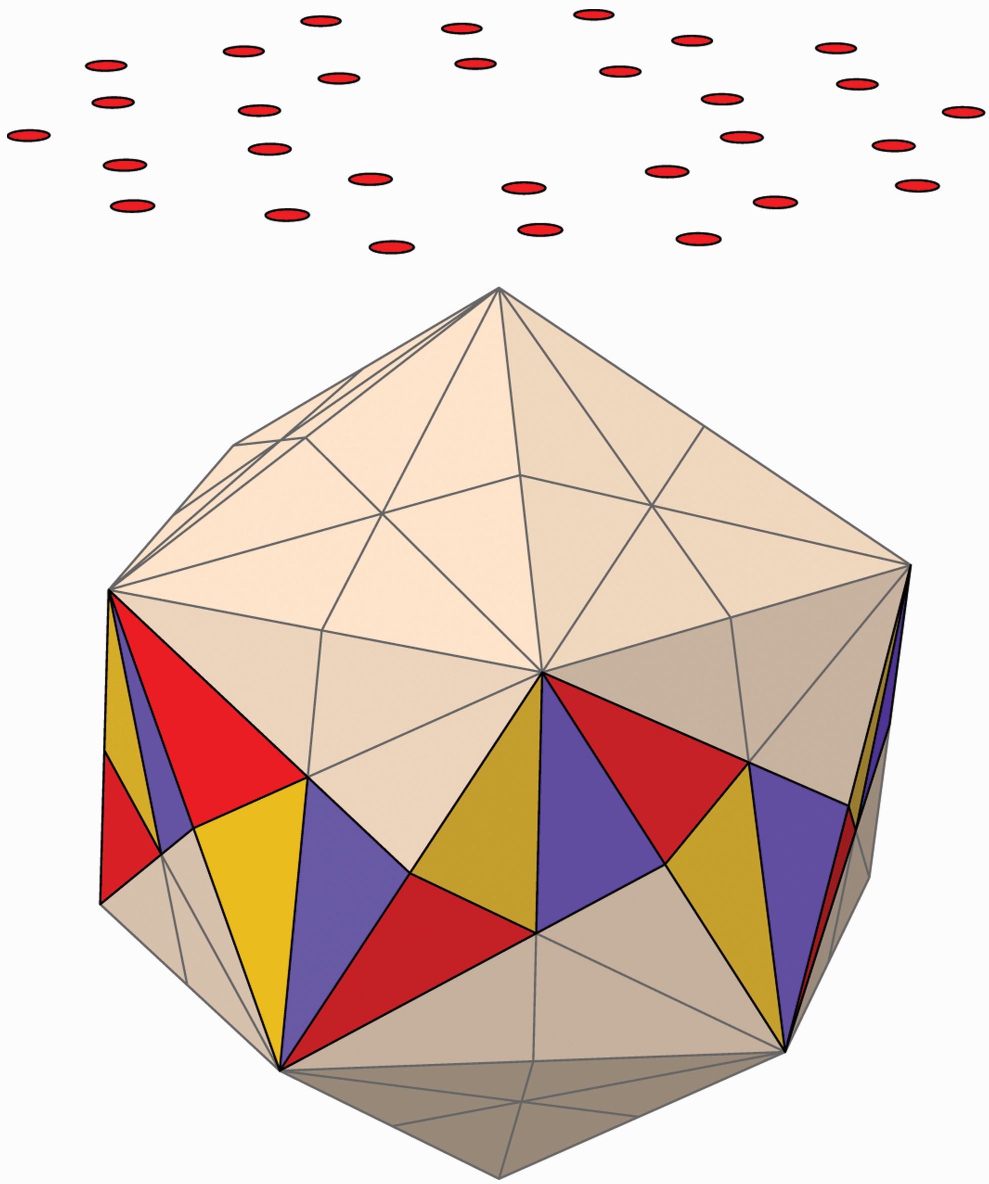
ISSN 0002-9920

Notices

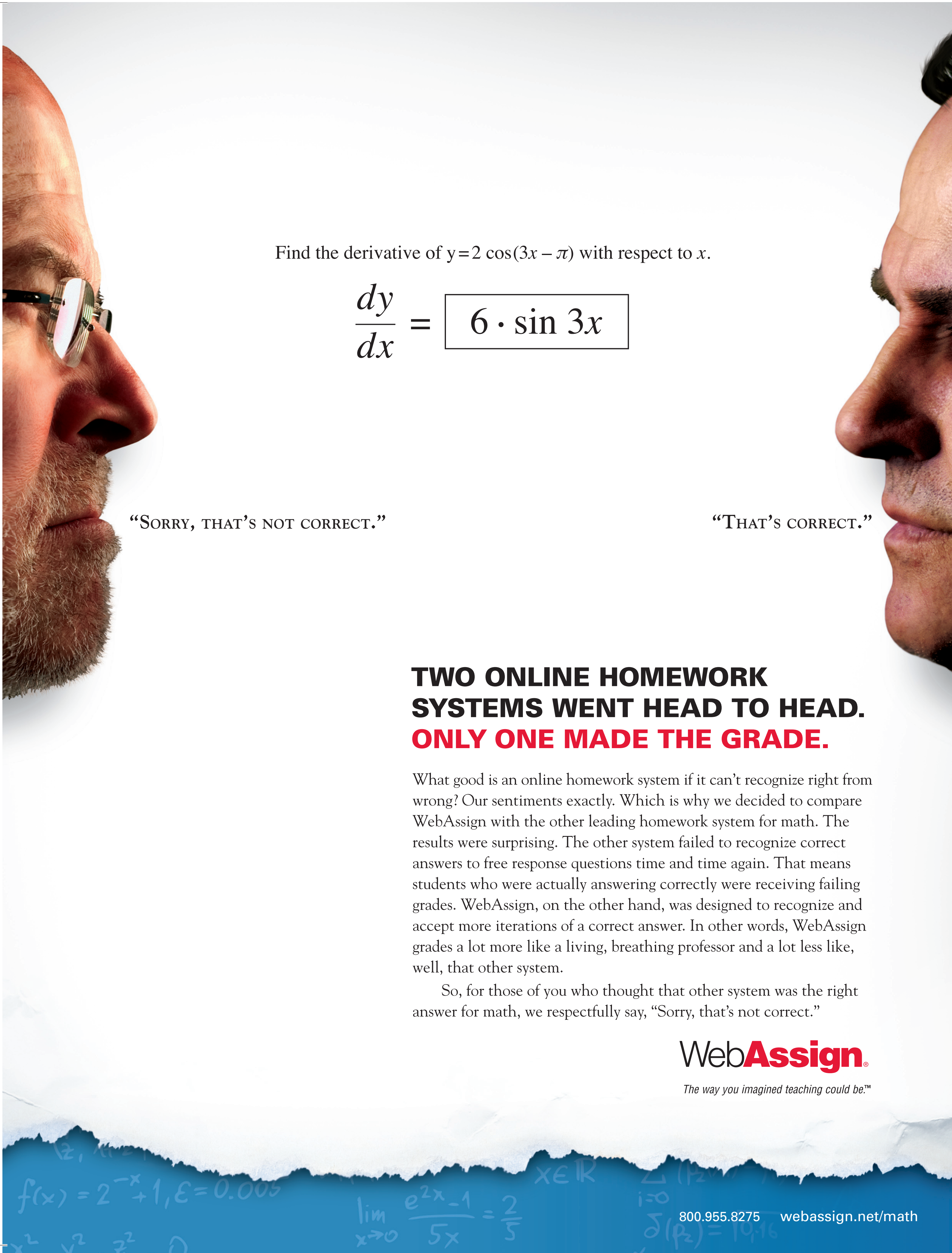
of the American Mathematical Society

September 2011

Volume 58, Number 8



About the Cover:
The magical Coxeter transformation
(see page 1200)


Find the derivative of y = 2 cos(3x – π) with respect to x.
dy/dx = 6 · sin 3x
"Sorry, that's not correct."
"That's correct."
TWO ONLINE HOMEWORK SYSTEMS WENT HEAD TO HEAD.
ONLY ONE MADE THE GRADE.
What good is an online homework system if it can't recognize right from wrong? Our sentiments exactly. Which is why we decided to compare WebAssign with the other leading homework system for math. The results were surprising. The other system failed to recognize correct answers to free response questions time and time again. That means students who were actually answering correctly were receiving failing grades. WebAssign, on the other hand, was designed to recognize and accept more iterations of a correct answer. In other words, WebAssign grades a lot more like a living, breathing professor and a lot less like, well, that other system.
So, for those of you who thought that other system was the right answer for math, we respectfully say, "Sorry, that's not correct."
WebAssign®
The way you imagined teaching could be.™
800.955.8275
webassign.net/math

ONE PLUS ONE EQUALS MORE THAN JUST TWO…

Become a Member of the

AMS *& the* AWM

VISIT THE AMS BOOTH AT ICERM

40 YEARS AND COUNTING –
AWM'S CELEBRATION OF WOMEN
IN MATHEMATICS

September 17 & 18, 2011
Brown University
Providence, RI

AMS
AMERICAN MATHEMATICAL SOCIETY

The American Mathematical Society furthers mathematical research and scholarship and serves the global community through publications, meetings, advocacy and programs.

AMS.ORG

AWM
AWM 40TH ANNIVERSARY 40 1971–2011

ASSOCIATION FOR
WOMEN IN MATHEMATICS

The Association for Women in Mathematics encourages women and girls to study and to have active careers in the mathematical sciences, and promotes equal opportunity and the equal treatment of women and girls in the mathematical sciences.

AWM-MATH.ORG

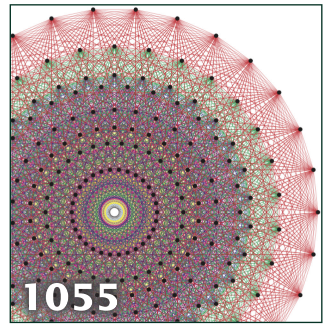
Notices

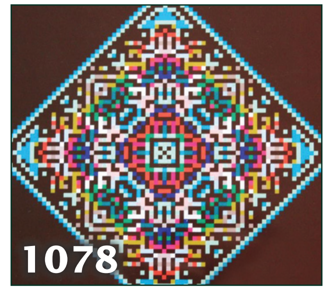
of the American Mathematical Society

September 2011

Communications

Commentary





Features

The September issue features many exciting and diverse articles. One, by David Borthwick and Skip Garibaldi, is on the group E_8 and its importance for physics. Another, by Fields Medalist S.-T. Yau and Steve Nadis, is about string theory and the shape of the universe. David Zitarelli writes about the 1904 Mathematics Congress in St. Louis. A number of authors share their memories of Gerhard Hochschild. Keith Stroyan, in his education column, discusses why so many students take calculus. Peter Olver contributes the first publication column on journals in flux. Susan Hezlet and others report on the workshop at MSRI on the changing nature of mathematics journals. And Eric Friedlander (president of the AMS) and Frank Morgan debate the merits of the Fellows Program.

—Steven G. Krantz, Editor

Notices

of the American Mathematical Society

SUBSCRIPTION INFORMATION: Subscription prices for Volume 59 (2012) are US$531 list; US$424.80 institutional member; US$318.60 individual member; US$459 corporate member. (The subscription price for members is included in the annual dues.) A late charge of 10% of the subscription price will be imposed upon orders received from nonmembers after January 1 of the subscription year. Add for postage: Surface delivery outside the United States and India—US$27; in India—US$40; expedited delivery to destinations in North America—US$35; elsewhere—US$120. Subscriptions and orders for AMS publications should be addressed to the American Mathematical Society, P.O. Box 845904, Boston, MA 02284-5904 USA. All orders must be prepaid.

ADVERTISING: *Notices* publishes situations wanted and classified advertising, and display advertising for publishers and academic or scientific organizations. Advertising material or questions may be sent to `classads@ams.org` (classified ads) or `notices-ads@ams.org` (display ads).

SUBMISSIONS: Articles and letters may be sent to the editor by email at `notices@math.wustl.edu`, by fax at 314-935-6839, or by postal mail at Department of Mathematics, Washington University in St. Louis, Campus Box 1146, One Brookings Drive, St. Louis, MO 63130. Email is preferred. Correspondence with the managing editor may be sent to `notices@ams.org`. For more information, see the section "Reference and Book List".

NOTICES ON THE AMS WEBSITE: Supported by the AMS membership, most of this publication is freely available electronically through the AMS website, the Society's resource for delivering electronic products and services. Use the URL `http://www.ams.org/notices/` to access the *Notices* on the website.

