will provide a framework for advancing our use of hierarchical methods in our attempt to understand the climate system.
**Organizing Committee:** Amy Braverman, Rupert Klein, Andrew Majda, Olivier Pauluis, Bjorn Stevens.
**Application and Information:** Information and an application form is available at: `http://www.ipam.ucla.edu/programs/CL2010`. Applications for individual workshops will be posted on individual workshop home pages. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

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**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.**

## April 2010

* 12–16 **IMA Workshop: Transport and Mixing in Complex and Turbulent Flows**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
**Description:** Enhanced mixing and transport properties are distinguishing characteristics of both turbulent and more structured complex flows. The concepts of eddy diffusion and eddy viscosity, for example, were introduced as attempts to "parameterize" these effects to produce reduced models for theoretical analysis and simulations. At the same time turbulent mixing and transport is the focus of significant attention from a fundamental point of view, based in some cases on the Navier-Stokes equations and in other cases on models or special flows amenable to more thorough analytical investigations. This workshop is concerned with modern mathematical approaches to the study of transport and mixing in turbulence and other complex flows, including transitional flows with significant attention to applications from the applied sciences, predominantly geophysics.
**Information:** `http://www.ima.umn.edu/2009-2010/W4.12-16.10/`.

## June 2010

* 1–5 **IMA Workshop: Natural Locomotion in Fluids and on Surfaces: Swimming, Flying, and Sliding**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
**Description:** Natural locomotion in fluids includes the swimming of fish and microorganisms and the flying of birds and insects. Other creatures employ similar movements on solid and fluid surfaces, e.g., snails, snakes, and water striders. Nature has exploited the complex fluid dynamics of time-dependent three-dimensional flows over a wide range of Reynolds numbers to evolve a variety of interesting mechanisms of locomotion. This workshop will focus on the mechanics of these behaviors and the current state of theoretical and experimental work in the field. The scope will cover the dynamics from low to high Reynolds numbers, emphasizing the links between the fluid dynamics and the nature of the evolved mechanisms. The inclusion of movement over solid and fluid surfaces introduces new phenomena involving surface stresses and complex fluid layers.
**Information:** `http://www.ima.umn.edu/2009-2010/W6.1–5.10/`

## July 2010

* 12–15 **SIAM Conference on the Life Sciences (LS10)**, The David L. Lawrence Convention Center, Pittsburgh, Pennsylvania.
**Description:** This conference is organized by the SIAM Activity Group on the Life Sciences.
**Information:** `http://www.siam.org/meetings/ls10/`.

* 12–16 **2010 SIAM Annual Meeting (AN10)**, The David L. Lawrence Convention Center, Pittsburgh, Pennsylvania.
**Description:** SIAM's Annual Meeting provides a broad view of the state of the art in applied mathematics, computational science, and their applications through invited presentation, prize lectures, minisymposia, and contributed papers and posters.
**Information:** `http://www.siam.org/meetings/an10/index.php`.

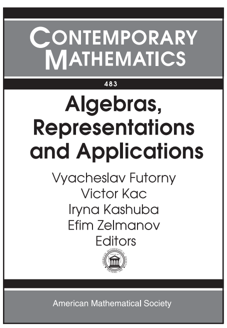
* 26–30 **6th International Conference on Lévy Processes: Theory and Applications**, Technical University of Dresden, Dresden, Germany.
**Description:** The focus is on recent developments in the theory of Lévy and jump processes and their applications. There will be invited talks and poster sessions.
**Scientific Committee:** Jean Bertoin (Paris VI, France), Serge Cohen (Toulouse, France), Davar Khosnevisan (Utah, USA), Andreas Kyprianou (Bath, UK), Alexander Lindner (Braunschweig, Germany), Makoto Maejima (Keio, Japan), Thomas Mikosch (Copenhagen, Denmark), Victor Pérez-Abreu (CIMAT, Mexico), Jan Rosinski (U. Tennessee, USA), Réne Schilling (Dresden, Germany).
**Information:** `http://www.math.tu-dresden.de/levy2010`; email: `levy2010@tu-dresden.de`. It is also possible to contact: Réne Schilling (TU Dresden) or Alexander Lindner (TU Braunschweig) directly.

* 26–August 6 **Winter School on Topics in Noncommutative Geometry**, Departamento de Matematica, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina.
**Description:** The school will cover different topics in non-commutative geometry and its connections with other areas of mathematics and physics, such as operator index theory, strings, representations, operator algebras, and K-Theory. As of December 2008, the following people have agreed in principle to come and give a course: Henrique Bursztyn, Joachim Cuntz, Pavel Etingof, Victor Ginzburg, Victor Kac, Max Karoubi, Henri Moscovici, Holger Reich, Nicolai Reshetikhin, Marc Rieffel, Jonathan Rosenberg, Georges Skandalis, Boris Tsygan.
**Organizers:** G. Cortiñas, M. Farinati, J. A. Guccione, J. J. Guccione, M. Graña.
**Scientific Committee:** G. Cortiñas, J. Cuntz, B. Tsygan.
**Information:** `http://cms.dm.uba.ar/Members/gcorti/workgroup.GNC/3EILS`.

# 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




### Algebras, Representations and Applications

**Vyacheslav Futorny**, *Universidade de São Paulo, Brazil*, **Victor Kac**, *Massachusetts Institute of Technology, Cambridge, MA*, **Iryna Kashuba**, *Universidade de São Paulo, Brazil*, and **Efim Zelmanov**, *University of California, San Diego, La Jolla, CA*, Editors

This volume contains contributions from the conference on "Algebras, Representations and Applications" (Maresias, Brazil, August 26–September 1, 2007), in honor of Ivan Shestakov's 60th birthday.

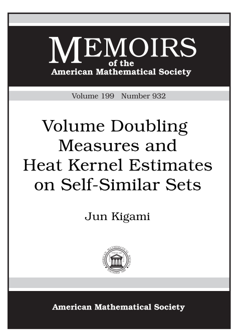
This book will be of interest to graduate students and researchers working in the theory of Lie and Jordan algebras and superalgebras and their representations, Hopf algebras, Poisson algebras, Quantum Groups, Group Rings and other topics.

**Contents: J. Q. Adashev**, **A. K. Khuhoyberdiyev**, and **B. A. Omirov**, Classification of complex naturally graded quasi-filiform Zinbiel algebras; **H. Albuquerque** and **A. P. Santana**, Akivis superalgebras and speciality; **V. A. Artamonov** and **I. A. Chubarov**, Properties of some semisimple Hopf algebras; **Y. Bahturin** and **D. Pagon**, Classifying simple color Lie superalgebras; **V. Bekkert** and **Y. Drozd**, Derived categories for algebras with radical square zero; **P. Benito** and **F. Martín-Herce**, Tits construction, triple systems and pairs; **M. R. Bremner**, **I. R. Hentzel**, **L. A. Peresi**, and **H. Usefi**, Universal enveloping algebras of the four-dimensional Malcev algebra; **I. Cunha** and **A. Elduque**, The supermagic square in characteristic 3 and Jordon superalgebras; **W. F. Santos** and **I. L. Franco**, Monoidal categories of comodules for coquasi Hopf algebras and Radford's formula; **E. G. Goodaire** and **C. P. Milies**, Group identities on symmetric units in alternative loop algebras; **D. Jakelić** and **A. Moura**, On multiplicity problems for finite-dimensional representations of hyper loop algebras; **J. Laliena** and **S. Sacristán**, Maximal subalgebras of simple alternative superalgebras; **L. Makar-Limanov**, **U. Turusbekova**, and **U. Umirbaev**, Automorphisms of elliptic Poisson algebras; **C. Martínez** and **E. Zelmanov**, Jordon superalgebras and their representations; **K. Meyberg**, A new proof of Itô's theorem; **F. Montaner** and **M. Tocón**, The ideal of the Lesieur-Croisot elements of a Jordon algebra. II; **J. M. Pérez Izquierdo**, Unital algebras, ternary derivations, and local triality; **P. Plaumann**, **L. Sabinina**, and **L. Sbitneva**, A decomposition of *LF*-quasigroups; **A. Savage**, Braided and coboundary monoidal categories; **P. Schultz**, Bases for direct powers; **S. R. Sverchkov**, Structure and representations of Jordan algebras arising from intermolecular recombination.

**Contemporary Mathematics**, Volume 483

May 2009, 285 pages, Softcover, ISBN: 978-0-8218-4652-0, LC 2008044490, 2000 *Mathematics Subject Classification:* 17A70, 17B10, 17B65, 17C10, 17D05, 16G60, 16W30, 18D10, **AMS members US$63**, List US$79, Order code CONM/483

## Analysis



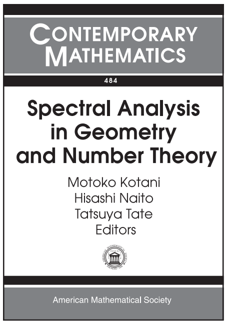

### Volume Doubling Measures and Heat Kernel Estimates on Self-Similar Sets

**Jun Kigami**, *Kyoto University, Japan*

**Contents:** Prologue; Scales and volume doubling property of measures; Construction of distances; Heat kernel and volume doubling property of measures; Appendix; Bibliography.

**Memoirs of the American Mathematical Society**, Volume 199, Number 932

May 2009, 94 pages, Softcover, ISBN: 978-0-8218-4292-8, LC 2008055058, 2000 *Mathematics Subject Classification:* 28A80, 60J35; 31C25, 60J45, **Individual member US$39**, List US$65, Institutional member US$52, Order code MEMO/199/932




## Spectral Analysis in Geometry and Number Theory

**Motoko Kotani**, *Tohoku University, Sendai, Japan*, and **Hisashi Naito** and **Tatsuya Tate**, *Nagoya University, Japan*, Editors

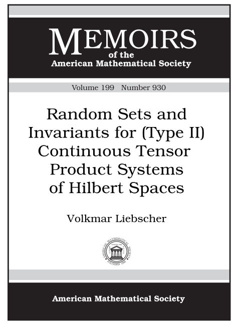
This volume is an outgrowth of an international conference in honor of Toshikazu Sunada on the occasion of his sixtieth birthday. The conference took place at Nagoya University, Japan, in 2007.

Sunada's research covers a wide spectrum of spectral analysis, including interactions among geometry, number theory, dynamical systems, probability theory and mathematical physics. Readers will find papers on trace formulae, isospectral problems, zeta functions, quantum ergodicity, random waves, discrete geometric analysis, value distribution, and semiclassical analysis. This volume also contains an article that presents an overview of Sunada's work in mathematics up to the age of sixty.