[*Notices of the American Mathematical Society* (ISSN 0002-9920) is published monthly except bimonthly in June/July by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2294 USA, GST No. 12189 2046 RT****. Periodicals postage paid at Providence, RI, and additional mailing offices. POSTMASTER: Send address change notices to *Notices of the American Mathematical Society*, P.O. Box 6248, Providence, RI 02940-6248 USA.] Publication here of the Society's street address and the other information in brackets above is a technical requirement of the U.S. Postal Service. Tel: 401-455-4000, email: `notices@ams.org`.

Departments

From the AMS Secretary

I thank Randi D. Ruden for her splendid editorial work, and for helping to assemble this issue. She is essential to everything that I do.

—Steven G. Krantz, Editor

AMS Fellows Program: Positive for Mathematics

In the early fall, AMS members will be asked to vote whether or not to approve the creation of an AMS Fellows Program as spelled out in the detailed AMS proposal to be found at www.ams.org/about-us/governance/elections/fellows-info. My strongly held personal opinion is that approval of this program would bring benefits to members of the AMS, to the mathematical community, and to the AMS. I write to convey my enthusiasm for this program and to explain why I think we should approve its creation.

Our mathematical community has been conservative in celebrating contributions beyond the truly exceptional. The purpose of the AMS Fellows Program is to recognize the excellence of many more of its members. I feel strongly that wider recognition of accomplishments is a basic good, for it supports diversity, encourages commitment, and improves overall morale. The proposed AMS Fellows Program would give distinction to a relatively large number of accomplished mathematicians (the proposal envisions approximately 1,500 Fellows once the program is in steady state): mathematicians from a broad range of institutions, mathematicians with diverse backgrounds, mathematicians who excel in their discipline. The AMS Fellows Program complements AMS efforts to encourage funding of travel and research of many early career mathematicians.

Each year, my university and my college announce with fanfare the election of faculty to various academic fellowships. This is a happy event that bolsters the prestige of the newly elected fellows and their home departments. Articles in the local press and student newspapers highlight the accomplishment of individuals and their disciplines. The AMS Fellows Program would give publicity and recognition to mathematicians and to mathematics and would support arguments of those who seek more support for mathematics.

My hope is that the AMS Fellows Program, if implemented, would boost the visibility of the AMS and encourage membership. For a start, one would have to be a member of the AMS to be an AMS Fellow. Many members of the AMS would take an interest in the selection process and take pleasure whenever a friend/colleague was elected an AMS Fellow. Publicity for the AMS Fellows Program would be publicity for the fellows selected, for their departments, for mathematics, and for the AMS.

As you may know, SIAM quickly instituted its own fellows program, one that was modeled on the program proposed years ago within the AMS. Leaders of SIAM report widespread enthusiasm and positive energy for their society. Having observed this successful implementation, the AMS can proceed with confidence to create its own fellows program.

The selection process of the proposed AMS Fellows Program has been carefully scripted. The initial "seed pool" would consist of AMS members who have been chosen by their peers to give an invited address at a (sectional, national, or international) AMS meeting, at the ICM, or at the ICIAM, as well as AMS members who have been awarded an AMS research prize. The selection of future fellows would be the responsibility of an AMS Fellows Selection Committee whose composition and perspective will vary. The intent of the proposed program is to recognize excellence within our mathematical community and to reflect the many aspects of the achievements of AMS members.

Finally, past balloting for the AMS Fellows Program has shown that well over 60 percent of AMS members support the creation of the AMS Fellows Program. The AMS Fellows Program is a program whose time has come!

Eric M. Friedlander
President, AMS
eric@math.northwestern.edu

Keep Math Inclusive

AMS President Friedlander has asked me to present arguments against the proposal for AMS Fellows. A friend of mine voiced eloquently some concerns, which would take substantial thought and effort to address:

> The difficulty inherent in a Fellows program is that it adds an element of politics to mathematics. There will be individuals, many of them, who feel unfairly excluded. There will be questions as to whether or not the choices are equitable with regard to gender and race, with some people feeling that certain groups receive too few nominations and other people feeling that those same groups receive too many. It will create resentments that may linger for years.
>
> Within departments, there will be tensions. Certain individuals will be nominated and others will be ignored. There will be favoritism, often unintentional. Mathematicians will be more likely to be nominated if they work with others who have been named fellows previously. Certain schools will have many members, and equally talented schools will have few, just because of luck and circumstance.
>
> Finally, it will be a huge time sink. Wouldn't we all rather be thinking about mathematics instead of thinking about who should be in the next pool of nominees? Should we really be taking the strongest research mathematicians and asking them to spend a substantial amount of time on this task?

According to a 2007 *scienceline* article on "Equality of Mathematicians" by Morgan Peck:

> In the years before he vanished, Grothendieck became a passionate spokesman about the danger of further tethering science to politics, and his writing gave voice to a philosophy that most mathematicians still extol but many consider to be rapidly eroding.

The concerns that I want to focus on here are fundamental ones. Mathematics has been served long and well by an openness and inclusiveness that stems naturally from its commitment to truth, facts, evidence. One's contributions are judged by their intrinsic worth, without regard for status or personality. Senior and junior mathematicians work together as equals. Authors of mathematics papers are generally listed in alphabetical order rather than by seniority. When Hardy received a letter from an unknown source in India, the absence of higher degrees or honorary titles did not stop him from recognizing Ramanujan's brilliance for what it was.

The current proposal is of the opposite spirit. It would create two classes of mathematicians, Fellows and non-Fellows. A major rationale is to provide more influential spokespersons for mathematics. In comparison with current practice, in the future presumably advocates would be chosen somewhat less for the clarity of their arguments and somewhat more for their status. This is just being "practical", using methods that work in the realm of administration and politics.

It might even happen that recipients of certain grants and honors would be chosen somewhat less for their accomplishments and promise and somewhat more for their status as Fellows.

A salient feature of mathematics is its total commitment to truth, to making decisions and settling arguments not on the basis of who is powerful or influential but on the basis of who is right. In my opinion this is one of our greatest potential contributions to the world. It is our special task as mathematicians to show the world by example the power and freedom that such an approach provides.

The Fellows program would work opposite to that ultimate goal. By placing greater emphasis on status and inevitably thereby less emphasis on judgment and reason, we would be abandoning in practice the very thing we are trying to promote.

The immediate benefits in terms of additional funding and popularity might come swiftly. The costs in terms of the character of our community might be slower. But in the long run we could be giving up one of our greatest and signature contributions to the world.

I have always felt that we mathematicians are in this together, gladly talking to anyone who takes an interest in a good problem, adopting new methods if and only if they work regardless of where they come from, taking joy in a new result whatever the source. We don't need an elite class. We're proud just to be mathematicians.

Frank Morgan
AMS Vice President
`Frank.Morgan@williams.edu`

Did a 1-Dimensional Magnet Detect a 248-Dimensional Lie Algebra?

David Borthwick and Skip Garibaldi

You may have heard some of the buzz spawned by the recent paper [CTW+] in *Science*. That paper described a neutron scattering experiment involving a quasi-1-dimensional cobalt niobate magnet and led to rumors that E_8 had been detected "in nature". This is fascinating, because E_8 is a mathematical celebrity and because such a detection seems impossible: it is hard for us to imagine a realistic experiment that could directly observe a 248-dimensional object such as E_8.

The connection between the cobalt niobate experiment and E_8 is as follows. Around 1990, physicist Alexander Zamolodchikov and others studied perturbed conformal field theories in general; one particular application of this was a theoretical model describing a 1-dimensional magnet subjected to two magnetic fields. This model makes some numerical predictions that were tested in the cobalt niobate experiment, and the results were as predicted by the model. As the model involves E_8 (in a way we will make precise in the section "Affine Toda Field Theory"), one can say that the experiment provides evidence for "E_8 symmetry". No one is claiming to have directly observed E_8.

Our purpose here is to fill in some of the details omitted in the previous paragraph. We should explain that we are writing as journalists rather than mathematicians here, and we are not physicists. We will give pointers to the physics literature so that the adventurous reader can go directly to the words of the experts for complete details.

The Ising Model

The article in *Science* describes an experiment involving the magnetic material cobalt niobate ($CoNb_2O_6$). The material was chosen because the internal crystal structure is such that magnetic Co^{2+} ions are arranged into long chains running along one of the crystal's axes, and this could give rise to 1-dimensional magnetic behavior.[1] In

Figure 1. Photograph of an artificially grown single crystal of $CoNb_2O_6$. The experiment involved a 2-centimeter-long piece of this crystal, weighing about 8 grams. **(Image courtesy of Radu Coldea.)**

David Borthwick is professor of mathematics at Emory University. His email address is davidb@mathcs.emory.edu.

Skip Garibaldi is associate professor of mathematics at Emory University. His email address is skip@mathcs.emory.edu.

DB and SG were partially supported by NSF DMS-0901937 and NSA grant H98230-11-1-0178, respectively. We are grateful to Richard Borcherds, Radu Coldea, Jacques Distler, Giuseppe Mussardo, the referees, and others for their helpful remarks. We thank Bert Kostant and Richard Borcherds for bringing this topic to our attention.

[1] *Two additional practical constraints led to this choice of material: (1) large, high-quality single crystals of it can be grown as depicted in Figure 1, and (2) the strength of the magnetic interactions between the Co^{2+} spins is low enough that the quantum critical point corresponding to $g_x = 1$ in (Eq.2) can be matched by magnetic fields currently achievable in the laboratory.*

particular, physicists expected that this material would provide a realization of the famous Ising model, which we now describe briefly.

The term *Ising model* refers generically to the original, classical model.[2] This simple model for magnetic interactions was suggested by W. Lenz as a thesis problem for his student E. Ising, whose thesis appeared in Hamburg in 1922 [I]. The classical form of the model is built on a square, periodic, n-dimensional lattice, with the periods sufficiently large that the periodic boundary conditions don't play a significant role in the physics. Each site j is assigned a spin $\sigma_j = \pm 1$, interpreted as the projection of the spin onto some preferential axis. The energy of a given configuration of spins is

$$H = -J \sum_{\langle i,j \rangle} \sigma_i \sigma_j, \quad \text{(Eq.1)}$$

where J is a constant and the sum ranges over pairs $\langle i, j \rangle$ of nearest-neighbor sites. This Hamiltonian gives rise to a statistical ensemble of states that is used to model the thermodynamic properties of actual magnetic materials. The statistical ensemble essentially amounts to a probability distribution on the set of spin configurations, with each configuration weighted by $e^{-kH/T}$ (the Boltzmann distribution), where k is constant and T is the temperature. The assumption of this distribution makes the various physical quantities, such as individual spins, average energy, magnetization, etc., into random variables. For $J > 0$, spins at neighboring sites tend to align in the same direction; this behavior is called *ferromagnetic*, because this is what happens with iron.

To describe the cobalt niobate experiment, we actually want the quantum spin chain version of the Ising model. In this quantum model, each site in a 1-dimensional (finite periodic) chain is assigned a 2-dimensional complex Hilbert space. The Pauli spin matrices S^x, S^y, and S^z act on each of these vector spaces as spin observables, meaning they are self-adjoint operators whose eigenstates correspond to states of particular spin. For example, the ± 1 eigenvectors of S^z correspond to up and down spins along the z-axis. A general spin state is a unit vector in the 2-dimensional Hilbert space, which could be viewed as a superposition of up and down spin states, if we use those eigenvectors as a basis.

The Hamiltonian operator for the standard 1-dimensional quantum Ising model is given by

$$\hat{H} = -K \sum_j \left[S_j^z S_{j+1}^z + g_x S_j^x \right]. \quad \text{(Eq.2)}$$

In the quantum statistical ensemble one assigns probabilities to the eigenvectors of $\hat{H}$ weighted by the corresponding energy eigenvalues. This then defines, via the Boltzmann distribution again, a probability distribution on the unit ball in the total Hilbert space of the system.

Just as in the classical case, physical quantities become random variables with distributions that depend on the temperature and constants K and g_x. It is by means of these distributions that the model makes predictions about the interrelationships of these quantities.

The first term in the Hamiltonian (Eq.2) has a ferromagnetic effect (assuming $K > 0$), just as in the classical case. That is, it causes spins of adjacent sites to align with each other along the z-axis, which we will refer to as the *preferential* axis. (Experimental physicists might call this the "easy" axis.) The second term represents the influence of an external magnetic field in the x-direction, perpendicular to the z-direction—we'll refer to this as the *transverse* axis. The effect of the second term is *paramagnetic*, meaning that it encourages the spins to align with the transverse field.

The 1-dimensional quantum Ising spin chain exhibits a phase transition at zero temperature. The phase transition (also called a critical point) is the point of transition between the ferromagnetic regime ($g_x < 1$, where spins tend to align along the z-axis) and the paramagnetic ($g_x > 1$). The critical point ($g_x = 1$) is distinguished by singular behavior of various macroscopic physical quantities, such as the *correlation length*. Roughly speaking, this is the average size of the regions in which the spins are aligned with each other.

To define correlation length a little more precisely, we consider the statistical correlation between the z-components of spins at two sites separated by a distance r. These spins are just random variables whose joint distribution depends on the constants K and g_x, as well as the separation r and the temperature T. (We are assuming r is large compared with the lattice spacing, but small compared with the overall dimensions of the system.) For $g_x > 1$ the correlation falls off exponentially as $e^{-r/\xi}$, because spins lined up along the x-axis will be uncorrelated in the z-direction; the constant ξ is the correlation length. In contrast, at the critical point $g_x = 1$ and $T = 0$, the decay of the spin correlation is given by a power law; this radical change of behavior corresponds to the divergence of ξ. This phase transition has been observed experimentally in a $LiHoF_4$ magnet [BRA].

One might wonder why an external magnetic field is included by default in the quantum case but not in the classical case. The reason for this is a correspondence between the classical models and the quantum models of one lower dimension. The quantum model includes a notion of time evolution of an observable according to the Schrödinger equation, and the correspondence involves interpreting one of the classical dimensions as imaginary time in the quantum model. Under

[2] *For more details on this model, see, for example,* [MW 73] *or* [DFMS, Chap. 12].

this correspondence, the classical interaction in the spatial directions gives the quantum ferromagnetic term, while interactions in the imaginary time direction give the external field term (see [Sa, §2.1.3] for details).

Although there are some important differences in the physical interpretation on each side, the classical-quantum correspondence allows various calculations to be carried over from one case to the other. For example, the critical behavior of the 1-dimensional transverse-field quantum Ising model (Eq.2) at zero temperature, with the transverse field parameter tuned to the critical value $g_x = 1$, can be "mapped" onto equivalent physics for the classical 2-dimensional Ising model (Eq.1) at a nonzero temperature. The latter case is the famous phase transition of the 2-dimensional classical model, which was discovered by Peierls and later solved exactly by Onsager [O].

Adapting the Model to the Magnet

The actual magnet used in the experiment is not quite modeled by the quantum Ising Hamiltonian (Eq.2). In the ferromagnetic regime ($g_x < 1$), weak couplings between the magnetic chains create an effective magnetic field pointing along the preferential axis [CT]. The relevant model for the experiment is thus

$$\text{(Eq.3)} \qquad \hat{H} = -K \sum_j \left[S_j^z S_{j+1}^z + g_x S_j^x + g_z S_j^z \right],$$

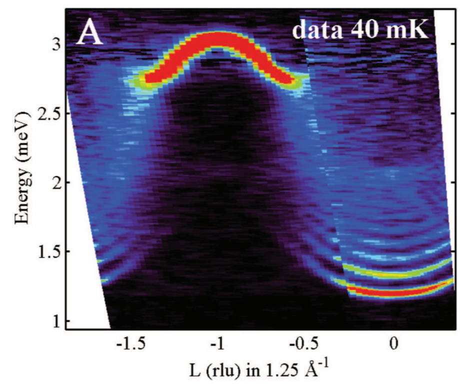
which is just (Eq.2) with an additional term $g_z S_j^z$ representing this internal magnetic field.

The first phase of the cobalt niobate experiment tested the appropriateness of (Eq.3) as a model for the magnetic dynamics in the absence of an external magnetic field, i.e., with $g_x = 0$. The experimental evidence does support the claim that this 3-dimensional object is behaving as a 1-dimensional magnetic system. For example, Figure 2 shows a comparison of the experimental excitation energies (as a function of wave vector) to theoretical predictions from the 1-dimensional model. The presence of a sequence of well-defined and closely spaced energy levels, as shown in these pictures, is predicted only in dimension 1.

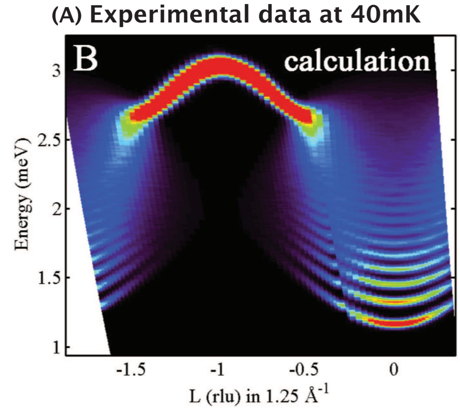
What Is E_8?

Before we explain how the rather simple quantum Ising model from the previous sections leads to a theory involving E_8, we had better nail down what it means to speak of "E_8". It's an ambiguous term, with at least the following six common meanings:

(1) The *root system* of type E_8. This is a collection of 240 points, called *roots*, in $\mathbb{R}^8$. The usual publicity photo for E_8 (reproduced in Figure 3A) is the orthogonal projection of the root system onto a copy of $\mathbb{R}^2$ in $\mathbb{R}^8$.



(A) Experimental data at 40mK



(B) Calculated

Figure 2. Comparison of excitations under no external magnetic field: experimental (top) versus predictions based on the 1-dimensional model (bottom). (Figure adapted from [CTW+] with permission of AAAS.)

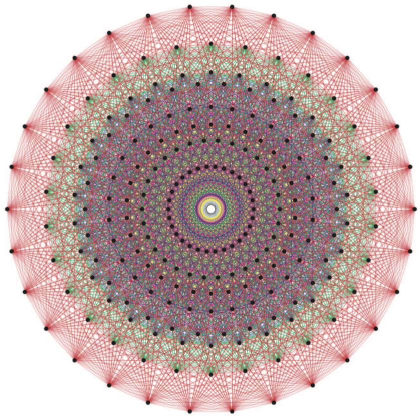
(2) The E_8 *lattice*, which is the subgroup of $\mathbb{R}^8$ (additively) generated by the root system.

(3) A *complex Lie group*—in particular, a closed subgroup of $GL_{248}(\mathbb{C})$—that is simple and 248-dimensional.

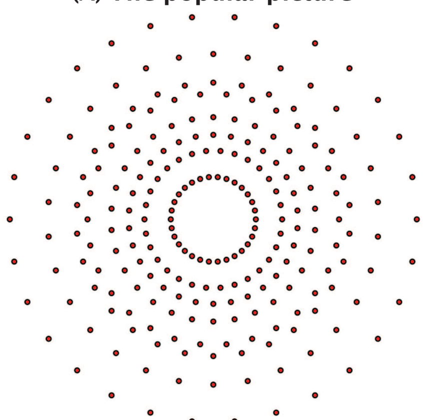
There are also three simple *real* Lie groups—meaning in particular that they are closed subgroups of $GL_{248}(\mathbb{R})$—whose complexification is the complex Lie group from (3). (The fact that there are exactly three is part of Elie Cartan's classification of simple real Lie groups; see [Se 02, §II.4.5] for an outline of a modern proof.) They are:

(4) The *split* real E_8. This is the form of E_8 that one can define easily over any field or even over an arbitrary scheme. Its Killing form has signature 8.

(5) The *compact* real E_8, which is the unique largest subgroup of the complex E_8 that is compact as a topological space. Its Killing form has signature -248.



(A) The popular picture



(B) Vertices only

Figure 3. The top panel (A) is the picture of E_8 that one finds in the popular press. Deleting some edges leaves you with the frontispiece of [Cox]. (Image courtesy of John Stembridge [St].) The bottom panel (B) is the same picture with the edges removed; it is the image of the root system of E_8 in a Coxeter plane.

(6) The remaining real form of E_8 is sometimes called "quaternionic". Its Killing form has signature -24.

In physics, the split real E_8 appears in supergravity [MS] and the compact real E_8 appears in heterotic string theory [GHMR]. These two appearances in physics, however, are purely theoretical; the models in which they appear are not yet subject to experiment. It is the compact real E_8 (or, more precisely, the associated Lie algebra) that appears in the context of the cobalt niobate experiment, making this the first actual experiment to detect a phenomenon that could be modeled using E_8.

There have also been two recent frenzies in the popular press concerning E_8. One concerned the computation of the Kazhdan-Lusztig-Vogan polynomials which you can read about in the prizewinning paper [V]; that work involved the split real E_8. The other frenzy was sparked by the manuscript [L]. The E_8 referred to in [L] is clearly meant to be one of the real forms, but the manuscript contains too many contradictory statements to be sure which one[3], and in any case the whole idea has serious difficulties as explained in [DG].

Groups Versus Algebras

Throughout this article we conflate a real Lie group G, which is a manifold, with its Lie algebra $\mathfrak{g}$, which is the tangent space to G at the identity and is a real vector space endowed with a nonassociative multiplication. This identification is essentially harmless and is standard in physics. Even when physicists discuss symmetry "groups", they are frequently interested in symmetries that hold only in a local sense, and so the Lie algebra is actually the more relevant object.

Real Versus Complex

Moreover, physicists typically compute within the complexification $\mathfrak{g} \otimes \mathbb{C}$ of $\mathfrak{g}$. This is the complex vector space with elements of the form $x + iy$ for $x, y \in \mathfrak{g}$, where complex conjugation acts via $x + iy \mapsto x - iy$. Note that one can recover $\mathfrak{g}$ as the subspace of elements fixed by complex conjugation. Therefore, morally speaking, working with the $\mathbb{R}$-algebra $\mathfrak{g}$ (as mathematicians often do) amounts to the same as working with $\mathfrak{g} \otimes \mathbb{C}$ together with complex conjugation (as physicists do). This is an example of the general theory of Galois descent as outlined in, e.g., [J 79, §X.2] or [Se 79, §X.2].

From the Ising Model to E_8

What possible relevance could a 248-dimensional algebra have for a discrete one-dimensional statistical physics model? This is a long and interesting story, and we can only give a few highlights here.

As we mentioned above, the 1-dimensional quantum Ising model from (Eq.2) undergoes a phase transition at zero temperature at the critical value of the transverse magnetic field strength. If the system is close to this critical point, the correlation length (described in the section "The Ising Model" in this article) will be very large compared with the lattice spacing, and so we can assume that the discrete spins vary smoothly across nearby lattice sites. In this regime we can thus effectively

[3] *There are three places in* [L] *where a particular form of* E_8 *might be specified. At the top of page 18 is a form containing a product of the nonsplit, noncompact form of* F_4 *and the compact* G_2*; therefore it is the split real* E_8 *by* [J 71, p. 118] *or* [GaS, §3]. *The form of* E_8 *described in the middle of page 21 is supposed to contain a copy of* $\mathfrak{so}(7,1) \oplus \mathfrak{so}(8)$, *but there is no such real form of* E_8. *Finally, on page 29, the quaternionic* E_8 *is mentioned in the text.*

model the system using continuous "field" variables, i.e., using quantum field theory. For the 1-dimensional quantum Ising model, the corresponding continuous theory is a quantum field theory of free, spinless fermionic particles in 1+1 space-time dimensions.

To understand what happens as the critical point is approached, one can apply "scaling" transformations that dilate the macroscopic length scales (e.g., the correlation length) while keeping the microscopic lengths (e.g., the lattice spacing) unchanged. (See, e.g., [Sa, §4.3] for a more thorough explanation of this.) The limiting theory at the critical point should then appear as a fixed point for these transformations, called the *scaling limit*. Polyakov famously argued in [P] that the scaling limit should be distinguished by invariance with respect to local conformal transformations. This paper established the link between the study of phase transitions and *conformal field theory* (CFT).

In [BPZ], Belavin, Polyakov, and Zamolodchikov showed that certain simple CFTs called *minimal models* could be solved completely in terms of (and so are determined by) a Hilbert space made of a finite number of "discrete series" (unitary, irreducible) representations of the Virasoro algebra, see [He, Chap. 2] or [DFMS, Chap. 7] for more details. These representations are characterized by the eigenvalue c assigned to the central element, called the *central charge*, which can be computed directly from the scaling limit of the statistical model. This works out beautifully in the case of the critical 1-dimensional quantum Ising model: In that case, the central charge is $c = 1/2$, the minimal model is built from the three discrete series representations of the Virasoro algebra with that central charge, and this CFT exactly matches the Ising phase transition; see [BPZ, App. E], [DFMS, §7.4.2], or [Mu, §14.2] for details.