**Contents:** *Short biography and work of Professor Sunada:* **A. Katsuda** and **P. W. Sy**, Brief profile of Professor Toshikazu Sunada; **A. Katsuda** and **P. W. Sy**, An overview of Sunada's work up to age 60; *Articles:* **C. Gordon**, Sunada's isospectrality technique: Two decades later; **S. Ishiwata**, A central limit theorem on modified graphs of nilpotent covering graphs; **T. Kobayashi**, Hidden symmetries and spectrum of the Laplacian on an indefinite Riemannian manifold; **N. Kurokawa** and **H. Ochiai**, Spectra of alternating Hilbert operators; **J. Masamune**, A Liouville property and its application to the Laplacian of an infinite graph; **M. Minamide**, A note on zero-free regions for the derivative of Selberg zeta functions; **M. Morishita** and **Y. Terashima**, Chern-Simons variation and Deligne cohomology; **T. Morita**, Renormalized Rauzy-Veech-Zorich inductions; **H. Naito**, Visualization of standard realized Crystal lattices; **J. Noguchi**, Value distribution and distribution of rational points; **M. Pollicott**, Limiting distributions for geodesics excursions on the modular surface; **M. S. Risager** and **Z. Rudnick**, On the statistics of the minimal solution of a linear Diophantine equation and uniform distribution of the real part of orbits in hyperbolic spaces; **L. Saloff-Coste** and **W. Woess**, Computations of spectral radii on $\mathcal{G}$-spaces; **M. Horsham** and **R. Sharp**, Lengths, quasi-morphisms and statistics for free groups; **N. Koldan**, **I. Prokhorenkov**, and **M. Shubin**, Semiclassical asymptotics on manifolds with boundary; **K.-I. Sugiyama**, On geometric analogues of the Birch and Swinnerton-Dyer conjecture for low dimensional hyperbolic manifolds; **T. Sunada** and **H. Urakawa**, Ray-Singer zeta functions for compact flat manifolds; **T. Tate**, Bernstein measures on convex polytopes; **S. Zelditch**, Real and complex zeros of Riemannian random waves.

**Contemporary Mathematics**, Volume 484

May 2009, 342 pages, Softcover, ISBN: 978-0-8218-4269-0, LC 2008046241, 2000 *Mathematics Subject Classification:* 58J50, 11M36, 37C30; 35P05, 60J60, **AMS members US$79**, List US$99, Order code CONM/484




## Random Sets and Invariants for (Type II) Continuous Tensor Product Systems of Hilbert Spaces

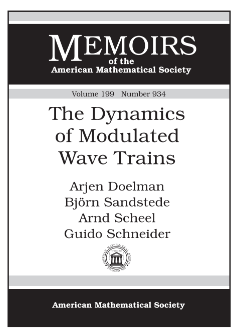
**Volkmar Liebscher**, *GSF–National Research Centre for Environment and Health, Neuherberg, Germany*

**Contents:** Introduction; Basics; From product systems to random sets; From random sets to product systems; An hierarchy of random sets; Direct integral representations; Measurability in product systems: An algebraic approach; Construction of product systems from general measure types; Beyond separability: Random bisets; An algebraic invariant of product systems; Conclusions and outlook; Bibliography.

**Memoirs of the American Mathematical Society**, Volume 199, Number 930

May 2009, 101 pages, Softcover, ISBN: 978-0-8218-4318-5, LC 2008055041, 2000 *Mathematics Subject Classification:* 60G55; 81S25, **Individual member US$40**, List US$66, Institutional member US$53, Order code MEMO/199/930

# Differential Equations



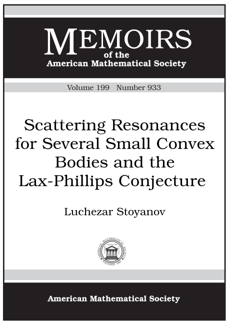

## The Dynamics of Modulated Wave Trains

**Arjen Doelman**, *CWI, Amsterdam, The Netherlands*, **Björn Sandstede**, *University of Surrey, Guildford, United Kingdom*, **Arnd Scheel**, *University of Minnesota, Minneapolis, MN*, and **Guido Schneider**, *Universität Stuttgart, Germany*

**Contents:** Notation; Introduction; The Burgers equation; The complex cubic Ginzburg–Landau equation; Reaction-diffusion equations: Set-up and results; Validity of the Burgers equation in reaction-diffusion equations; Validity of the inviscid Burgers equation in reaction-diffusion systems; Modulations of wave trains near sideband instabilities; Existence and stability of weak shocks; Existence of shocks in the long-wavelength limit; Applications; Bibliography.

**Memoirs of the American Mathematical Society**, Volume 199, Number 934

May 2009, 105 pages, Softcover, ISBN: 978-0-8218-4293-5, LC 2008055480, 2000 *Mathematics Subject Classification:* 35K57, 35A35, 35Q53, 37L99, **Individual member US$40**, List US$66, Institutional member US$53, Order code MEMO/199/934




## Scattering Resonances for Several Small Convex Bodies and the Lax-Phillips Conjecture

**Luchezar Stoyanov**, *University of Western Australia, Crawley, Australia*

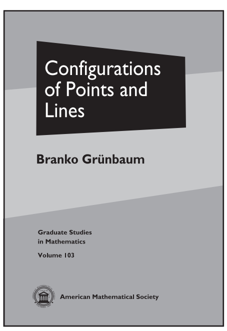
**Contents:** Introduction; An abstract meromorphicity theorem; Preliminaries; Ikawa's transfer operator; Resolvent estimates for transfer operators; Uniform local meromorphicity; Proof of the Main Theorem; Curvature estimates; Bibliography.

**Memoirs of the American Mathematical Society**, Volume 199, Number 933

May 2009, 76 pages, Softcover, ISBN: 978-0-8218-4294-2, LC 2008055068, 2000 *Mathematics Subject Classification:* 58J50, 54C40, 14E20; 37A60, 46E25, 20C20, **Individual member US$37**, List US$62, Institutional member US$50, Order code MEMO/199/933

# Discrete Mathematics and Combinatorics

COURSE ADOPTION




## Configurations of Points and Lines

**Branko Grünbaum**, *University of Washington, Seattle, WA*

This is the only book on the topic of geometric configurations of points and lines. It presents in detail the history of the topic, with its surges and declines since its beginning in 1876. It covers all the advances in the field since the revival of interest in geometric configurations some 20 years ago. The author's contributions are central to this revival. In particular, he initiated the study of 4-configurations (that is, those that contain four points on each line, and four lines through each point); the results are fully described in the text. The main novelty in the approach to all geometric configurations is the concentration on their symmetries, which make it possible to deal with configurations of rather large sizes. The book brings the readers to the limits of present knowledge in a leisurely way, enabling them to enjoy the material as well as entice them to try their hand at expanding it.

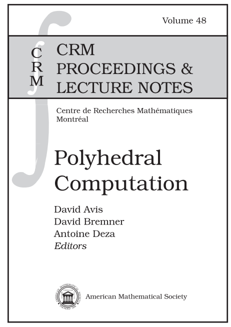
*This item will also be of interest to those working in geometry and topology.*

**Contents:** Beginnings; 3-Configurations; 4-Configurations; Other configurations; Properties of configurations; Postscript; Appendix: The Euclidean, projective, and extended Euclidean planes; References.

**Graduate Studies in Mathematics**, Volume 103

May 2009, approximately 480 pages, Hardcover, ISBN: 978-0-8218-4308-6, LC 2009000303, 2000 *Mathematics Subject Classification:* 01A55, 01A60, 05-03, 05B30, 05C62, 51-03, 51A20, 51A45, 51E30, 52C30, **AMS members US$60**, List US$75, Order code GSM/103

# Geometry and Topology




## Polyhedral Computation

**David Avis**, *McGill University, Montréal, QC, Canada*, **David Bremner**, *University of New Brunswick, Fredericton, NB, Canada*, and **Antoine Deza**, *McMaster University, Hamilton, ON, Canada*, Editors

Many polytopes of practical interest have enormous output complexity and are often highly degenerate, posing severe difficulties for known general-purpose algorithms. They are, however, highly structured, and attention has turned to exploiting this structure, particularly symmetry. Initial applications of this approach have permitted computations previously far out of reach, but much remains to be understood and validated experimentally.

The papers in this volume give a good snapshot of the ideas discussed at a Workshop on *Polyhedral Computation* held at the CRM in Montréal in October 2006 and, with one exception, the current state of affairs in this area. The exception is the inclusion of an often cited 1980 technical report of Norman Zadeh, which was never published in a journal and has passed into the folklore of the discipline. This paper illustrates beautifully the work still to be done in the field: it gives a simple pivot rule for the simplex method for which it is still unknown if it yields a polynomial time algorithm.

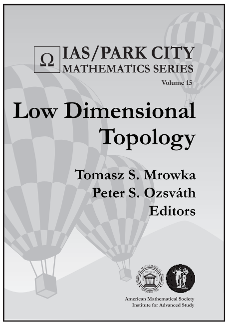
*This item will also be of interest to those working in applications.*

Titles in this series are co-published with the Centre de Recherches Mathématiques.

**Contents:** **D. Avis** and **S. Moriyama**, On combinatorial properties of linear program digraphs; **E. Boros**, **K. Elbassioni**, **V. Gurvich**, and **K. Makino**, Generating vertices of polyhedra and related problems of monotone generation; **D. Bremner**, **M. D. Sikirić**, and **A. Schürmann**, Polyhedral representation conversion up to symmetries; **S. Columbano**, **K. Fukuda**, and **C. N. Jones**, An output-sensitive algorithm for multi-parametric LCPs with sufficient matrices; **A. Deza** and **F. Xie**, Hyperplane arrangements with large average diameter; **T. Theobald**, Enumerating the Nash equilibria of rank-1 games; **N. Zadeh**, What is the worst case behavior of the simplex algorithm?; **D. Avis**, Postscript to "What is the worst case behavior of the simplex algorithm?".

**CRM Proceedings & Lecture Notes**, Volume 48

April 2009, 147 pages, Softcover, ISBN: 978-0-8218-4633-9, LC 2008054354, 2000 *Mathematics Subject Classification:* 52B55, 90C05, **AMS members US$60**, List US$75, Order code CRMP/48




## Low Dimensional Topology

**Tomasz S. Mrowka**, *Massachusetts Institute of Technology, Cambridge, MA*, and **Peter S. Ozsváth**, *Columbia University, New York, New York*, Editors

Low-dimensional topology has long been a fertile area for the interaction of many different disciplines of mathematics, including differential geometry, hyperbolic geometry, combinatorics, representation theory, global analysis, classical mechanics, and theoretical physics. The Park City Mathematics Institute summer school in 2006 explored in depth the most exciting recent aspects of this interaction, aimed at a broad audience of both graduate students and researchers.