The discrete series representations mentioned above are described by c and another parameter h which have some relations between them, and there are tight constraints on the possible values of c and h to be unitary [FQS]. To prove that all of these values of c and h indeed correspond to irreducible unitary representations, one employs the *coset construction* of Goddard, Kent, and Olive; see [GKO] or [DFMS, Chap. 18]. This construction produces such representations by restricting representations of an affine Lie algebra, i.e., a central extension of the (infinite-dimensional) loop algebra of a compact Lie algebra $\mathfrak{g}$. Using the coset construction, there are two ways to obtain the $c = 1/2$ minimal model that applies to our zero-field Ising model: we could use either of the compact Lie algebras $\mathfrak{su}(2)$ or E_8 as the base $\mathfrak{g}$ for the affine Lie algebra [DFMS, §18.3, §18.4.1]. These two algebras are the only choices that lead to $c = 1/2$ [Mu, §14.2].

Of course, the appearance of E_8 here is somewhat incidental. The minimal model could be described purely in terms of Virasoro representations, without reference to either $\mathfrak{su}(2)$ or E_8. As we explain below, E_8 takes center stage only when we consider a perturbation of the critical Ising model as in (Eq.3).

Magnetic Perturbation and Zamolodchikov's Calculation

In a 1989 article [Z], Zamolodchikov investigated the field theory for a model equivalent to the 1-dimensional quantum Ising model (Eq.2), in the vicinity of the critical point, but perturbed by a small magnetic field directed along the preferential spin axis. In other words, he considered the field theory model corresponding to (Eq.3) with $g_x \approx 1$ and g_z very small. Note the change of perspective: for Zamolodchikov g_x is fixed, and the perturbation consists of a small change in the value of g_z. But in the cobalt niobate experiment, this magnetic "perturbation" is already built in—it is the purely internal effect arising from the interchain interactions as we described in the section "Adapting the Model to the Magnet". The experimenters can't control the strength of the internal field, they only vary g_x. Fortunately, the internal magnetic field g_z turns out to be relatively weak, so when the external field g_x is tuned close to the critical value, the experimental model matches the situation considered by Zamolodchidkov.

The qualitative features of the particle spectrum for the magnetically perturbed Ising model had been predicted by McCoy and Wu [MW 78]. Those earlier calculations show a large number of stable particles for small g_x, with the number decreasing as g_x approaches 1. Zamolodchikov's paper makes some predictions for the masses of these particles at $g_x = 1$.

As we noted above, the $c = 1/2$ minimal model is the conformal field theory associated with the phase transition of the unperturbed quantum Ising model. The perturbed field theory is no longer a conformal field theory, but Zamolodchikov found six local integrals of motion for the perturbed field theory and conjectured that these were the start of an infinite series. On this basis, he made the fundamental conjecture:

(Z1) The perturbation gives an integrable field theory.

One implication of (Z1) is that the resulting scattering theory should be "purely elastic", meaning that the number of particles and their individual momenta would be conserved asymptotically. Zamolodchikov combined this purely elastic scattering assumption with three rather mild assumptions on the particle interactions of the theory [Z, p. 4236]:

(Z2) There are at least 2 particles, say p_1 and p_2.
(Z3) Both p_1 and p_2 appear as bound-state poles on the scattering amplitude for two p_1's.
(Z4) The particle p_1 appears as a bound-state pole in the scattering amplitude between p_1 and p_2.

Assumptions (Z3) and (Z4) merely assert that certain coupling constants that govern the interparticle interactions are nonzero, so they could be viewed as an assumption of some minimum level of interaction between the two particles.

The word "particle" bears some explaining here, because it is being used here in the sense of quantum field theory: a stable excitation of the system with distinguishable particle-like features such as mass and momentum. However, it is important to note that the continuum limit of the Ising model is made to look like a field theory only through the application of a certain transformation (Jordan-Wigner; see [Sa, §4.2]) that makes "kink" states (boundaries between regions of differing spin) the basic objects of the theory. So Zamolodchikov's particles aren't electrons or ions. The field theory excitations presumably correspond to highly complicated aggregate spin states of the original system. On the statistical physics side the usual term for this kind of excitation is *quasiparticle*. In the experiment these quasiparticles are detected just as ordinary particles would be, by measuring the reaction to a beam of neutrons.

From the mild assumptions (Z2)–(Z4), Zamolodchikov showed that the simplest purely elastic scattering theory consistent with the integrals of motion contains eight particles with masses listed in Table 1. (See [He, §14.3] for more background on these calculations.) These predictions were quickly corroborated by computational methods, through numerical diagonalization of the Hamiltonian (Eq.3); see [HeS] or [SZ]. In Table 1, m_1 and m_2 are the masses of the two original particles p_1 and p_2. Note that only the ratios of the masses, such as m_2/m_1, are predicted; in the discrete model (Eq.3) the individual masses would depend on the overall length of the lattice, and in passing to the scaling limit we give up this information.

Zamolodchikov's results give some indications of a connection with the algebra or root system E_8. The spins of the six integrals of motion he calculated were

$$s = 1, 7, 11, 13, 17, 19.$$

The conjecture is that this is the start of a sequence of integrals of motion whose spins include all values of s relatively prime to 30. These numbers are suggestive because 30 is the Coxeter number of E_8 and the remainders of these numbers modulo 30 are the exponents of E_8 (see, for example, [Bo] for a definition of Coxeter number and exponent). This was taken as a hint that the conjectured integrable field theory could have a model based on E_8, and in fact such a connection with E_8 had already been proposed by Fateev based on other theoretical considerations [Z, pp. 4247, 4248].

$$\begin{aligned}
m_2 &= 2\cos\tfrac{\pi}{5} m_1 &&\approx 1.618 m_1\\
m_3 &= 2\cos\tfrac{\pi}{30} m_1 &&\approx 1.989 m_1\\
m_4 &= 2\cos\tfrac{\pi}{5}\cos\tfrac{7\pi}{30} m_1 &&\approx 2.405 m_1\\
m_5 &= 4\cos\tfrac{\pi}{5}\cos\tfrac{2\pi}{15} m_1 &&\approx 2.956 m_1\\
m_6 &= 4\cos\tfrac{\pi}{5}\cos\tfrac{\pi}{30} m_1 &&\approx 3.218 m_1\\
m_7 &= 8(\cos\tfrac{\pi}{5})^2\cos\tfrac{7\pi}{30} m_1 &&\approx 3.891 m_1\\
m_8 &= 8(\cos\tfrac{\pi}{5})^2\cos\tfrac{2\pi}{15} m_1 &&\approx 4.783 m_1
\end{aligned}$$

Table 1. The masses of the particles predicted by Zamolodchikov.

Affine Toda Field Theory

Soon after Zamolodchikov's first paper appeared, Fateev and Zamolodchikov conjectured in [FZ] that if you take a minimal model CFT constructed from a compact Lie algebra $\mathfrak{g}$ via the coset construction and perturb it in a particular way, then you obtain the *affine Toda field theory* (ATFT) associated with $\mathfrak{g}$, which is an integrable field theory. This was confirmed in [EY] and [HoM].

If you do this with $\mathfrak{g} = \mathsf{E}_8$, you arrive at the conjectured integrable field theory investigated by Zamolodchikov and described in the previous paragraph. That is, if we take the E_8 ATFT as a starting point, then the assumptions (Z1)–(Z4) become deductions. This is the essential role of E_8 in the numerical predictions relevant to the cobalt niobate experiment. (In the next section, we will explain how the masses that Zamolodchikov found arise naturally in terms of the algebra structure. But that is just a bonus.)

What Is the Role of E_8 in the Affine Toda Field Theory?

To say the ATFT in question is "associated" with E_8 leaves open a range of possible interpretations, so we should spell out precisely what this means. The ATFT construction from a compact Lie algebra $\mathfrak{g}$ proceeds by choosing a Cartan subalgebra[4] $\mathfrak{h}$ in $\mathfrak{g}$—it is a real inner product space with inner product the Killing form $(\ ,\ )$ and is isomorphic to $\mathbb{R}^8$ in the case $\mathfrak{g} = \mathsf{E}_8$. Let ϕ be a scalar field in 2-dimensional Minkowski space-time, taking values in $\mathfrak{h}$. Then the Lagrangian density for the affine Toda field theory is

$$\text{(Eq.4)} \qquad \frac{1}{2}(\partial_\mu \phi, \partial^\mu \phi) - (e^{\beta\phi} E e^{-\beta\phi}, \overline{E}),$$

[4] *It doesn't matter which one you choose, because any one can be mapped to any other via some automorphism of* $\mathfrak{g}$.

where β is a coupling constant. Here E is a regular semisimple element of $\mathfrak{g} \otimes \mathbb{C}$ that commutes with its complex conjugate $\overline{E}$. More precisely, for $x \in \mathfrak{h}$ a principal regular element, conjugation by $e^{2\pi i x/h}$ with h the Coxeter number of $\mathfrak{g}$ gives a $\mathbb{Z}/h$-grading on $\mathfrak{g} \otimes \mathbb{C}$, and the element E belongs to the $e^{2\pi i/h}$-eigenspace. (Said differently, the centralizer of E is a Cartan subalgebra of $\mathfrak{g} \otimes \mathbb{C}$ in apposition to $\mathfrak{h} \otimes \mathbb{C}$ in the sense of [K 59, p. 1018].)

The structure of E_8 thus enters into the basic definitions of the fields and their interactions. However, E_8 does not act by symmetries on this set of fields.

Why Is It E_8 That Leads to Zamolodchikov's Theory?

We opened this section by asserting that perturbing a minimal model CFT constructed from $\mathfrak{g}$ via the coset construction leads to an ATFT associated with $\mathfrak{g}$. For this association to make sense, the perturbing field is required to have "conformal dimension" $2/(h+2)$. The two coset models for the Ising model give us two possible perturbation theories. Starting from $\mathfrak{su}(2)$, which has $h = 2$, we could perturb using the field of conformal dimension $1/2$, which is the energy. This perturbation amounts to raising the temperature away from zero, which falls within the traditional framework of the Ising model and is well understood.

The other choice is to start from E_8, which has $h = 30$, and perturb using the field of conformal dimension $1/16$, which is the magnetic field along the preferential axis.[5] This is exactly the perturbation that Zamolodchikov considered in his original paper. This means that if an ATFT is used to describe the magnetically perturbed Ising model, we have no latitude in the choice of a Lie algebra: it must be E_8.

Why Is It the Compact Form of E_8?

As Folland noted recently in [Fo], physicists tend to think of Lie algebras in terms of generators and relations, without even specifying a background field if they can help it. So it can be difficult to judge from the appearance of a Lie algebra in the physics literature whether any particular form of the algebra is being singled out.

Nevertheless, the algebras appearing here are the compact ones. The reason is that the minimal model CFTs involve unitary representations of the Virasoro algebra. The coset construction shows that these come from representations of affine Lie algebras that are themselves constructed from compact finite-dimensional algebras. And it is these finite-dimensional Lie algebras that appear in the ATFT.

What about E_6 and E_7?

So far, we have explained why it is E_8 that is related to the cobalt niobate experiment. This prompts the question: given a simple compact real Lie algebra $\mathfrak{g}$, does it give a theory describing some other physical setup? Or, to put it differently, what is the physical setup that corresponds to a theoretical model involving, say, E_6 or E_7? In fact, the field theories based on these other algebras do have interesting connections to statistical models. For example, E_7 Toda field theory describes the thermal perturbation of the tricritical Ising model and the E_6 theory the thermal deformation of the tricritical three-state Potts model. These other models are easily distinguished from the magnetically perturbed Ising model by their central charges. It will be interesting to see whether physicists can come up with ways to probe these other models experimentally. The E_7 model might be easiest—the unperturbed, CFT version has already been realized, for example, in the form of helium atoms on krypton-plated graphite [TFV].

The Zamolodchikov Masses and E_8's Publicity Photo

Translating Zamolodchikov's theory into the language of affine Toda field theory provides a way to transform his calculation of the particle masses listed in Table 1 into the solution of a rather easy system of linear equations, and that in turn is connected to the popular image of the E_8 root system from Figure 3A. These are connections that work for a general ATFT, and we will now describe them in that level of generality.

An ATFT is based on a compact semisimple real Lie algebra $\mathfrak{g}$, such as the Lie algebra of the compact real E_8. We assume further that this algebra is simple and is not $\mathfrak{su}(2)$. Then from $\mathfrak{g}$ we obtain a simple root system R spanning $\mathbb{R}^\ell$ for some $\ell \geq 2$; this is canonically identified with the dual $\mathfrak{h}^*$ of the Cartan subalgebra mentioned at the end of the previous section.

We briefly explain how to make a picture like Figure 3B for R. (For background on the vocabulary used here, please see [Bo] or [Ca].) Pick a set B of simple roots in R. For each $\beta \in R$, write s_β for the reflection in the hyperplane orthogonal to β. The product $w := \prod_{\beta \in B} s_\beta$ with respect to any fixed ordering of B is called a *Coxeter element*, and its characteristic polynomial has $m(x) := x^2 - 2\cos(2\pi/h)x + 1$ as a simple factor [Bo, VI.1.11, Prop. 30], where h is the Coxeter number of R. The primary decomposition theorem gives a uniquely determined plane P in $\mathbb{R}^\ell$ on which w restricts to have minimal polynomial $m(x)$, i.e., is a rotation through $2\pi/h$—we call P the *Coxeter*

[5] *The conformal dimension of the magnetic field is fixed by the model. It corresponds to the well-known critical exponent* $1/8$ *that governs the behavior of the spontaneous magnetization of the Ising model as the critical point is approached.*

plane for w. The picture in Figure 3B is the image of R under the orthogonal projection $\pi : \mathbb{R}^\ell \to P$ in the case where $R = \mathsf{E}_8$. We remark that while P depends on the choice of w, all Coxeter elements are conjugate under the orthogonal group [Ca, 10.3.1], so none of the geometric features of $\pi(R)$ are changed if we vary w, and we will refer to P as simply a Coxeter plane for R.

In Figure 3B, the image of R lies on eight concentric circles. This is a general feature of the projection in P and is not special to the case $R = \mathsf{E}_8$. Indeed, the action of w partitions R into ℓ orbits of h elements each [Bo, VI.1.11, Prop. 33(iv)], and w acts on P as a rotation. So the image of R necessarily lies on ℓ circles.

The relationship between the circles in Figure 3B and physics is given by the following theorem.

Theorem. *Let* $\mathfrak{g}$ *be a compact* simple *Lie algebra that is not* $\mathfrak{su}(2)$*, and write* R *for its root system. For an affine Toda field theory constructed from* $\mathfrak{g}$*, the following multisets are the same, up to scaling by a positive real number:*

(1) *The (classical) masses of the particles in the affine Toda theory.*
(2) *The radii of the circles containing the projection of* R *in a Coxeter plane.*
(3) *The entries in a Perron-Frobenius eigenvector for a Cartan matrix of* R*.*

The terms in (3) may need some explanation. The restriction of the inner product on $\mathbb{R}^\ell$ to R is encoded by an ℓ-by-ℓ integer matrix C, called the *Cartan matrix* of R. You can find the matrix for $R = \mathsf{E}_8$ in Figure 4A. We know a lot about the Cartan matrix, no matter which R one chooses—for example, its eigenvalues are all real and lie in the interval $(0, 4)$, see [BLM, Th. 2]. Further, the matrix $2 - C$ has all nonnegative entries and is irreducible in the sense of the Perron-Frobenius theorem, so its largest eigenvalue—hence the smallest eigenvalue of C—has a 1-dimensional eigenspace spanned by a vector $\vec{x}$ with all positive entries. (Such an eigenvector is exhibited in Figure 4B for the case $R = \mathsf{E}_8$.) This $\vec{x}$ is the vector in (3), and it is an eigenvector of C with eigenvalue $4\sin^2(\pi/2h)$, so calculating $\vec{x}$ amounts to solving an easy system of linear equations.

Sketch of Proof. The theorem above has been known to physicists since the early 1990s; here is a gloss of the literature. Freeman showed that (1) and (3) are equivalent in [Fr]. We omit his argument, which amounts to computations in the complex Lie algebra $\mathfrak{g} \otimes \mathbb{C}$, but it is worth noting that his proof does rely on $\mathfrak{g}$ being compact.

The equivalence of (2) and (3) can be proved entirely in the language of root systems and finite reflection groups; see, for example, [FLO] or [Cor, §2]. The Dynkin diagram (a graph with vertex set B) is a tree, so it has a 2-coloring $\sigma : B \to \{\pm 1\}$, and one picks w to be a corresponding Coxeter element as in [Ca, §10.4]. Conveniently, the elements $\sigma(\beta)\beta$ for $\beta \in B$ are representatives of the orbits of w on R; see [K85, p. 250, (6.9.2)] or [FLO, p. 91]. It is elementary to find the inner products of $\pi(\sigma(\beta)\beta)$ with the basis vectors for P given in [Ca, §10.4], hence the radius of the circle containing $\pi(\sigma(\beta)\beta)$. The entries of the Perron-Frobenius eigenvector appear naturally, because these entries are part of the expressions for the basis vectors for P.

Alternatively, Kostant shows the equivalence of (1) and (2) in [K10] using Lie algebras. □

$$\begin{pmatrix} 2 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & -1 & 0 & 0 & 0 & 0 \\ -1 & 0 & 2 & -1 & 0 & 0 & 0 & 0 \\ 0 & -1 & -1 & 2 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 2 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 2 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 2 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 2 \end{pmatrix}$$

(A)

$$\begin{pmatrix} m_2 & m_4 & m_6 & m_8 & m_7 & m_5 & m_3 & m_1 \end{pmatrix}$$

(B)

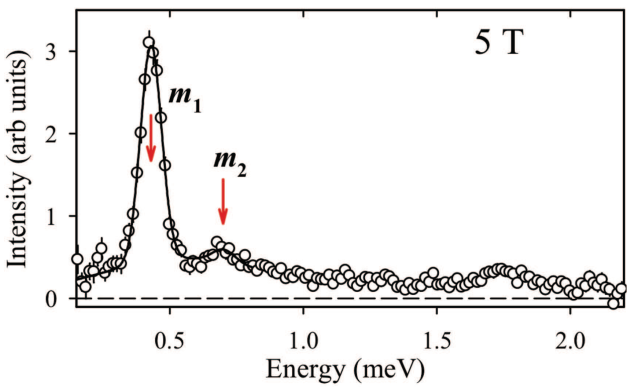
Figure 4. The Cartan matrix (A) for the root system E_8 and a Perron-Frobenius eigenvector (B), where the entries are as in Table 1.

There is a deeper connection between the particles in the ATFT and the roots in the root system. Physicists identify the w-orbits in the root system with particles in the ATFT. The rule for the coupling of particles in a scattering experiment (called a "fusing" rule) is that the scattering amplitude for two particles Ω_1 and Ω_2 has a bound-state pole corresponding to Ω_3 if and only if there are roots $\rho_i \in \Omega_i$ so that $\rho_1 + \rho_2 + \rho_3 = 0$ in $\mathbb{R}^\ell$; see [Do] and [FLO]. This leads to a "Clebsch-Gordan" necessary condition for the coupling of particles; see [Br]. We remark that these fusing rules are currently only theoretical—it is not clear how they could be tested experimentally.

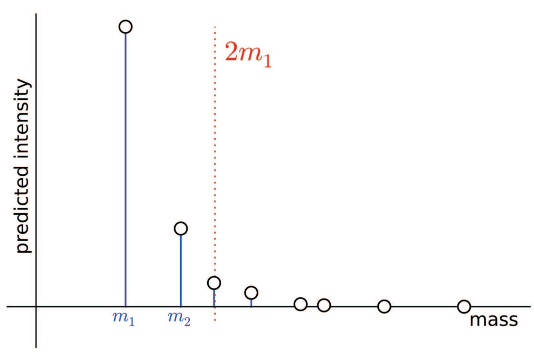
Back to the Experiment

Let's get back to the cobalt niobate experiment. As we noted above, when the external magnetic field is very close to the critical value that induces the phase transition, it was expected that the experimental system would be modeled by the critical 1-dimensional quantum Ising model perturbed by a small magnetic field directed along the preferential axis. This model is the subject of Zamolodchikov's perturbation theory, and the resulting field theory has been identified as the E_8 ATFT.

To test this association, the experimenters conducted neutron scattering experiments on the magnet. Figure 5A shows an intensity plot of scattered neutrons averaged over a range of scattering angles. Observations were actually made at a series of external field strengths, from 4.0 tesla (T) to 5.0 T, with the second peak better resolved at the lower energies. Both peaks track continuously as the field strength is varied. Figure 5A represents the highest field strength at which the second peak could be resolved.



(A) Masses detected



(B) Predictions

Figure 5. The top panel (A) is an example intensity plot, exhibiting the two detected masses under a transverse magnetic field of 5 tesla, 90% of the critical strength. (Figure adapted from [CTW+ with permission of AAAS].) The bottom panel (B) shows the relative intensities obtained from the form factors computed in [DM, p. 741, Table 3]. The axes have the same labels as in the top panel. The dotted vertical line marks the onset of the incoherent continuum.

The two peaks give evidence of the existence of at least two particles in the system, which was one of Zamolodchikov's core assumptions. And, indeed, the ratio of the masses appears to approach the golden ratio—see Figure 6—as the critical value (about 5.5 T) is approached, just as Zamolodchikov predicted twenty years earlier.

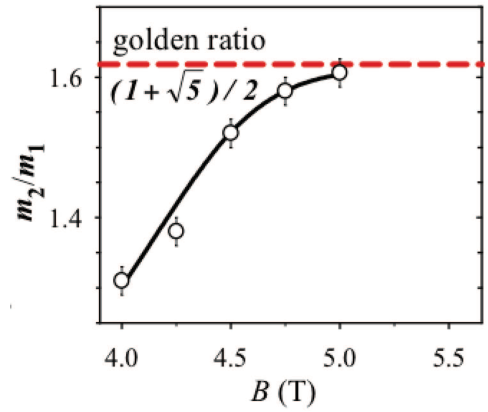


Figure 6. The ratio m_2/m_1 of the masses of the two lightest particles approaches the golden ratio as the transverse magnetic field approaches critical strength of 5.5 tesla. (Figure adapted from [CTW+] with permission of AAAS.)

We can also compare the relative intensities of the first two mass peaks to the theoretical predictions exhibited in Figure 5B. Here again we see approximate agreement between the observations and theoretical predictions. The figure shows a threshold at $2m_1$, where a continuous spectrum is generated by the scattering of the lightest particle with itself. Particles with masses at or above this threshold will be very difficult to detect, as their energy signature is expected to consist of rather small peaks that overlap with the $2m_1$ continuum.[6] Hence the fact that only two particles out of eight were observed is again consistent with the theoretical model.

Experimental Evidence for E_8 Symmetry?

We can now finally address the question from the title of this paper, slightly rephrased: Did the experimenters detect E_8? First, we should say that they themselves do not claim to have done so. Rather, they claim to have found experimental evidence for the theory developed by Zamolodchikov et al. and described above—which we shall call below simply *Zamolodchikov's theory*—and that this in turn means giving evidence for E_8 symmetry.

The argument for these claims goes as follows. The E_8 ATFT is an integrable field theory describing the magnetically perturbed Ising model (Eq.3) and satisfying (Z1)–(Z4). In that situation, Zamolodchikov and Delfino-Mussardo made some numerical predictions regarding the relative masses of the particles and relative intensities

[6]*Possibly because of this, the region above this threshold has been called the "incoherent continuum", a suggestive and Lovecraftian term.*

of the scattering peaks. The experimental data show two peaks, but the second peak is resolved only at lower energies. The ratios of masses and intensities are certainly consistent with the theoretical predictions, although the ratios appear to be measured only rather roughly.

At this point, we want to address three objections to this line of argument that we heard when giving talks on the subject.

Objection #1: Confirmatory Experimental Results Are Not Evidence

We heard the following objection: experiments can never provide evidence for a scientific theory; they can only provide evidence against it. (This viewpoint is known as *falsificationism*.) This is of course preposterous. Science progresses only through the acceptance of theories that have survived enough good experimental tests, even if the words "enough" and "good" are open to subjective interpretations.

A less extreme version of this same objection is: confirmatory experimental results are automatically suspect in view of notorious historical examples of experimenter's bias such as cold fusion and N-rays. This sort of objection is better addressed to the experimental physics community, which as a whole is familiar with these specific examples and with the general issue of experimenter's bias. As far as we know, no such criticisms have been raised concerning the methods described in [CTW+].