The present volume is based on lectures presented at the summer school on low-dimensional topology. These notes give fresh, concise, and high-level introductions to these developments, often with new arguments not found elsewhere. The volume will be of use both to graduate students seeking to enter the field of low-dimensional topology and to senior researchers wishing to keep up with current developments. The volume begins with notes based on a special lecture by John Milnor about the history of the topology of manifolds. It also contains notes from lectures by Cameron Gordon on the basics of three-manifold topology and surgery problems, Mikhail Khovanov on his homological invariants for knots, John Etnyre on contact geometry, Ron Fintushel and Ron Stern on constructions of exotic four-manifolds, David Gabai on the hyperbolic geometry and the ending lamination theorem, Zoltán Szabó on Heegaard Floer homology for knots and three manifolds, and John Morgan on Hamilton's and Perelman's work on Ricci flow and geometrization.

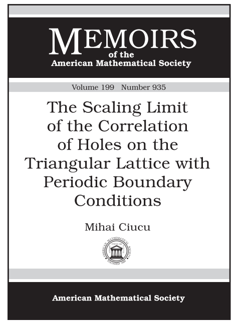
Titles in this series are co-published with the Institute for Advanced Study/Park City Mathematics Institute. Members of the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) receive a 20% discount from list price.

**Contents: P. S. Ozsváth** and **T. S. Mrowka**, Introduction; **J. Milnor**, Fifty years ago: Topology of manifolds in the 50's and 60's; **C. Gordon**, Dehn surgery and 3-manifolds; **D. Gabai**, Hyperbolic geometry and 3-manifold topology; **J. W. Morgan**, Ricci flow and Thurston's geometrization conjecture (with notes by Max Lipyanskiy); **M. Asaeda** and **M. Khovanov**, Notes on link homology; **Z. Szabó**, Lecture notes on Heegard Floer homology; **J. Etnyre**, Contact geometry in low dimensional topology; **R. Fintushel** and **R. J. Stern**, Six lectures on four 4-manifolds.

**IAS/Park City Mathematics Series**, Volume 15

May 2009, approximately 325 pages, Hardcover, ISBN: 978-0-8218-4766-4, 2000 *Mathematics Subject Classification:* 53-XX, 57-XX, 58-XX, **AMS members US$55**, List US$69, Order code PCMS/15

# Mathematical Physics




## The Scaling Limit of the Correlation of Holes on the Triangular Lattice with Periodic Boundary Conditions

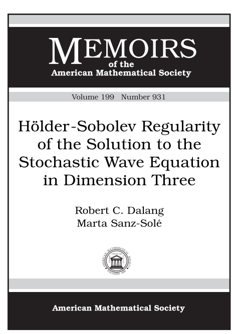
**Mihai Ciucu**, *Indiana University, Bloomington, IN*

**Contents:** Introduction; Definition of $\hat{\omega}$ and statement of main result; Deducing Theorem 1.2 from Theorem 2.1 and Proposition 2.2; A determinant formula for $\hat{\omega}$; An exact formula for $U_s(a,b)$; Asymptotic singularity and Newton's divided difference operator; The asymptotics of the entries in the $U$-part of $M'$; The asymptotics of the entries in the $P$-part of $M'$; The evaluation of $\det(M'')$; Divisibility of $\det(M'')$ by the powers of $q-\zeta$ and $q-\zeta^{-1}$; The case $q=0$ of Theorem 8.1, up to a constant multiple; Divisibility of $\det(dM_0)$ by the powers of $(x_i-x_j)-\zeta^{\pm 1}(y_i-y_j)-ah$ and $(z_i-w_j)-\zeta^{\pm 1}(z_i-w_j)-ah$; Divisibility of $\det(dM_0)$ by the powers of $(x_i-z_j)-\zeta^{\pm 1}(y_i-w_j)$; The proofs of Theorem 2.1 and Proposition 2.2; The case of arbitrary slopes; Random covering surfaces and physical interpretation; Appendix. A determinant evaluation; Bibliography.

**Memoirs of the American Mathematical Society**, Volume 199, Number 935

May 2009, 100 pages, Softcover, ISBN: 978-0-8218-4326-0, LC 2008055522, 2000 *Mathematics Subject Classification:* 82B23, 82D99; 05A16, 41A63, 60F99, **Individual member US$40**, List US$66, Institutional member US$53, Order code MEMO/199/935

# Probability




## Hölder-Sobolev Regularity of the Solution to the Stochastic Wave Equation in Dimension Three

**Robert C. Dalang**, *Ecole Polytechnique Fédérale, Lausanne, Switzerland*, and **Marta Sanz-Solé**, *Universitat de Barcelona, Spain*

**Contents:** Introduction; The fundamental solution of the wave equation and the covariance function; Hölder-Sobolev regularity of the stochastic integral; Path properties of the solution of the stochastic wave equation; Sharpness of the results; Integrated increments of the covariance function; Bibliography.

**Memoirs of the American Mathematical Society**, Volume 199, Number 931

May 2009, 80 pages, Softcover, ISBN: 978-0-8218-4288-1, LC 2008055046, 2000 *Mathematics Subject Classification:* 60H15; 60J45, 35R60, 35L05, **Individual member US$34**, List US$57, Institutional member US$46, Order code MEMO/199/931

# New AMS-Distributed Publications

## Algebra and Algebraic Geometry


### Foncteurs en Grassmanniennes, Filtration de Krull et Cohomologie des Foncteurs

**Aurélien Djament**, *Université Paris 13, Villetaneuse, France*

Let $F$ be the category of functors between vector spaces over a finite field. The *grassmannian functor categories* are obtained by replacing the source of this category by the category of pairs formed by a vector space and an element of one of its grassmannians. These categories have a very rich algebraic structure; the author studies in particular their finite objects and their homological properties.

The author gives a very general vanishing property in functor cohomology, which he applies to the stable $K$-theory of finite fields: He obtains a generalization of the Betley–Suslin theorem, which expresses certain extension groups of $GL_\infty$-modules in terms of functor cohomology.

The author's second application of the grassmannian functor categories concerns the Krull filtration of the category $F$. He gives a conjectural description of this filtration and explores its powerful implications. With the help of tools provided by G. Powell, the author shows a weak form of this conjecture, in the case where the basis field has two elements. Consequently, he establishes the noetherian character of new functors.

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

**Contents:** *Partie I. Préliminaires:* Rappels sur la catégorie $\mathcal{F}$; La catégorie $\mathcal{F}_{surj}$; Catégories de comodules sur un foncteur en coalgèbres de Boole; Les catégories $\mathcal{E}^f_{Gr,I}$, $\tilde{\mathcal{E}}^f_{GR}$, et $\mathcal{E}^f_{Pl,n}$; *Partie II. Les catégories de foncteurs en grassmanniennes:* Les catégories $\mathcal{F}_{Gr,I}$; La catégorie $\tilde{\mathcal{F}}_{Gr}$; La catégorie $\mathcal{F}_{Gr,I}$ comme catégorie de modules; Les catégories $\mathcal{F}_{Pl,n}$; Foncteurs hom internes et foncteurs de division dans $\mathcal{F}_{Gr,I}$; *Partie III. Propriétés cohomologiques du foncteur $\omega$. Applications:* Théorème d'annulation cohomologique; Foncteur $\omega$ et foncteurs hom internes; La filtration de Krull de la catégorie $\mathcal{F}$; Résultats d'annulation cohomologie dans $\mathcal{F}_{inj}$; *Partie IV. Foncteur $\omega$ et $\nabla$-nilpotence:* Introduction: la catégorie $\mathcal{F}/\mathcal{F}_\omega$; Préliminaires relatifs aux foncteurs $\omega$ et $\tilde{\nabla}_n$; Théorèmes fondamentaux; Adjonctions; Propriétés de finitude dans les catégories abéliennes; Catégories de foncteurs; Index; Index des notations; Bibliographie.

**Mémoires de la Société Mathématique de France**, Number 111

November 2008, 213 pages, Softcover, ISBN: 978-2-85629-248-8, 2000 *Mathematics Subject Classification:* 16P60, 18A25, 18G15, 20C33, 16E20, 16P40, 18A40, 18C15, 18D15, 18E35, 18G05, 19D99, 55S10, **Individual member US$50**, List US$55, Order code SMFMEM/111

## Analysis

### Notes on Functional Analysis

**Rajendra Bhatia**, *Indian Statistical Institute, New Delhi, India*

These notes are a record of a one-semester course on Functional Analysis given by the author to second-year Master of Statistics students at the Indian Statistical Institute, New Delhi. Students taking this course have a strong background in real analysis, linear algebra, measure theory and probability, and the course proceeds rapidly from the definition of a normed linear space to the spectral theorem for bounded selfadjoint operators in a Hilbert space.

The book is organized as twenty-six lectures, each corresponding to a ninety-minute class session. This may be helpful to teachers planning a course on this topic. Well-prepared students can read it on their own.

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**Contents:** Banach spaces; Dimensionality; New Banach Spaces from old; The Hahn–Banach theorem; The uniform boundedness principle; The open mapping theorem; Dual spaces; Some applications; The weak topology; The second dual and the weak* topology; Hilbert spaces; Orthonormal bases; Linear operators; Adjoint operators; Some special operators in Hilbert space; The resolvent and the spectrum; Subdivision of the spectrum; Spectra of normal operators; Square roots and the polar decomposition; Compact operators; The spectrum of a compact operator; Compact operators and invariant subspaces; Trace ideals; The spectral theorem–I; The spectral theorem–II; The spectral theorem–III; Index.

**Hindustan Book Agency**

January 2009, 248 pages, Hardcover, ISBN: 978-81-85931-89-0, 2000 *Mathematics Subject Classification:* 46-01, **AMS members US$35**, List US$44, Order code HIN/38

## Functional Analysis

**S. Kesavan**, *Institute of Mathematical Sciences, Chennai, India*

The material presented in this book is suited for a first course in Functional Analysis which can be followed by master's students. While all the standard material expected of such a course is covered, efforts have been made to illustrate the use of various theorems via examples taken from differential equations and the calculus of variations, either through brief sections or through exercises. In fact, this book will be particularly useful for students who would like to pursue a research career in the applications of mathematics.

The book includes a chapter on weak and weak* topologies and their applications to the notions of reflexivity, separability and uniform convexity. The chapter on the Lebesgue spaces also presents the theory of one of the simplest classes of Sobolev spaces. The book includes a chapter on compact operators and the spectral theory for compact self-adjoint operators on a Hilbert space.

Each chapter has large collection of exercises at the end. These illustrate the results of the text, show the optimality of the hypotheses of various theorems via examples or counterexamples, or develop simple versions of theories not elaborated on in the text.

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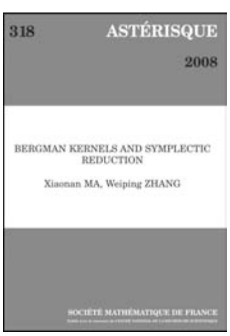
**Contents:** Preliminaries; Normed linear spaces; Hahn–Banach theorems; Baire's theorem and applications; Weak and weak* topologies; $L^p$ spaces; Hilbert spaces; Compact operators; Bibliography; Index.