Objection #2: It Still Doesn't Seem Like Enough Data

Recall that the experimental results can be summarized as a limited set of numbers that approximately agree with the theoretical predictions. Based on this, we have heard the following objection: if you start by looking at this small amount of data, how can you claim to have pinned down something as complex as E_8? This question contains its own answer. One doesn't analyze the results of the experiment by examining the data, divorced from all previous experience and theoretical framework. Instead, humanity already knows a lot about so-called critical point phenomena,[7] and there is a substantial theoretical model that is expected to describe the behavior of the magnet. The experiment described in [CTW+] was a test of the relevance and accuracy of Zamolodchikov's theory, not an investigation of magnets beginning from no knowledge at all.

To put it another way, someone who approaches science from the viewpoint of this objector would necessarily reject many results from experimental physics that are based on similar sorts of indirect evidence. To give just one example of such a result, the reported observations of the top quark in [A+ 95a] and [A+ 95b] were not direct observations but rather confirmations of theoretical predictions made under the assumption that the top quark exists.

Objection #3: The Numerical Predictions Don't Require E_8

If you examine the papers [Z] by Zamolodchikov and [DM] by Delfino and Mussardo, you see that the numerical predictions are made without invoking E_8. At this point, one might object that E_8 is not strictly necessary for the theoretical model. But, as we explained in the section "Magnetic Perturbation and Zamolodchikov's Calculation", the role of E_8 in the theory is that by employing it, Zamolodchikov's *assumption* (Z1) is turned into a *deduction*. That is, by including E_8, we reduce the number of assumptions and achieve a more concise theoretical model. Moreover, the E_8 version of the theory justifies the amazing numerological coincidences between Zamolodchikov's calculations and the E_8 root system.

Evidence for E_8 Symmetry?

Finally, we should address the distinction between "detecting E_8" and "finding evidence for E_8 symmetry". Although the former is pithier, we're only talking about the latter here. The reason is that, as far as we know, there is no direct correspondence between E_8 and any physical object. This is in contrast, for example, to the case of the gauge group SU(3) of the strong force in the standard model in particle physics. One can meaningfully identify basis vectors of the Lie algebra $\mathfrak{su}(3)$ with gluons, the mediators of the strong force, which have been observed in the laboratory. With this distinction in mind, our view is that the experiment cannot be said to have detected E_8 but that it has provided evidence for Zamolodchikov's theory and hence for E_8 symmetry as claimed in [CTW+].

Summary

The experiment with the cobalt niobate magnet consisted of two phases. In the first phase, the experimenters verified that in the absence of an external magnetic field, the 1-dimensional quantum Ising model (Eq.3) accurately describes the spin dynamics, as predicted by theorists. In the second phase, the experimenters added an external magnetic field directed transverse to the spins' preferred axis and tuned this field close to the value required to reach the quantum critical regime. In that situation, Zamolodchikov et al. had predicted the existence of eight distinct types of particles in a field theory governed by the compact Lie algebra E_8. The experimenters observed the two smallest

[7] *See, for example, the twenty-volume series* Phase Transitions and Critical Phenomena *edited by C. Domb and J. L. Lebowitz.*

particles and confirmed two numerical predictions: the ratio of the masses of the two smallest particles (predicted by Zamolodchikov) and the ratio of the intensities corresponding to those two particles (predicted by Delfino-Mussardo).

In this article, we have focused on the E_8 side of the story because E_8 is a mathematical celebrity. But there is a serious scientific reason to be interested in the experiment apart from E_8: it is the first experimental test of the perturbed conformal field theory constructed by Zamolodchikov around 1990. Also, it is the first laboratory realization of the critical state of the quantum 1-dimensional Ising model in such a way that it can be manipulated—the experimenters can continuously vary the transverse field strength g_x in (Eq.3) across a wide range while preserving the 1-dimensional character—and the results observed directly. Since the Ising model is the fundamental model for quantum phase transitions, the opportunity to probe experimentally its very rich physics represents a breakthrough.

References

[A+ 95a] S. Abachi et al., Search for high mass top quark production in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV, *Phys. Rev. Lett.* **74** (1995), no. 13, 2422–2426.

[A+ 95b] F. Abe et al., Observation of top quark production in $p\bar{p}$ collisions with the Collider Detector at Fermilab, *Phys. Rev. Lett.* **74** (1995), no. 14, 2626–2631.

[BLM] S. Berman, Y. S. Lee, and R. V. Moody, The spectrum of a Coxeter transformation, affine Coxeter transformations, and the defect map, *J. Algebra* **121** (1989), no. 2, 339–357.

[Bo] N. Bourbaki, *Lie Groups and Lie Algebras: Chapters 4–6*, Springer-Verlag, Berlin, 2002.

[BPZ] A. A. Belavin, A. M. Polyakov, and A. B. Zamolodchikov, Infinite conformal symmetry in two-dimensional quantum field theory, *Nuclear Phys. B* **241** (1984), 333–380.

[Br] H. W. Braden, A note on affine Toda couplings, *J. Phys. A* **25** (1992), L15–L20.

[BRA] D. Bitko, T. F. Rosenbaum, and G. Aeppli, Quantum critical behavior for a model magnet, *Phys. Rev. Lett.* **77** (1996), 940–943.

[Ca] R. W. Carter, *Simple Groups of Lie Type*, Wiley, 1989.

[Cor] E. Corrigan, *Recent Developments in Affine Toda Quantum Field Theory*, Particles and Fields (G. W. Semenoff and L. Vinet, eds.), Springer, 1999, pp. 1–34. [Also available at arXiv:hep-th/9412213.]

[Cox] H. S. M. Coxeter, *Regular Complex Polytopes*, Cambridge University Press, 1991.

[CT] S. T. Carr and A. M. Tsvelik, Spectrum and correlation functions of a quasi-one-dimensional quantum Ising model, *Physical Rev. Letters* **90** (2003), no. 17, 177206.

[CTW+] R. Coldea, D. A. Tennant, E. M. Wheeler, E. Wawrzynska, D. Prabhakaran, M. Telling, K. Habicht, P. Smibidl, and K. Kiefer, Quantum criticality in an Ising chain: Experimental evidence for emergent E_8 symmetry, *Science* **327** (2010), 177–180.

[DFMS] P. Di Francesco, P. Mathieu, and D. Sénéchal, *Conformal Field Theory*, Graduate Texts in Contemporary Physics, Springer-Verlag, New York, 1997.

[DG] J. Distler and S. Garibaldi, There is no "Theory of Everything" inside E_8, *Comm. Math. Phys.* **298** (2010), 419–436.

[DM] G. Delfino and G. Mussardo, The spin-spin correlation function in the two-dimensional Ising model in a magnetic field at $T = T_c$, *Nuclear Phys. B* **455** (1995), 724–758.

[Do] P. Dorey, Root systems and purely elastic S-matrices, *Nuclear Phys. B* **358** (1991), no. 3, 654–676.

[EY] T. Eguchi and S.-K. Yang, Deformations of conformal field theories and soliton equations, *Phys. Lett. B* **224** (1989), no. 4, 373–378.

[FLO] A. Fring, H. C. Liao, and D. I. Olive, The mass spectrum and coupling in affine Toda theories, *Phys. Lett. B* **266** (1991), 82–86.

[Fo] G. B. Folland, Speaking with the natives: Reflections on mathematical communication, *Notices Amer. Math. Soc.* **57** (2010), no. 9, 1121–1124.

[FQS] D. Friedan, Z. Qiu, and S. Shenker, Conformal invariance, unitarity, and critical exponents in two dimensions, *Phys. Rev. Lett.* **52** (1984), no. 18, 1575–1578.

[Fr] M. D. Freeman, On the mass spectrum of affine Toda field theory, *Phys. Lett. B* **261** (1991), no. 1-2, 57–61.

[FZ] V. A. Fateev and A. B. Zamolodchikov, Conformal field theory and purely elastic S-matrices, *Internat. J. Modern Phys. A* **5** (1990), no. 6, 1025–1048.

[GaS] S. Garibaldi and N. Semenov, *Degree 5 invariant of E_8*, Int. Math. Res. Not. IMRN (2010), no. 19, 3746–3762.

[GHMR] D. J. Gross, J. A. Harvey, E. Martinec, and R. Rohm, Heterotic string, *Physical Review Letters* **54** (1985), no. 6, 502–505.

[GKO] P. Goddard, A. Kent, and D. Olive, Virasoro algebras and coset space models, *Phys. Letters B* **152** (1985), no. 1–2, 88–92.

[He] M. Henkel, *Conformal Invariance and Critical Phenomena*, Texts and Monographs in Physics, Springer-Verlag, Berlin, 1999.

[HeS] M. Henkel and H. Saleur, The two-dimensional Ising model in a magnetic field: A numerical check of Zamolodchikov's conjecture, *J. Phys. A* **22** (1989), 513–518.

[HoM] T. J. Hollowood and P. Mansfield, Rational conformal field theories at, and away from, criticality as Toda field theories, *Phys. Lett. B* **226** (1989), no. 1–2, 73–79.

[I] E. Ising, Beitrag zur Theorie des Ferromagnetismus, *Z. Phys.* **31** (1925), 253–258.

[J 71] N. Jacobson, *Exceptional Lie algebras*, Lecture Notes in Pure and Applied Mathematics, vol. 1, Marcel-Dekker, New York, 1971.

[J 79] ———, *Lie Algebras*, Dover, 1979.

[K 59] B. Kostant, The principal three-dimensional subgroup and the Betti numbers of a complex simple Lie group, *Amer. J. Math.* **81** (1959), 973–1032.

[K 85] ———, The McKay correspondence, the Coxeter element and representation theory, *Astérisque* (1985), no. Numero Hors Serie, 209–255, The mathematical heritage of Élie Cartan (Lyon, 1984).

[K 10] ———, Experimental evidence for the occurrence of E_8 in nature and the radii of the Gosset circles, *Selecta Math. (NS)* **16** (2010), no. 3, 419–438.

[L] A. Garrett Lisi, *An exceptionally simple theory of everything*, arXiv:0711.0770 [hep-th], 2007.

[MS] N. Marcus and J. H. Schwarz, Three-dimensional supergravity theories, *Nuclear Phys. B* **228** (1983), no. 1, 145–162.

[Mu] G. Mussardo, *Statistical Field Theory*, Oxford Graduate Texts, Oxford University Press, Oxford, 2010.

[MW 73] B. M. McCoy and T. T. Wu, *The Two-Dimensional Ising model*, Harvard University Press, 1973.

[MW 78] ———, Two-dimensional Ising field theory in a magnetic field: Breakup of the cut in the two-point function, *Phys. Rev. D* **18** (1978), no. 4, 1259–1267.

[O] L. Onsager, Crystal statistics. I. A two-dimensional model with an order-disorder transition, *Phys. Rev. (2)* **65** (1944), 117–149.

[P] A. M. Polyakov, Conformal symmetry of critical fluctuations, *JETP Lett.* **12** (1970), 381.

[Sa] S. Sachdev, *Quantum Phase Transitions*, Cambridge University Press, Cambridge, 1999.

[Se 79] J.-P. Serre, *Local Fields*, Graduate Texts in Mathematics, vol. 67, Springer, New York-Berlin, 1979.

[Se 02] ———, *Galois Cohomology*, Springer-Verlag, 2002, originally published as *Cohomologie galoisienne* (1965).

[St] J. Stembridge, *Coxeter planes*, `http://www.math.lsa.umich.edu/~jrs/coxplane.html`.

[SZ] I. R. Sagdeev and A. B. Zamolodchikov, Numerical check of the exact mass spectrum of the scaling limit of $T = T_c$ Ising model with magnetic field, *Modern Physics Letters B* **3** (1989), no. 18, 1375–1381.

[TFV] M. J. Tejwani, O. Ferreira, and O. E. Vilches, Possible Ising transition in a ^{4}He monolayer adsorbed on Kr-plated graphite, *Phys. Rev. Letters* **44** (1980), no. 3, 152–155.

[V] D. Vogan, The character table for E_8, *Notices of the AMS* **54** (2007), no. 9, 1022–1034.

[Z] A. B. Zamolodchikov, Integrals of motion and S-matrix of the (scaled) $T = T_c$ Ising model with magnetic field, *Int. J. Modern Physics* **4** (1989), no. 16, 4235–4248.