**Hindustan Book Agency**

January 2009, 281 pages, Hardcover, ISBN: 978-81-85931-87-6, 2000 *Mathematics Subject Classification:* 46-01, **AMS members US$35**, List US$44, Order code HIN/39




## Bergman Kernels and Symplectic Reduction

**Xiaonan Ma**, *École Polytechnique, Palaiseau, France*, and **Weiping Zhang**, *Nankai University, Tianjin, China*

The authors generalize several recent results concerning the asymptotic expansions of Bergman kernels to the framework of geometric quantization and establish an asymptotic symplectic identification property. More precisely, they study the asymptotic expansion of the $G$-invariant Bergman kernel of the spin$^c$ Dirac operator associated with high tensor powers of a positive line bundle on a symplectic manifold admitting a Hamiltonian action of a compact connected Lie group $G$.

The authors also develop a way to compute the coefficients of the expansion, and compute the first few of them; especially, they obtain the scalar curvature of the reduction space from the $G$-invariant Bergman kernel on the total space. These results generalize the corresponding results in the non-equivariant setting, which have played a crucial role in the recent work of Donaldson on stability of projective manifolds, to the geometric quantization setting.

As another kind of application, the authors establish some Toeplitz operator type properties in semi-classical analysis in the framework of geometric quantization.

The method used is inspired by Local Index Theory, especially by the analytic localization techniques developed by Bismut and Lebeau.

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**Contents:** Introduction; Connections and Laplacians associated to a principal bundle; $G$-invariant Bergman kernels; Evaluation of $P^{(r)}$; Applications; Computing the coefficient $\Phi_1$; The coefficient $P^{(2)}(0,0)$; Bergman kernel and geometric quantization; Bibliography; Index.

**Astérisque**, Number 318

November 2008, 154 pages, Softcover, ISBN: 978-2-85629-255-6, 2000 *Mathematics Subject Classification:* 32A25, 58J37, 53D50, 53D20, 32L10, **Individual member US$50**, List US$55, Order code AST/318

## Inequalities: An Approach through Problems

**B. J. Venkatachala**, *Indian Institute of Science, Banglore, India*

This book is an introduction to the study of fundamental inequalities such as the arithmetic mean-geometric mean inequality, the Cauchy–Schwarz inequality, the Chebyshev inequality, the rearrangement inequality, and the inequalities for convex and concave functions. The emphasis is on the use of these inequalities for solving problems. The book's special feature is a chapter on the geometrical inequalities that studies relations between various geometrical measures. It contains more than 300 problems, many of which are applications of inequalities. A large number of problems are taken from the International Mathematical Olympiads (IMO) and many national olympiads from countries across the world.

The book should be very useful for students participating in mathematical contests. It should also help graduate students consolidate their knowledge of inequalities by way of applications.

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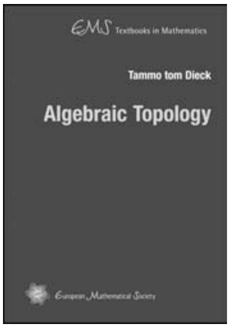
**Contents:** Some basic inequalities; Techniques for proving inequalities; Geometric inequalities; Applications involving inequalities; Problems on inequalities; Solutions to problems.

**Hindustan Book Agency**

January 2009, 400 pages, Hardcover, ISBN: 978-81-85931-88-3, 2000 *Mathematics Subject Classification:* 26D15, 26D20, **AMS members US$38**, List US$48, Order code HIN/37

# Geometry and Topology




## Algebraic Topology

**Tammo tom Dieck**, *University of Göttingen, Germany*

This book is written as a textbook on algebraic topology. The first part covers the material for two introductory courses about homotopy and homology. The second part presents more advanced applications and concepts (duality, characteristic classes, homotopy groups of spheres, bordism). The author recommends starting an introductory course with homotopy theory. For this purpose, classical results are presented with new elementary proofs. Alternatively, one could start more traditionally with singular and axiomatic homology. Additional chapters are devoted to the geometry of manifolds, cell complexes and fibre bundles. A special feature is the rich supply of nearly 500 exercises and problems. Several sections include topics which have not appeared before in textbooks as well as simplified proofs for some important results.

Prerequisites are standard point set topology (as recalled in the first chapter), elementary algebraic notions (modules, tensor product), and some terminology from category theory. The aim of the book is to introduce advanced undergraduate and graduate (master's) students to basic tools, concepts and results of algebraic topology. Sufficient background material from geometry and algebra is included.

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**Contents:** Topological spaces; The fundamental group; Covering spaces; Elementary homotopy theory; Cofibrations and fibrations; Homotopy groups; Stable homotopy. Duality; Cell complexes; Singular homology; Homology; Homological algebra; Cellular homology; Partitions of unity in homotopy theory; Bundles; Manifolds; Homology of manifolds; Cohomology; Duality; Characteristic classes; Homology and homotopy; Bordism; Bibliography; Symbols; Index.

**EMS Textbooks in Mathematics**, Volume 8

September 2008, 578 pages, Hardcover, ISBN: 978-3-03719-048-7, 2000 *Mathematics Subject Classification:* 55-01, 57-01, **AMS members US$62**, List US$78, Order code EMSTEXT/8

## Flag Varieties: An Interplay of Geometry, Combinatorics, and Representation Theory

**V. Lakshmibai** and **Justin Brown**, *Northeastern University, Boston, MA*

Flag varieties are important geometric objects and their study involves an interplay of geometry, combinatorics, and representation theory. This book is a detailed account of this interplay. In the area of representation theory, the book discusses complex semisimple Lie algebras and semisimple algebraic groups; in addition, the representation theory of symmetric groups is discussed. In the area of algebraic geometry, the book explains in detail Grassmannian varieties, flag varieties, and their Schubert subvarieties.

Because of the connections with root systems, many of the geometric results admit elegant combinatorial description, a typical example being the description of the singular locus of a Schubert variety. This is shown to be a consequence of standard monomial theory (abbreviated SMT). Thus the book includes SMT and some important applications—singular loci of Schubert varieties, toric degenerations of Schubert varieties, and the relationship between Schubert varieties and classical invariant theory.

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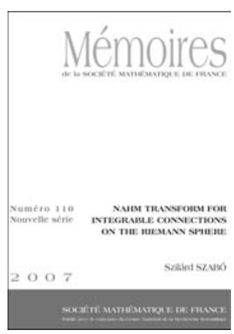
**Contents:** Introduction; Preliminaries; Structure theory of semisimple rings; Representation theory of finite groups; Representation theory of the symmetric group; Symmetric polynomials; Schur–Weyl duality and the relationship between representations of $Sd$ and $GL_n(C)$; Structure theory of complex semisimple Lie algebras; Representation theory of complex semisimple Lie algebras; Generalities on algebraic groups; Structure theory of reductive groups; Representation theory of semisimple algebraic groups; Geometry of the grassmannian, flag and their Schubert varieties via standard monomial theory; Singular locus of a Schubert variety in the flag variety $SL_n/B$; Applications; Appendix: Chevalley groups; Bibliography; List of symbols; Index.

**Hindustan Book Agency**

January 2009, 288 pages, Hardcover, ISBN: 978-81-85931-92-0, 2000 *Mathematics Subject Classification:* 14M15, **AMS members US$38**, List US$48, Order code HIN/40




## Nahm Transform for Integrable Connections on the Riemann Sphere

**Szilárd Szabó**, *University Louis Pasteur, Strasbourg, France*

The author defines Nahm transform for parabolic integrable connections with regular singularities and one Poincaré rank 1 irregular singularity on the Riemann sphere. After a first definition using $L^2$-cohomology, he gives an algebraic description in terms of hypercohomology. Exploiting these different interpretations, he gives the transformed object by explicit analytic formulas as well as geometrically, by its spectral curve. Finally, he shows that this transform is (up to a sign) an involution.

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

**Contents:** Introduction; Notations and statement of the results; Analysis of the Dirac operator; The transform of the integrable connection; Interpretation from the point of view of Higgs bundles; The inverse transform; Index; Bibliography.

**Mémoires de la Société Mathématique de France**, Number 110

November 2008, 114 pages, Softcover, ISBN: 978-2-85629-251-8, 2000 *Mathematics Subject Classification:* 53C07, 14H60, **Individual member US$36**, List US$40, Order code SMFMEM/110

## Surveys in Differential Geometry. Volume X

### Essays in Geometry in Memory of S.-S. Chern

**Shing-Tung Yau**, *Harvard University, Cambridge, MA*, Editor

This volume includes lectures on geometry and topology related to the works of the late and venerated S.-S. Chern. The lectures were presented at the 2005 Journal of Differential Geometry conference at Harvard University.

This larger format re-issue includes a correction to the table of contents, a revised preface, and an updated series listing at the front of the book.

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**Contents: B. Dai**, **C.-L. Terng**, and **K. Uhlenbeck**, On the space-time monopole equation; **V. Guillemin**, **S. Sternberg**, and **J. Weitsman**, The Erhardt function for symbols; **K. Liu**, Recent results on the moduli spaces of Riemann surfaces; **W. Meeks**, Applications of minimal surfaces to the topology of three-manifolds; **V. Moncrief**, An integral equation for spacetime curvature in general relativity; **A. Nietzke** and **C. Vafa**, Topological strings and their physical applications; **R. P. Thomas**, Notes on GIT and symplectic reduction for bundles and varieties; **S.-T. Yau**, Perspectives on geometric analysis; **S.-W. Zhang**, Distributions in algebraic dynamics.

**International Press**

December 2008, 430 pages, Hardcover, ISBN: 978-1-57146-122-3, 2000 *Mathematics Subject Classification:* 03-02, **AMS members US$76**, List US$95, Order code INPR/69.R

# Mathematical Physics


## Random Schrödinger Operators

**Margherita Disertori**, *ETH-Zurich, Switzerland*, **Werner Kirsch**, *Universität Hagen, Germany*, **Abel Klein**, *University of California, Irvine, CA*, **Frédéric Klopp**, *Université Paris-Nord, Villetaneuse, France*, and **Vincent Rivasseau**, *Université Paris XI, Orsay, France*

During the last thirty years, random Schrödinger operators, which originated in condensed matter physics, have been studied intensively and very productively. The theory is at the crossroads of a number of mathematical fields: the theory of operators, partial differential equations, the theory of probabilities, in particular the study of stochastic processes and that of random walks and Brownian motion in a random environment. This monograph aims to give the reader a panorama of the subject, from the now-classic foundations to very recent developments.

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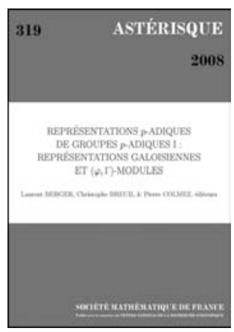
**Contents: W. Kirsch**, An invitation to random Schrödinger operators (with an appendix by F. Klopp); **A. Klein**, Multiscale analysis and localization of random operators; **M. Disertori** and **V. Rivasseau**, Random matrices and the Anderson model.

**Panoramas et Synthèses**, Number 25

November 2008, 213 pages, Softcover, ISBN: 978-2-85629-254-9, 2000 *Mathematics Subject Classification:* 82B44, 35J10, 47B80, 60H25, 81Q10, **Individual member US$65**, List US$72, Order code PASY/25

# Number Theory




## Représentations $p$-adiques de Groupes $p$-adiques I: Représentations Galoisiennes et $(\varphi,\Gamma)$-Modules

**Laurent Berger**, *Université de Lyon, France*, **Christophe Breuil**, *CNRS & IHES, Bures-sur-Yvette, France*, and **Pierre Colmez**, *École Polytechnique, Jussieu, France*, Editors

This volume is the first in a series of three dedicated to the $p$-adic Langlands correspondence for $\mathrm{GL}_2(\mathbf{Q}_p)$. The correspondence itself is the subject of the second volume (local aspects) and the third volume (global and geometric aspects). This book begins with a general introduction by Breuil to the three volumes.

The articles in this first volume have three broad themes : the study of classical $p$-adic representations and $(\varphi,\Gamma)$-modules, the study of families of $p$-adic representations, and the study of relative $p$-adic representations.

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**Contents: C. Breuil**, Introduction générale; **L. Berger**, Equations différentielles $p$-adiques et $(\varphi,N)$-modules filtrés; **F. Andreatta** and **O. Brinion**, Surconvergence des représentations $p$-adiques: le cas relatif; **P. Colmez**, Espaces vectoriels de dimension finie et représentations de de Rham; **P. Colmez**, Conducteur d'Artin d'une représentation de de Rham; **P. Colmez**, Représentations triangulines de dimension 2; **K. Kedlaya**, Slope filtrations for relative Frobenius; **L. Berger** and **P. Colmez**, Familles de représentations de de Rham et monodromie $p$-adique; **F. Andreatta** and **A. Iovita**, Global applications of relative $(\phi,\Gamma)$-modules I;

Appendix A. Galois cohomology via the Tate–Sen method; Appendix B. Artin–Schreier theory; References.

**Astérisque**, Number 319

January 2009, 419 pages, Softcover, ISBN: 978-2-85629-256-3, 2000 *Mathematics Subject Classification:* 11F80, 11G99, 11Sxx, 11S15, 11S20, 11S80, 12H25, 13K05, 14E22, 14F30, 14F20, **Individual member US$119**, List US$132, Order code AST/319

## Arithmetical Aspects of the Large Sieve Inequality

**Olivier Ramaré**, *Université Lille 1, France*, and **D. S. Ramana**, *Harish-Chandra Research Institute, Allahabad, India*

This book is an elaboration of a series of lectures given at the Harish–Chandra Research Institute. The reader will be taken through a journey on the arithmetical sides of the large sieve inequality which, when applied to the Farey dissection, will reveal connections between this inequality, the Selberg sieve and other less used notions such as pseudo-characters and the $\Lambda_Q$-function, as well as extend these theories.

One of the leading themes of these notes is the notion of so-called *local models* that throws a unifying light on the subject. As examples and applications, the authors present, among other things, an extension of the Brun–Tichmarsh Theorem, a new proof of Linnik's Theorem on quadratic residues, and an equally novel one of the Vinogradov's Three Primes Theorem; the authors also consider the problem of small prime gaps, of sums of two squarefree numbers and several other ones, some of them new, like a sharp upper bound for the number of twin primes $p$ that are such that $p + 1$ is squarefree. In the end the problem of equality in the large sieve inequality is considered, and several results in this area are also proved.

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**Contents:** Introduction; The large sieve inequality; An extension of the classical arithmetical theory of the large sieve; Some general remarks on arithmetical functions; A geometric interpretation; Further arithmetical applications; The Siegel zero effect; A weighted hermitian inequality; A first use of local models; Twin primes and local models; The three primes theorem; The Selberg sieve; Fourier expansion of sieve weights; The Selberg sieve for sequences; An overview; Some weighted sequences; Small gaps between primes; Approximating by a local model; Selecting other sets of moduli; Sums of two squarefree numbers; On a large sieve equality; Appendix; Notations; References; Index.

**Hindustan Book Agency**

January 2009, 210 pages, Softcover, ISBN: 978-81-85931-90-6, 2000 *Mathematics Subject Classification:* 11Nxx, 11M20, 11P32, **AMS members US$30**, List US$38, Order code HIN/36

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### Director

The International School for Advanced Studies (known as SISSA) seeks candidates for the position of Director of the School. SISSA (http://www.sissa.it) is a public university founded in 1978 in Trieste, Italy. Its mission is to perform leading-edge scientific research and to educate Ph.D. students and postdoctoral fellows. SISSA is comprised of about 70 faculty members, 240 Ph.D. students, 100 postdoctoral fellows, and no undergraduates. It is formed of 8 scientific departments spanning the areas of theoretical physics, mathematics, and neuroscience. The faculty and student body is international, with 42 nations represented; the English language is used in teaching, research, and all academic affairs.

The successful candidate is expected to assume the directorship by November 2010, initially for a term of 3 years, with the possibility of renewal. The director must be of an academic stature for appointment as a tenured professor in one of the existing sectors of SISSA, and will be responsible (1) for the academic and financial functions of the school and (2) for the relations of the school with national and local levels of government. The profile of candidates should include a record of outstanding scientific contributions in theoretical physics, mathematics, neuroscience, or related fields of science. Experience in managing institutional operations, knowledge of the Italian language and familiarity with the Italian university system are advantageous, while applicants currently outside the Italian university system are particularly encouraged.

Inquiries and statements of interest are welcome both from candidates and from those wishing to nominate third parties. Please send statements of interest or documented nominations to the Search Committee by May 15, 2009, using the address: SEARCH@sissa.it. (Search committee secretary: Alex Meehan, tel.: +39-040-3787463).

We confirm that SISSA does not discriminate on the basis of color, age, sex, race, religion, or national origin.

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## KOREA

### KOREA INSTITUTE FOR ADVANCED STUDY (IXZAS)
### School of Mathematics & School of Computational Sciences
### Postdoctoral Research Fellowships

The School of Mathematics and the School of Computational Sciences at the Korea Institute for Advanced Study (KIAS) invite applicants for the positions at the level of postdoctoral research fellows in pure and applied mathematics. KIAS, incepted in 1996, is committed to the excellence of research in basic sciences (mathematics, theoretical physics, and computational sciences) through high-quality research programs and a strong faculty body consisting of distinguished scientists and visiting scholars.

Applicants are expected to have demonstrated exceptional research potential, through the doctoral dissertation and beyond. The annual salary ranges approximately from W29,000,000–W42,000,000 and, in addition, a research fund of W7,000,000–W10,000,000 is provided each year.

Appointments may start as early as September 2009. The initial appointment will be for two years with a possibility of renewal for two additional years. Those interested are encouraged to contact faculty members in their research areas. Also please visit http://www.kias.re.kr for more information. Applicants should send a cover letter specifying the research area, a CV, a publication list, a summary of research plan, and should arrange for three letters of reference to be sent to:

School of Mathematics:
Ms. Minsung Lee (minsung@kias.re.kr)
KIAS 207-43, Cheongnyangni 2-dong
Dongdaemun-gu, Seoul, 1 3 0-722, Korea

School of Computational Sciences:
Mr. Oh Beom Kwon (accbum@kias.re.kr)
KIAS 207-43, Cheongnyangni 2-dong
Dongdaemun-gu, Seoul, 1 3 0-722, Korea

Email applications are strongly encouraged.

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## SINGAPORE

### NANYANG TECHNOLOGICAL UNIVERSITY
### Division of Mathematical Sciences

The Division of Mathematical Sciences http://www.spms.ntu.edu.sg/mas of the Nanyang Technological University (NTU), Singapore, is looking to add to its tenure-track faculty at all ranks. We encourage strong candidates in the areas of **Pure Mathematics, Applied Mathematics, Probability and Statistics** as well as **Theoretical Computer Science** to apply.

NTU is a research university, with low teaching loads, excellent facilities, ample research funding and support for conference travel. The Division of Mathematical Sciences consists of active and talented faculty members working in a variety of areas. Its student body includes some of the best in the region. It offers undergraduate programs in mathematical sciences and mathematics & economics, and a graduate program awarding Master's and Ph.D. degrees. Salary and benefits are competitive with the top universities around the world.

We seek people with excellent achievements in both research and teaching. Interested candidates are requested to send the following material to: MASrecruit@ntu.edu.sg.

- Application Letter
- Curriculum Vitae
- Research Statement
- Teaching Statement
- Names of at least three referees

Apart from the above faculty positions, there are also **16** three-to-five-year research fellowships (from fresh postdocs to senior research fellows) available. Applicants with a strong background in **one of the areas** of coding/cryptography and computational mathematics/image processing/computer vision are encouraged to send their application letters, detailed CVs, and the names/contact emails of two references to: ccrg_postdoc@ntu.edu.sg (for coding and cryptography) or compmath@ntu.edu.sg (for computational mathematics/image processing/computer vision).

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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.

## Urbana, Illinois

*University of Illinois at Urbana-Champaign*

### March 27–29, 2009

*Friday – Sunday*

### Meeting #1047

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: January
Program first available on AMS website: February 12, 2009
Program issue of electronic *Notices*: March
Issue of *Abstracts*: Volume 30, Issue 2

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: 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

**Jeffrey C. Lagarias**, University of Michigan, *From Apollonian circle packings to Fibonacci Numbers* (Erdős Memorial Lecture).

**Jacob Lurie**, Massachusetts Institute of Technology, *On the classification of topological field theories*.

**Gilles Pisier**, Texas A&M University, *Complex interpolation between Hilbert, Banach, and operator spaces*.

**Akshay Venkatesh**, New York University-Courant Institute, *L-functions: Identities and estimates*.

### Special Sessions

*Algebra, Geometry and Combinatorics*, **Rinat Kedem** and **Alexander T. Yong**, University of Illinois at Urbana-Champaign.

*Algebraic Methods in Statistics and Probability*, **Marlos A. G. Viana**, University of Illinois at Chicago.

*Complex Dynamics and Value Distribution*, **Aimo Hinkkanen** and **Joseph B. Miles**, University of Illinois at Urbana-Champaign.

*Concrete Aspects of Real Positive Polynomials*, **Victoria Powers**, Emory University, and **Bruce Reznick**, University of Illinois at Urbana-Champaign.