String Theory and the Geometry of the Universe's Hidden Dimensions

Shing-Tung Yau and Steve Nadis

This article is adapted from a talk that Shing-Tung Yau gave at the University of California, Berkeley, on February 10, 2011. The talk was written by Yau and Nadis, based on their book, The Shape of Inner Space *(Basic Books, 2010). Both the talk and the book are presented from Yau's perspective, with the story told in Yau's voice.*

I'd like to talk about how mathematics and physics can come together to the benefit of both fields, particularly in the case of Calabi-Yau spaces and string theory. This, not coincidentally, is the subject of the new book I have coauthored, *The Shape of Inner Space*. This book tells the story of those spaces. It also tells some of my own story and a bit of the history of geometry as well. In that spirit, I'm going to back up and talk about my personal introduction to geometry and the evolution of the ideas that are discussed in this book.

I wanted to write this book to give people a sense of how mathematicians think and approach the world. I also want people to realize that mathematics does not have to be a wholly abstract discipline, disconnected from everyday phenomena, but is instead crucial to our understanding of the physical world.

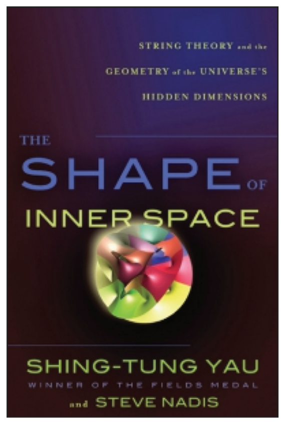
So we're now going to step back a bit in time. Or perhaps I should say step back in spacetime…

Riemannian Geometry

When I arrived in Berkeley in 1969 for graduate study, I learned that the concept of geometry had

Shing-Tung Yau is the William Casper Graustein Professor of Mathematics at Harvard University. His email address is yau@math.harvard.edu.

Steve Nadis, a writer based in Cambridge, Massachusetts, is the coauthor (with Yau) of The Shape of Inner Space *(Basic Books, 2010). His email address is* stevenadis@comcast.net.



gone through a radical change in the nineteenth century, thanks to the contributions of Gauss and Riemann. Riemann revolutionized our notions of space, freeing up mathematics in the process.

Objects no longer had to be confined to the flat, linear space of Euclidean geometry. Riemann instead proposed a much more abstract conception of space—of any possible dimension—in which we could describe distance and curvature. In fact, one can develop a form of calculus that is especially suited to such an abstract space.

About fifty years later, Einstein realized that this kind of geometry, which involved curved spaces, was exactly what he needed to unify Newtonian gravity with special relativity. This insight culminated in his famous theory of general relativity.

I learned about Riemannian geometry during my first year at Berkeley in 1969. It was different from the classical geometry that I studied in college in Hong Kong, where we focused on curves and surfaces in linear space. At Berkeley, I took courses from Spanier on algebraic topology, Lawson on Riemannian geometry, and Morrey on partial differential equations. I also audited courses on many other subjects, including general relativity, taking in as much information as I could possibly assimilate.

Algebraic topology was rather new to me. But, after a couple of months, I was able to understand what a fundamental group is, while also picking up some elementary facts about homotopy and homology theory.

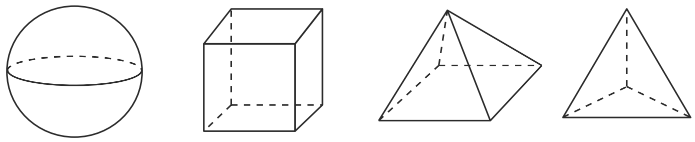


Figure 1. In topology, a sphere, cube, square pyramid, and tetrahedron—among other shapes—are all considered equivalent. [Xianfeng (David) Gu and Xiaotian (Tim) Yin in *The Shape of Inner Space*.]

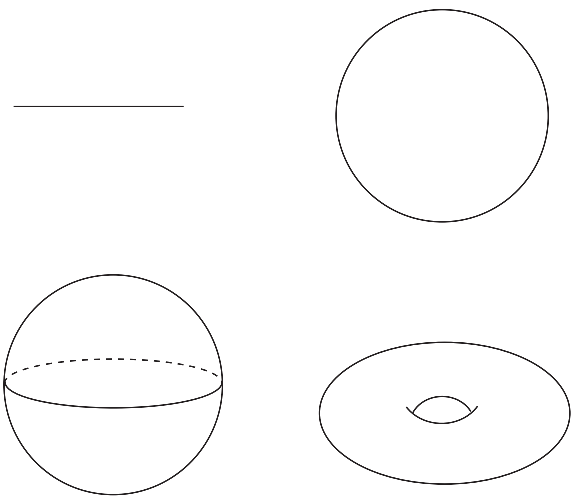


Figure 2. In topology, there are just two kinds of one-dimensional spaces that are fundamentally different from one another: a line and a circle. Two-dimensional (orientable) surfaces can be classified by their genus or number of holes. A sphere of genus 0, with no holes, is fundamentally distinct from a donut of genus 1, which has one hole. [Xianfeng (David) Gu and Xiaotian (Tim) Yin in *The Shape of Inner Space*.]

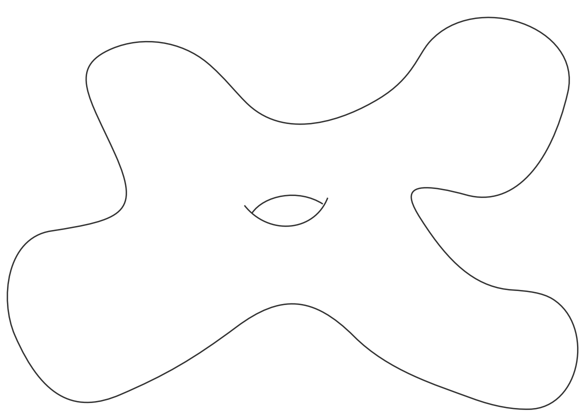


Figure 3. The donut has the same topology as this less familiar (and perhaps less tasty) object, but they have a different shape (or geometry). [Courtesy of Xiaotian (Tim) Yin.]

There were about five hundred graduate students in the mathematics department at the time, and nobody had an office. We were in Campbell Hall, and instructors used the T building—the wood building in front of Evans Hall.

I spent all my free time in the mathematics library, which served as my unofficial office, where I constantly searched for interesting articles to pass the time. During the Christmas holiday of that year, when everybody else went home, I read John Milnor's paper in the *Journal of Differential Geometry*[1] on the relation of the fundamental group to the curvature of a manifold. I found that exciting because those were exactly the concepts that I had just studied. And Milnor was such a good writer that I understood everything in his paper. He referred to another paper by Preissman[2] that sounded interesting to me.

From these papers, I learned that if the space has negative curvature, there is a strong constraint on the "fundamental group"—a concept from topology. Such a group consists of closed loops in that space, each of which has an initial point fixed. The elements of this group, which can be deformed to each other, are considered equivalent. Preissman's theorem says that, in the fundamental group of manifolds with negative curvature, every two commuting elements can be written as a multiple of some other element in the group. This was intriguing, and I started to toy around with Preissman's paper, trying to see what would happen if the space is allowed to have nonpositive curvature. This was the first time I got into statements linking the curvature of a space—a precise description of the geometry—to a much cruder, more general way of characterizing shape, which we call topology.

Topology is a concept of a space that is unrelated to the way that we measure distance in that space. In that sense, topology describes a space much less precisely than geometry does. We need to know all the details of a space to measure the distance between any two points. The sum of all those details, which spell out the curvature at every point, is what we mean by geometry (Figures 1, 2, 3).

A donut and a coffee mug, for example, have the same topology, but they have a different shape or geometry. A sphere and an ellipsoid, similarly, have the same topology, but they generally have a different shape. The sphere is a topological space with no fundamental group, as every closed loop can be shrunk to a point continuously. But there

[1] *J. Milnor, A note on curvature and fundamental group,* J. Differential. Geometry **2** *(1968), 1–7.*

[2] *A. Preissman, Quelques propriétés globales des espaces de Riemann,* Comment. Math. Helv. **15** *(1942–1943), 175–216.*

are closed curves on the surface of a torus that cannot be shrunk to a point continuously.

I wrote down my generalization of Preissman's theorem, which links topology to geometry.[3]

While I was photocopying those notes in the Xerox room, I ran into Arthur Fisher, a mathematical physicist. He insisted on knowing what I had written. After reading through my notes, he told me that any principle that related curvature with topology would be useful in physics. His comments have stayed with me ever since.

General Relativity

We learned through special relativity that space and time should not be treated separately but should instead be merged together to form spacetime. Einstein struggled in his attempt to obtain a fundamental description of gravity. But he got some help from his friend Marcel Grossman, a mathematician, who told him of the work of other mathematicians, Riemann and Ricci.

Riemann provided the framework of abstract space, as well as the means for defining distance and curvature in such a space. Riemann thus supplied the background space or setting in which gravity, as Einstein formulated it, plays out.

But Einstein also drew on the work of Ricci, who defined a special kind of curvature that could be used to describe the distribution of matter in spacetime. In fact, the Ricci curvature can be viewed as the trace of the curvature tensor. A remarkable feature of this curvature is that it satisfied the conservation law due to the identity of Bianchi. And it was exactly this conservation law that enabled Einstein to provide a geometric picture of gravity. Rather than considering gravity as an attractive force between massive objects, it could instead be thought of as the consequence of the curvature of spacetime due to the presence of massive objects. The precise way in which spacetime is curved tells us how matter is distributed.

To those readers interested in history, it is always instructive to find out what Einstein, himself, had to say on the subject. "Since the gravitational field is determined by the configuration of masses and changes with it, the geometric structure of this space is also dependent on physical factors," he wrote. "Thus, according to this theory, space is—exactly as Riemann guessed—no longer absolute; its structure depends on physical influences. [Physical] geometry is no longer an isolated, self-contained science like the geometry of Euclid."[4]

But it still took Einstein many years to formulate his famous field equations. First he developed the special theory of relativity, establishing the equivalence of so-called inertial frames of reference, which he presented in 1905. A couple of years later, he realized that gravity could not be treated within special relativity, which was a linear theory, but instead needed to be treated in a separate, nonlinear theory. He then began to work on the latter theory, which came to be known as *general relativity*, admitting that "it took me a long time to see what coordinates at all meant in physics." The notion of equivalence, which held that the laws of gravity should be true in any coordinate system, had been his guiding principle. By 1912, he started to realize that the gravitational potential should be described by a second-order symmetric tensor—a Riemannian metric with a Lorentzian signature.[5]

Two additional problems had to be solved as well, Einstein noted: 1. How can a field law, expressed in terms of the special theory of relativity, be transferred to the case of a Riemannian metric? 2. What are the laws that determine the Riemannian metric itself?[6]

He worked on these problems from 1912 to 1914 with Grossman. Together they determined that the mathematical methods for solving the first problem could be found in the differential calculus of Ricci and Levi-Civita. They further discovered that the solution of the second problem depended on a mathematical construction ("differential invariants of the second order") that had already been established by Riemann.

However, his collaboration with Grossman did not lead to the final form of the field equation of gravity, as the equation they found was not covariant and did not satisfy the conservation law. In November 1915 he finally found the correct version of his equation, which was around the same time that David Hilbert did so independently. But Einstein carried things an important step further, as he alone was able to link his theory with "the facts of astronomical experience".

Reflecting on his accomplishment, Einstein wrote, "In the light of the knowledge attained, the happy achievement seems almost a matter of course, and any intelligent student can grasp it without too much trouble. But the years of anxious searching in the dark, with their intense longing, their alternations of confidence and exhaustion, and the final emergence into the light—only those who have experienced it can understand that."[7]

Einstein's struggle to understand gravity is remarkable and his success in this area even more

[3] *Shing-Tung Yau, On the fundamental group of compact manifolds of non-positive curvature,* Annals of Mathematics *93 (May 1971), pp. 579–585.*

[4] *A. Einstein,* The Problem of Space, Ether, and the Field in Physics, *In Mein Weltbild, Querido Verlag, Amsterdam, 1934.*

[5] *Abraham Pais,* Subtle Is the Lord, *Oxford University Press, New York, 1982.*

[6] *A. Einstein,* Notes on the Origin of the General Theory of Relativity, *In Mein Weltbild, Querido Verlag, Amsterdam, 1934.*

[7] *A. Einstein and M. Grossman,* Entwurf einer verallgemeinerten Relativitätstheorie und einer Theorie der Gravitation, *Teubner, Leipzig and Berlin, 1913.*

Figure 4. Twelve million light years away, a supermassive black hole, approximately 70 million times more massive than the sun, is thought to reside in the center of the spiral Galaxy M81. (Image courtesy of NASA.)

so. One thing that is resoundingly apparent is the critical contribution of Riemannian geometry to that effort.