*Differential Geometry and Its Applications*, **Stephanie B. Alexander**, University of Illinois at Urbana-Champaign, and **Jianguo Cao**, University of Notre Dame.

*Geometric Function Theory and Analysis on Metric Spaces*, **Sergiy Merenkov**, **Jeremy Taylor Tyson**, and **Jang-Mei Wu**, University of Illinois at Urbana-Champaign.

*Geometric Group Theory*, **Sergei V. Ivanov**, **Ilya Kapovich**, **Igor Mineyev**, and **Paul E. Schupp**, University of Illinois at Urbana-Champaign.

*Graph Theory*, **Alexander V. Kostochka** and **Douglas B. West**, University of Illinois at Urbana-Champaign.

*Holomorphic and CR Mappings*, **John P. D'Angelo**, **Jiri Lebl**, and **Alex Tumanov**, University of Illinois at Urbana-Champaign.

*Hyperbolic Geometry and Teichmuller Theory*, **Jason Deblois**, University of Illinois at Chicago, **Richard P. Kent IV**, Brown University, and **Christopher J. Leininger**, University of Illinois at Urbana-Champaign.

*Local and Homological Methods in Commutative Algebra*, **Florian Enescu**, Georgia State University, and **Sandra Spiroff**, University of Mississippi.

*Mathematical Visualization*, **George K. Francis**, University of Illinois at Urbana-Champaign, **Louis H. Kauffman**, University of Illinois at Chicago, **Dennis Martin Roseman**, University of Iowa, and **Andrew J. Hanson**, Indiana University.

*Nonlinear Partial Differential Equations and Applications*, **Igor Kukavica**, University of Southern California, and **Anna L. Mazzucato**, Pennsylvania State University.

*Number Theory in the Spirit of Erdős*, **Kevin Ford** and **A. J. Hildebrand**, University of Illinois at Urbana-Champaign.

*Operator Algebras and Operator Spaces*, **Zhong-Jin Ruan**, **Florin P. Boca**, and **Marius Junge**, University of Illinois at Urbana-Champaign.

*Probabilistic and Extremal Combinatorics*, **Jozsef Balogh** and **Zoltan Furedi**, University of Illinois at Urbana-Champaign.

*The Interface Between Number Theory and Dynamical Systems*, **Florin Boca**, University of Illinois at Urbana-Champaign, **Jeffrey Lagarias**, University of Michigan, and **Kenneth Stolarsky**, University of Illinois at Urbana-Champaign.

*The Logic and Combinatorics of Algebraic Structures.*, **John Snow**, Concordia University, and **Jeremy Alm**, Illinois College.

*Time, Scale, and Frequency Methods in Harmonic Analysis*, **Richard S. Laugesen**, University of Illinois at Urbana-Champaign, and **Darrin M. Speegle**, St. Louis University.

*Topological Dynamics and Ergodic Theory*, **Alica Miller**, University of Louisville, and **Joseph Rosenblatt**, University of Illinois at Urbana-Champaign.

*Topological Field Theories, Representation Theory, and Algebraic Geometry*, **Thomas Nevins**, University of Illinois at Urbana-Champaign, and **David Ben-Zvi**, University of Texas at Austin.

*q-Series and Partitions*, **Bruce Berndt**, University of Illinois at Urbana-Champaign, and **Ae Ja Yee**, Pennsylvania State University.

# Raleigh, North Carolina

## *North Carolina State University*

### April 4–5, 2009

*Saturday – Sunday*

### Meeting #1048

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: January 2009
Program first available on AMS website: February 19, 2009
Program issue of electronic *Notices*: April 2009
Issue of *Abstracts*: Volume 30, Issue 2

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: 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

**Nathan M. Dunfield**, University of Illinois at Urbana-Champaign, *Surfaces in finite covers of 3-manifolds: The virtual Haken conjecture*.

**Reinhard C. Laubenbacher**, Virginia Bioinformatics Institute, *Algebraic models in systems biology*.

**Jonathan C. Mattingly**, Duke University, *Stochastically forced fluid equations: Transfer between scales and ergodicity*.

**Raman Parimala**, Emory University, *Arithmetic of linear algebraic groups over 2-dimensional geometric fields*.

**Michael S. Waterman**, University of Southern California, *Reading DNA sequences: Twenty-first century technology with eighteenth century mathematics* (Einstein Public Lecture in Mathematics).

### Special Sessions

*Advancements in Turbulent Flow Modeling and Computation*, **Leo G. Rebholz**, Clemson University, and **Traian Iliescu**, Virginia Polytechnic Institute and State University.

*Algebraic Groups and Symmetric Spaces*, **Stacy Beun**, Cabrini College, and **Aloysius Helminck**, North Carolina State University.

*Applications of Algebraic and Geometric Combinatorics*, **Seth M. Sullivant**, Harvard University, and **Carla D. Savage**, North Carolina State University.

*Applications of Dynamical Systems to Problems in Biology*, **John E. Franke** and **James F. Selgrade**, North Carolina State University.

*Brauer Groups, Quadratic Forms, Algebraic Groups, and Lie Algebras*, **Eric S. Brussel** and **Skip Garibaldi**, Emory University.

*Commutative Rings and Monoids*, **Scott T. Chapman**, Sam Houston State University, and **James B. Coykendall**, North Dakota State University.

*Computational Methods in Lie Theory*, **Eric Sommers**, University of Massachusetts, Amherst, and **Molly Fenn**, North Carolina State University.

*Deferred Correction Methods and their Applications*, **Elizabeth L. Bouzarth** and **Anita T. Layton**, Duke University.

*Enumerative Geometry and Related Topics*, **Richard L. Rimanyi**, University of North Carolina, Chapel Hill, and **Leonardo C. Mihalcea**, Duke University.

*Galois Module Theory and Hopf Algebras*, **Robert G. Underwood**, Auburn University Montgomery, and **James E. Carter**, College of Charleston.

*Geometry of Differential Equations*, **Thomas A. Ivey**, College of Charleston, and **Irina A. Kogan**, North Carolina State University.

*Homotopical Algebra with Applications to Mathematical Physics*, **Thomas J. Lada**, North Carolina State University, and **Jim Stasheff**, University of North Carolina, Chapel Hill.

*Kac-Moody Algebras, Vertex Algebras, Quantum Groups, and Applications*, **Bojko N. Bakalov**, **Kailash C. Misra**, and **Naihuan N. Jing**, North Carolina State University.

*Low-Dimensional Topology and Geometry*, **Nathan M. Dunfield**, University of Illinois at Urbana-Champaign, **John B. Etnyre**, Georgia Institute of Technology, and **Lenhard Ng**, Duke University.

*Mathematical Progress and Challenges for Biological Materials*, **Mansoor A. Haider**, North Carolina State University, and **Gregory Forest**, University of North Carolina, Chapel Hill.

*Mathematics of Immunology and Infectious Diseases*, **Stanca M. Ciupe**, Duke University, and **Jonathan Forde**, Hobart and William Smith Colleges.

*Nonlinear Dynamics and Control*, **Anthony M. Bloch**, University of Michigan, Ann Arbor, and **Dmitry Zenkov**, North Carolina State University.

*Numerical Solution of Partial Differential Equations and Applications*, **Alina Chertock** and **Zhilin Li**, North Carolina State University.

*Recent Advances in Symbolic Algebra and Analysis*, **Michael F. Singer** and **Agnes Szanto**, North Carolina State University.

*Rings, Algebras, and Varieties in Combinatorics*, **Patricia Hersh**, North Carolina State University, **Christian Lenart**, SUNY Albany, and **Nathan Reading**, North Carolina State University.

*Stochastic Dynamics*, **Yuri Bakhtin**, Georgia Institute of Technology, and **Scott McKinley** and **Jonathan C. Mattingly**, Duke University.

*The Mathematics of Biochemical Reaction Networks*, **Anne Shiu**, University of California Berkeley, **Manoj Gopalkrishnan**, University of Southern California, and **Gheorghe Craciun**, University of Wisconsin-Madison.

# Worcester, Massachusetts

## *Worcester Polytechnic Institute*

### April 25–26, 2009

*Saturday – Sunday*

### Meeting #1050

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: February 2009
Program first available on AMS website: March 12, 2009
Program issue of electronic *Notices*: April 2009
Issue of *Abstracts*: Volume 30, Issue 3

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: 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

**Octav Cornea**, Université; de Montréal, *Lagrangian submanifolds: From physics to number theory*.

**Fengbo Hang**, Courant Institute of New York University, *Topology of weakly differentiable maps*.

**Umberto Mosco**, Worcester Polytechnic Institute, *Fractal spectra between Scylla and Charybdis*.

**Kevin Whyte**, University of Illinois at Chicago, *A rapid survey of coarse geometry*.

### Special Sessions

*Algebraic Graph Theory, Association Schemes, and Related Topics*, **William J. Martin**, Worcester Polytechnic Institute, and **Sylvia A. Hobart**, University of Wyoming.

*Analysis of Weakly Differentiable Maps with Constraints and Applications*, **Fengbo Hang**, Courant Institute, New York University, and **Mohammad Reza Pakzad**, University of Pittsburgh.

*Discrete Geometry and Combinatorics*, **Egon Schulte**, Northeastern University, and **Brigitte Servatius**, Worcester Polytechnic Institute.

*Effective Dynamics and Interactions of Localized Structures in Schrödinger Type Equations*, **Fridolin Ting**, Lakehead University.

*Number Theory*, **John T. Cullinan**, Bard College, and **Siman Wong**, University of Massachusetts, Amherst.

*Quasi-Static and Dynamic Evolution in Fracture Mechanics*, **Christopher J. Larsen**, Worcester Polytechnic Institute.

*Real and Complex Dynamics of Rational Difference Equations with Applications*, **M. R. S. Kulenovic** and **Orlando Merino**, University of Rhode Island.

*Scaling, Irregularities, and Partial Differential Equations*, **Umberto Mosco** and **Bogdan M. Vernescu**, Worcester Polytechnic Institute.

*Symplectic and Contact Topology*, **Peter Albers**, Purdue University/ETH Zurich, and **Basak Gurel**, Vanderbilt University.

*The Mathematics of Climate Change*, **Catherine A. Roberts** and **Gareth E. Roberts**, College of the Holy Cross, and **Mary Lou Zeeman**, Bowdoin College.

*Topological Robotics*, **Li Han** and **Lee N. Rudolph**, Clark University.

# San Francisco, California

*San Francisco State University*

### April 25–26, 2009

*Saturday – Sunday*

### Meeting #1049

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: February 2009
Program first available on AMS website: March 12, 2009
Program issue of electronic *Notices*: April 2009
Issue of *Abstracts*: Volume 30, Issue 3

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: 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

**Yehuda Shalom**, University of California Los Angeles, *Bounded generation of arithmetic groups and some recent applications*.

**Roman Vershynin**, University of California Davis, *Random matrices and asymptotic convex geometry*.

**Karen Vogtmann**, Cornell University, *Actions of automorphism groups of free groups*.

**Efim Zelmanov**, University of California San Diego, *Asymptotic properties of finite groups and finite-dimensional algebras*.

### Special Sessions

*Advances in the Theory of Integer Linear Optimization and its Extensions*, **Matthias Koeppe** and **Peter Malkin**, University of California Davis.

*Algebra and Number Theory with Polyhedra*, **Matthias Beck**, San Francisco State University, and **Christian Haase**, Freie Universität Berlin.

*Applications of Knot Theory to the Entanglement of Biopolymers*, **Javier Arsuaga**, San Francisco State University, **Kenneth Millett**, University of California Santa Barbara, and **Mariel Vazquez**, San Francisco State University.

*Aspects of Differential Geometry*, **David Bao**, San Francisco State University, and **Lei Ni**, University of California San Diego.

*Banach Algebras, Topological Algebras, and Abstract Harmonic Analysis*, **Thomas V. Tonev**, University of Montana-Missoula, and **Fereidoun Ghahramani**, University of Manitoba.

*Concentration Inequalities*, **Sourav Chatterjee**, University of California Berkeley, and **Roman Vershynin**, University of California Davis.

*Geometry and Topology of Orbifolds*, **Elizabeth Stanhope**, Lewis & Clark University, and **Joseph E. Borzellino**, California State University San Luis Obispo.

*Lie group actions, Teichmüller Flows and Number Theory*, **Jayadev Athreya**, Yale University, **Yitwah Cheung**, San Francisco State University, and **Anton Zorich**, Rennes University.

*Matroids in Algebra and Geometry*, **Federico Ardila**, San Francisco State University, and **Lauren Williams**, Harvard University.

*Nonlinear Dispersive Equations*, **Sebastian Herr**, University of California Berkeley, and **Jeremy L. Marzuola**, Columbia University.

*Nonlinear Partial Differential Equations*, **Igor Kukavica**, **Amjad Tuffaha**, and **Mohammed Ziane**, University of Southern California.

*Recent Progress in Geometric Group Theory*, **Seonhee Lim** and **Anne Thomas**, Cornell University.

# Waco, Texas

*Baylor University*

### October 16–18, 2009

*Friday – Sunday*

### Meeting #1051

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: August 2009
Program first available on AMS website: September 3, 2009
Program issue of electronic *Notices*: October 2009
Issue of *Abstracts*: Volume 30, Issue 4

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 30, 2009
For abstracts: August 25, 2009

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

### Invited Addresses

**David Ben-Zvi**, University of Texas at Austin, *Title to be announced.*

**Alexander A. Kiselev**, University of Wisconsin, *Title to be announced.*

**Michael C. Reed**, Duke University, *Title to be announced.*

**Igor Rodnianski**, Princeton University, *Title to be announced.*

### Special Sessions

*Commutative Algebra: Module and Ideal Theory* (Code: SS 4A), **Lars W. Christensen**, Texas Tech University, **Louiza Fouli**, University of Texas at Austin, and **David Jorgensen**, University of Texas at Arlington.

*Dynamic Equations on Time Scales: Analysis and Applications* (Code: SS 1A), **John M. Davis**, **Ian A. Gravagne**, and **Robert J. Marks**, Baylor University.

*Fusion Categories and Applications* (Code: SS 7A), **Deepak Naidu** and **Eric Rowell**, Texas A&M University.

*Harmonic Analysis and Partial Differential Equations* (Code: SS 8A), **Susan Fiedlander**, University of Southern California, **Natasa Pavlovic**, University of Texas at Austin, and **Nikolaos Tzirakis**, University of Illinois at Urbana-Champaign.

*Lie Groups, Lie Algebras, and Representations* (Code: SS 6A), **Markus Hunziker**, **Mark Sepanski**, and **Ronald Stanke**, Baylor University.

*Mathematical Models of Neuronal and Metabolic Mechanisms* (Code: SS 3A), **Janet Best**, Ohio State University, and **Michael Reed**, Duke University.

*Numerical Solutions of Singular or Perturbed Partial Differential Equation Problems with Applications* (Code: SS 2A), **Peter Moore**, Southern Methodist University, and **Qin Sheng**, Baylor University.

*Topological Methods for Boundary Value Problems for Ordinary Differential Equations* (Code: SS 5A), **Richard Avery**, Dakota State University, **Paul W. Eloe**, University of Dayton, and **Johnny Henderson**, Baylor University.

# University Park, Pennsylvania

*Pennsylvania State University*

### October 24–25, 2009

*Saturday – Sunday*

### Meeting #1052

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: August 2009
Program first available on AMS website: September 10, 2009
Program issue of electronic *Notices*: October 2009
Issue of *Abstracts*: Volume 30, Issue 4

### Deadlines

For organizers: March 24, 2009
For consideration of contributed papers in Special Sessions: July 7, 2009
For abstracts: September 1, 2009

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

### Invited Addresses

**Michael K. H. Kiessling**, Rutgers University, *Title to be announced.*

**Kevin R. Payne**, Universita degli di Milano, *Title to be announced.*

**Laurent Saloff-Coste**, Cornell University, *Title to be announced.*

**Robert C. Vaughan**, Penn State University, *Title to be announced.*

### Special Sessions

*Combinatorial and Homological Aspects of Commutative Algebra* (Code: SS 3A), **Amanda I. Beecher**, United States Military Academy, and **Alexandre B. Tchernev**, University at Albany.

*Difference Equations and Applications* (Code: SS 2A), **Michael A. Radin**, Rochester Institute of Technology.

*Geometry of Integrable and Non-Integrable Dynamics* (Code: SS 5A), **Boris Khesin**, University of Toronto, and **Mark Levi** and **Sergei Tabachnikov**, Pennsylvania State University.

*Homotopy Theory* (Code: SS 1A), **James Gillespie** and **Mark W. Johnson**, Pennsylvania State University, **Simona Paoli**, University of Haifa, and **Donald Yau**, Ohio State University.

*Integrable Systems and Related Areas* (Code: SS 4A), **Sam Evans** and **Michael Gekhtman**, University of Notre Dame, and **Luen-Chau Li**, Pennsylvania State University.

# Boca Raton, Florida

*Florida Atlantic University*

### October 30 – November 1, 2009

*Friday – Sunday*

### Meeting #1053

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: August 2009
Program first available on AMS website: September 17, 2009
Program issue of electronic *Notices*: October 2009
Issue of *Abstracts*: Volume 30, Issue 4

### Deadlines

For organizers: March 30, 2009

For consideration of contributed papers in Special Sessions: July 14, 2009
For abstracts: September 8, 2009

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

### Invited Addresses

**Spyros Alexakis**, Princeton University, *Title to be announced.*

**Kai-Uwe Bux**, University of Virginia, *Title to be announced.*

**Dino J. Lorenzini**, University of Georgia, *Title to be announced.*

**Eduardo D. Sontag**, Rutgers University, *Title to be announced.*

### Special Sessions

*Applied Partial Differential Equations* (Code: SS 10A), **Shar Sajjadi** and **Timothy A. Smith**, Embry Riddle Aeronautical University.

*Commutative Ring Theory* (Code: SS 3A), **Alan Loper**, Ohio State University, and **Lee C. Klingler**, Florida Atlantic University.

*Concentration, Functional Inequalities, and Isoperimetry* (Code: SS 2A), **Mario Milman**, Florida Atlantic University, **Christian Houdre**, Georgia Institute of Technology, and **Emanuel Milman**, Institute for Advanced Study.

*Constructive Mathematics* (Code: SS 1A), **Robert Lubarsky**, **Fred Richman**, and **Martin Solomon**, Florida Atlantic University.

*Dynamical Systems* (Code: SS 6A), **William D. Kalies** and **Vincent Naudot**, Florida Atlantic University.

*Enumerative Combinatorics* (Code: SS 4A), **Christian Krattenthaler**, University of Vienna, and **Aaron D. Meyerowitz**, **Heinrich Niederhausen**, and **Wandi Wei**, Florida Atlantic University.

*Harmonic Analysis* (Code: SS 5A), **Galia D. Dafni**, Concordia University, and **J. Michael Wilson**, University of Vermont, Burlington.

*Homological Aspects of Module Theory* (Code: SS 7A), **Andrew R. Kustin**, University of South Carolina, **Sean M. Sather-Wagstaff**, North Dakota State University, and **Janet Vassilev**, University of New Mexico.

*Invariants of Knots and Links* (Code: SS 9A), **Heather A. Dye**, McKendree University, **Mohamed Elhamdadi**, University of South Florida, and **Louis H. Kauffman**, University of Illinois at Chicago.

*Recent Advances in Probability and Statistics* (Code: SS 8A), **Lianfen Qian** and **Hongwei Long**, Florida Atlantic University.

# Riverside, California

## *University of California*

### November 7–8, 2009
*Saturday – Sunday*

### Meeting #1054
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: September 2009
Program first available on AMS website: September 24, 2009
Program issue of electronic *Notices*: November 2009
Issue of *Abstracts*: Volume 30, Issue 4

### Deadlines
For organizers: April 6, 2009
For consideration of contributed papers in Special Sessions: July 21, 2009
For abstracts: September 15, 2009

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

### Invited Addresses

**Christopher Hacon**, University of Utah, *Title to be announced.*

**Birge Huisgen-Zimmerman**, University of California Santa Barbara, *Title to be announced.*

**Jun Li**, Stanford University, *Title to be announced.*

**Joseph Teran**, University of California Los Angeles, *Title to be announced.*

### Special Sessions

*Algebraic Geometry* (Code: SS 1A), **Christopher Hacon**, University of Utah, and **Ziv Ran**, University of California Riverside.

*Fluid Mechanics* (Code: SS 5A), **James Kelliher** and **Qi Zhang**, University of California Riverside.

*Fractal Geometry, Dynamical Systems, Number Theory and Analysis on Rough Spaces* (Code: SS 6A), **Michel L. Lapidus**, University of California Riverside, **Hung Lu**, Hawaii Pacific University, and **Erin P. J. Pearse**, University of Iowa.

*History and Philosophy of Mathematics* (Code: SS 4A), **Shawnee L. McMurran**, California State University San Bernardino, and **James J. Tattersall**, Providence College.

*Homotopy Theory and Higher Algebraic Structures* (Code: SS 8A), **John Baez** and **Julie Bergner**, University of California Riverside.

*Interactions Between Algebraic Geometry and Noncommutative Algebra* (Code: SS 9A), **Kenneth R. Goodearl**, University of California Santa Barbara, **Daniel S. Rogalski**, University of California San Diego, and **James Zhang**, University of Washington.

*Knotting Around Dimension Three: A Special Session in Memory of Xiao-Song Lin* (Code: SS 11A), **Martin**

**Scharlemann**, University of California Santa Barbara, and **Mohammed Ait Nouh**, University of California Riverside.

*Noncommutative Geometry* (Code: SS 2A), **Vasiliy Dolgushev** and **Wee Liang Gan**, University of California Riverside.

*Operator Algebras* (Code: SS 13A), **Marta Asaeda** and **Aviv Censor**, University of California Riverside, and **Adrian Ioana**, Clay Institute and Caltech.

*Representation Theory* (Code: SS 3A), **Vyjayanthi Chari**, **Wee Liang Gan**, and **Jacob Greenstein**, University of California Riverside.

*Representations of Finite-Dimensional Algebras* (Code: SS 7A), **Frauke Bleher**, University of Iowa, **Birge Huisgen-Zimmermann**, University of California at Santa Barbara, and **Markus Schmidmeier**, Florida Atlantic University.

*Research Conducted by Students* (Code: SS 10A), **Robert G. Niemeyer** and **Jack R. Bennett**, University of California Riverside.

*Stochastic Analysis and Applications* (Code: SS 12A), **Michael L. Green**, **Alan J. Krinik**, and **Randall S. Swift**, California State Polytechnic University Pomona.

# Seoul, Korea

### December 16–20, 2009

*Wednesday – Sunday*

### Meeting #1055

*First Joint International Meeting of the AMS and the Korean Mathematical Society.*
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: June 2009
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 consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# San Francisco, California

## *Moscone Center West and the San Francisco Marriott*

### January 13–16, 2010

*Wednesday – Saturday*
*Joint Mathematics Meetings, including the 116th Annual Meeting of the AMS, 93rd 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 of Industrial and Applied Mathematics (SIAM).*
Associate secretary: Matthew Miller
Announcement issue of *Notices*: October 2009
Program first available on AMS website: November 1, 2009
Program issue of electronic *Notices*: January 2010
Issue of *Abstracts*: Volume 31, Issue 1

### Deadlines

For organizers: April 1, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Lexington, Kentucky

## *University of Kentucky*

### March 27–28, 2010

*Saturday – Sunday*
Southeastern Section
Associate secretary: Matthew Miller
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 28, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# St. Paul, Minnesota

## *Macalester College*

### April 10–11, 2010

*Saturday – Sunday*
Central Section
Associate secretary: Susan J. Friedlander
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 10, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Albuquerque, New Mexico

*University of New Mexico*

**April 17–18, 2010**
*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 17, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Newark, New Jersey

*New Jersey Institute of Technology*

**May 22–23, 2010**
*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: November 23, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Berkeley, California

*University of California Berkeley*

**June 2–5, 2010**
*Wednesday – Saturday*
*Eighth Joint International Meeting of the AMS and the Sociedad Matemática Mexicana.*
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: February 2010
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 consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Syracuse, New York

*Syracuse University*

**October 2–3, 2010**
*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: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Los Angeles, California

*University of California Los Angeles*

**October 9–10, 2010**
*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: March 10, 2010
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Notre Dame, Indiana

*Notre Dame University*

**October 29–31, 2010**

*Friday – Sunday*
Central Section
Associate secretary: Susan J. Friedlander
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: February 19, 2010
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# New Orleans, Louisiana

*New Orleans Marriott and Sheraton New Orleans Hotel*

**January 5–8, 2011**

*Wednesday – Saturday*
*Joint Mathematics Meetings, including the 117th Annual Meeting of the AMS, 94th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for 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 2010
Program first available on AMS website: November 1, 2010
Program issue of electronic *Notices*: January 2011
Issue of *Abstracts*: Volume 32, Issue 1

**Deadlines**

For organizers: April 1, 2010
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Statesboro, Georgia

*Georgia Southern University*

**March 12–13, 2011**

*Saturday – Sunday*
Southeastern Section
Associate secretary: Matthew Miller
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 12, 2010
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Worcester, Massachusetts

*College of the Holy Cross*

**April 9–10, 2011**

*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: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Boston, Massachusetts

*John B. Hynes Veterans Memorial Convention Center, Boston Marriott Hotel, and Boston Sheraton Hotel*

**January 4–7, 2012**

*Wednesday – Saturday*
*Joint Mathematics Meetings, including the 118th Annual Meeting of the AMS, 95th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the*

*National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).*

Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2011
Program first available on AMS website: November 1, 2011
Program issue of electronic *Notices*: January 2012
Issue of *Abstracts*: Volume 33, Issue 1

### Deadlines

For organizers: April 1, 2011
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# San Diego, California

## *San Diego Convention Center and San Diego Marriott Hotel and Marina*

### January 9–12, 2013

*Wednesday – Saturday*

*Joint Mathematics Meetings, including the 119th Annual Meeting of the AMS, 96th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).*

Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 2012
Program first available on AMS website: November 1, 2012
Program issue of electronic *Notices*: January 2012
Issue of *Abstracts*: Volume 34, Issue 1

### Deadlines

For organizers: April 1, 2012
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Baltimore, Maryland

## *Baltimore Convention Center, Baltimore Hilton, and Marriott Inner Harbor*

### January 15–18, 2014

*Wednesday – Saturday*

*Joint Mathematics Meetings, including the 120th Annual Meeting of the AMS, 97th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).*

Associate secretary: Matthew Miller
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: April 1, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# San Antonio, Texas

## *Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio*

### January 10–13, 2015

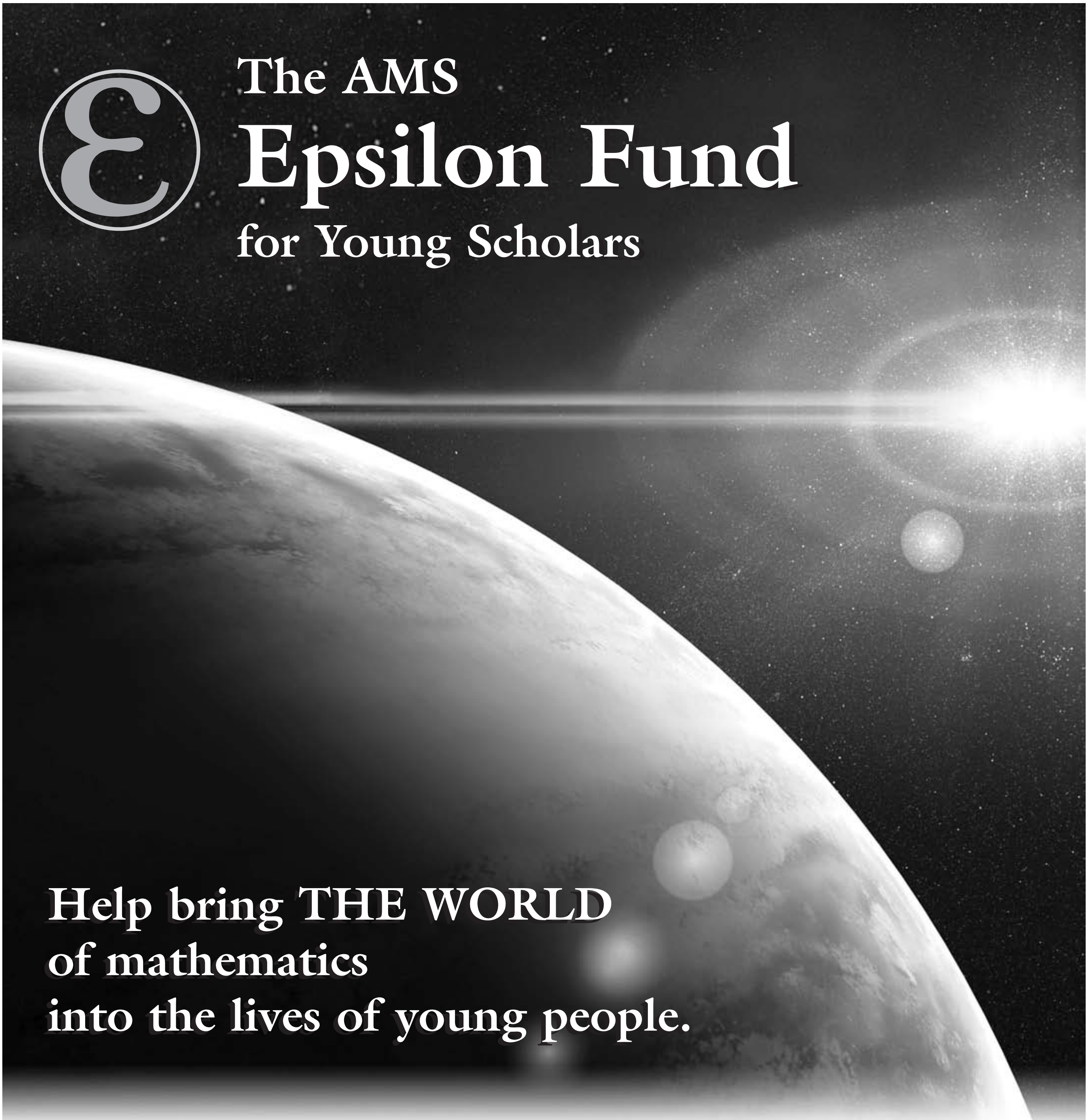
*Saturday – Tuesday*

*Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).*

Associate secretary: 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 consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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09/04

# Meetings and Conferences of the AMS

**Associate Secretaries of the AMS**

**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.

**Central Section: Susan J. Friedlander,** Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

**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: Matthew Miller,** Department of Mathematics, University of South Carolina, Columbia, SC 29208-0001, e-mail: miller@math.sc.edu; telephone: 803-777-3690.

**2009 Seoul, Korea Meeting:** 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.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information can be found at www.ams.org/meetings/.**

## Meetings:



### Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 89 in the January 2009 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:** (see http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

Co-sponsored conferences:

June 13–July 3, 2009: Mathematics Research Communities, Snowbird, UT (see www.ams.org/amsmtgs/mrc.html for more information).

# Opportunities

**Tata Institute of Fundamental Research**
**Centre for Applicable Mathematics, Bangalore, India**
http://math.tifrbng.res.in

**Positions available :** *Faculty / Post Doctoral*

Applications are invited from promising mathematicians working in the general area of Applicable Mathematics : Differential Equations (Theory/Computations), Fluid Mechanics, Probability and Stochastic Process, Statistics, Mathematical Biology, Mathematical Modeling. Applications from those working in other related areas of Analysis will also be considered. All levels involve teaching of at least one course in two semesters.

**Interested persons are invited to send**

**1. A letter of intent**
**2. Curriculum Vitae, including list of publications**
**3. Names and addresses of at least three referees**

**Email**: deanbmf@math.tifrbng.res.in

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