When I looked at the equations of Einstein more than a half century later, I was intrigued by the fact that matter controls only part of the curvature of spacetime. I wondered whether we could construct a spacetime that is a vacuum and thus has no matter, yet whose curvature is still pronounced, meaning that its gravity would be nonzero. Well, the famous Schwarzschild solution to Einstein's equations is such an example. This solution applies to a non-spinning black hole—a vacuum that, curiously, has mass owing to its extreme gravity.[8] But that solution admits a singular point, or singularity—a place where the laws of physics break down. [See Figure 4.]

I became interested in a different situation—a smooth space, without a singularity, that was compact and closed, unlike the open, extended space of the Schwarzschild solution. The question was: Could there be a compact space that contained no matter—a closed vacuum universe, in other words—whose force of gravity was nontrivial? I was obsessed with this question and believed that such a space could not exist. If I could prove that, I was sure that it would be an elegant theorem in geometry.

Calabi Conjecture

When I started thinking about this in the early 1970s, I did not realize that the geometer Eugenio Calabi had posed almost the exact same question. Calabi framed the problem in fairly complicated mathematical language—involving difficult concepts such as Kähler manifolds, Ricci curvature, and Chern classes—that ostensibly had nothing to do with physics.[9] Yet his abstract conjecture could also be framed in terms of Einstein's theory of general relativity. The additional information that he put in is that the space should admit some kind of internal symmetry called supersymmetry—a term coined by physicists. (Expressed in the language of geometry, this means an internal symmetry created by some constant spinors—constant in this case meaning spinors that are parallel. In the case of six-dimensional space, spaces with nontrivial constant spinors are Kähler manifolds unless the space is the Cartesian product of lower-dimensional spaces.) In that context, Einstein's question translated to: Can there be gravity, or the curving of space, in a closed vacuum—a compact supersymmetric space that has no matter?

For about three years, my friends and I tried to prove that the class of spaces proposed by Calabi could not exist. We, along with many others, considered them to be "too good to be true". We were skeptical not only because the conjecture argued for the existence of a closed vacuum with gravity but also because it implied that there was a systematic way of constructing many such examples. Despite the reasons we had for finding Calabi's argument dubious, try as we might, we could not prove that such spaces do not exist. (See Figure 5.)

In the spring of 1973, I was an assistant professor at Stony Brook. I had some correspondence with Robert Osserman on surface theory, and he seemed interested in my work on minimal surfaces. Since my girlfriend was in California at the time, I decided to ask whether I might be able to come to Stanford during the next year. To my surprise, Osserman replied immediately and offered me a visiting position.

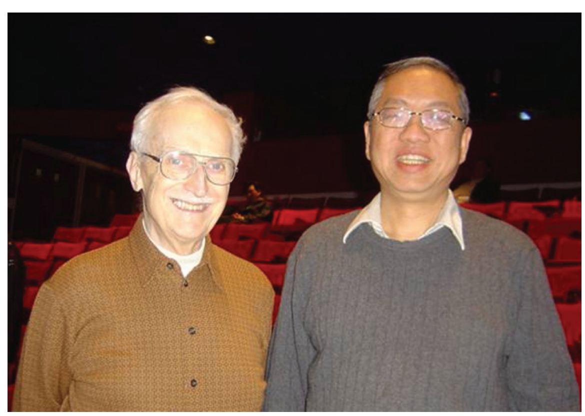


Figure 5. Eugenio Calabi and Shing-Tung Yau at the Harvard University Science Center. [Image courtesy of S. T. Yau.]

[8] *K. Schwarzschild,* Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie, *Sitzungsberichte der Deutschen Akademie der Wissenschaften zu Berlin, Klasse fur Mathematik, Physic, und Technik, 1916, 189.*

[9] *E. Calabi,* The Space of Kähler Metrics, *Proc. Int. Congr. Math. Amsterdam (1954), no. 2, 206–207.*

In late May of that year, I drove across the country with a graduate student. It was a long journey, and quite an experience, as both of us were relatively new to driving. Fortunately, I made it to Berkeley intact, with both the vehicle and my driving companion in one piece. There I met up with my friend S.-Y. Cheng, and together we went to Stanford to settle down. I worked hard on some papers that were to be presented at a huge three-week conference at Stanford in August.

Osserman and my teacher S. S. Chern (Figure 6) organized the conference. Perhaps my connections with them allowed me to present not one but two talks at this conference. But when I told some friends, while the meeting was under way, that I'd just found a counterexample to the Calabi conjecture, many geometers insisted that I give a separate presentation that evening. About thirty geometers gathered together on the third floor of the math building. The audience included Calabi, Chern, and other prominent mathematicians. I described my construction, and everybody seemed happy with it.

My argument incorporated the recent theorem of Cheeger-Gromoll called the splitting theorem in order to provide a structure theorem for manifolds with nonnegative first Chern class.[10] If the Calabi conjecture were true, such a manifold would have Kähler metrics with nonnegative Ricci curvature. Hence I could apply the Cheeger-Gromoll theorem to find an algebraic surface whose first Chern class was numerically nonnegative, which does not satisfy the conclusion of the structure theorem. Such a result, contradicting the Calabi conjecture, would have doomed the conjecture if it could be proven true.

All the same, Calabi advanced an argument as to why this approach should work. At the end of the conference, Chern announced that this counterexample was, arguably, the best outcome of the entire conference. I was astonished but happy.

However, about two months later, reality set in. Calabi wrote me a letter regarding some points in my argument that he could not understand. When I received his letter, I immediately realized that I had made a mistake: Although the algebraic surfaces upon which my argument rested could have a numerically nonnegative first Chern class, it need not be nonnegative. And that's where I'd gone astray.

I tried hard to come up with a new argument, working for two weeks straight with practically no sleep, pushing myself to the brink of collapse. Each time I found a possible counterexample, I soon found a subtle reason as to why it could not work. For example, I derived interesting Chern number inequalities for Kähler-Einstein manifolds, but, as with the previous cases, this did not advance my effort to disprove the Calabi conjecture. After many such abortive attempts, I concluded that the conjecture must be correct after all. Once I made up my mind, I switched gears completely, putting all my energies into proving it right. I finally did so, several years later, in 1976.[11]

An additional bonus was that many of my failed counterexamples became important theorems of their own years later when I finally proved that the conjecture was correct.[11, 12]

I should say that at the same Stanford conference, the physicist Robert Geroch gave a talk on an important question in general relativity called the positive mass conjecture, which holds that the total mass or energy in any closed physical system must be positive. Schoen and I eventually proved this conjecture after some difficult calculations involving minimal surfaces and a lot of hard work. I still remember that the first hint of a possible solution hit us during a conversation we had while walking toward my apartment on the lawns of the west campus of Berkeley.

The experience led us to think more about general relativity, and we eventually proved some theorems about black holes. My favorable interactions with general relativists also made me more open to collaborating with physicists in the development of string theory, although that didn't come until several years later.

In my proof of the Calabi conjecture, I found a general mechanism to construct spaces satisfying Calabi's equations, which are now called Calabi-Yau spaces. I had a strong sense that I had somehow stumbled onto a beautiful piece of mathematics. And as such, I felt it must be relevant to physics and to our deepest understanding of nature. However, I did not know exactly where these ideas might fit in, as I didn't know much physics at the time.

Figure 6. Shiing-Shen Chern and Shing-Tung Yau at the Academia Sinica in Taipei, Taiwan, in 1992. [Image courtesy of S. T. Yau.]

[10] *J. Cheeger and Detlef Gromoll, The splitting theorem for manifolds of nonnegative Ricci curvature,* J. Differential Geometry **6** *(1971), 119–128.*

[11] *Shing-Tung Yau, Calabi's conjecture and some new results in algebraic geometry,* Proc. Natl. Acad. Sci. **74** *(1977), no. 5, 1798–1799.*

[12] *A. Beauville, Variétés Kählériennes dont la première classe de Chern est nulle,* J. Differential Geometry **18** *(1983), 755–782.*

String Theory

In 1984 I received phone calls from two physicists, Gary Horowitz and Andy Strominger. They were excited about a model for describing the vacuum state of the universe, based on a new theory called string theory.

String theory is built on the assumption that particles, at their most basic level, are made of vibrating bits of strings—and exceedingly tiny strings at that. In order for the theory to be consistent with quantum mechanics (at least in some versions of string theory), spacetime requires a certain symmetry built into it called supersymmetry. Spacetime is also assumed to be ten-dimensional.

Horowitz and Strominger became interested in the multidimensional spaces whose existence I proved, mathematically, in my confirmation of the Calabi conjecture. They believed that these spaces might play an important role in string theory, as they seemed to be endowed with the right kind of supersymmetry—a property deemed essential to the theories they were working on. They asked me if their assessment of the situation was correct and, to their delight, I told them that it was. Or at least might be.

Then I got a phone call from Edward Witten, whom I'd met in Princeton the year before. Witten believed that this was one of the most exciting eras in theoretical physics, just like the time when quantum mechanics was being developed. He told me that everyone who made contributions to quantum mechanics in early days left their mark on the history of physics. He said that the important discoveries of early string theorists, such as Michael Green and John Schwarz,[13] could lead to the grand unification of all forces—the goal that Einstein had spent the last thirty years of his life working toward, although he did not succeed in the end.

Witten was now collaborating with Candelas, Horowitz, and Strominger, trying to figure out the shape, or geometry, of the six "extra" dimensions of string theory. The physicists proposed that these six dimensions were curled up into a minuscule space, which they called Calabi-Yau space—part of the same family of spaces, which Calabi originally proposed and I later proved to exist.[14] (See Figure 7.)

String theory, again, assumes that spacetime has ten dimensions overall. The three large spatial dimensions that we're familiar with, plus time, make up the four-dimensional spacetime of Einstein's theory. But there are also six additional dimensions hidden away in Calabi-Yau space, and this invisible space exists at every point in "real space", according to string theory, even though we can't see it (Figure 8).

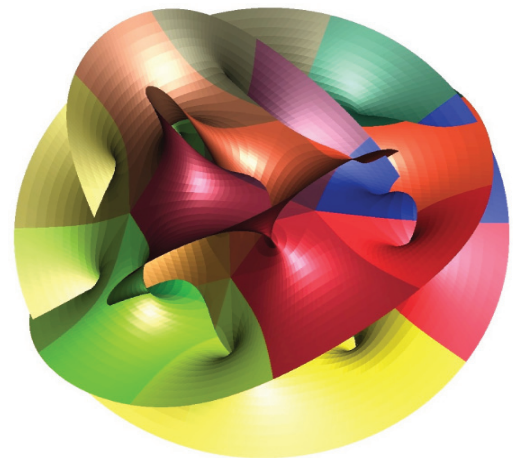


Figure 7. A two-dimensional "slice" of a Calabi-Yau space. [Andrew J. Hanson/Indiana University.]

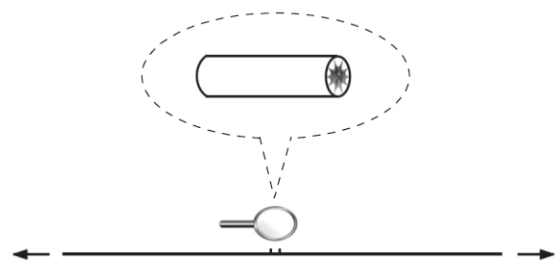


Figure 8. Our four-dimensional spacetime can be represented as a line that extends endlessly in both directions. Although a line, by definition, has no thickness, in this case we assume—as Kaluza and Klein did—that if we were to examine the line with a very powerful magnifying glass, we might discover that the line has some thickness after all. In string theory, it is assumed that this "line", in fact, harbors six extra dimensions in the shape of a Calabi-Yau space. No matter where you slice the line, you will uncover a Calabi-Yau space, and all the spaces exposed in this way would be identical. [Xianfeng (David) Gu and Xiaotian (Tim) Yin in *The Shape of Inner Space*.]

The existence of this extradimensional space is fantastic on its own, but string theory goes much farther. It says that the exact shape, or geometry, of Calabi-Yau space dictates the properties of our universe and the kind of physics we see. The shape of Calabi-Yau space—or the "shape of inner space", as we put it in our book—determines the kinds of particles that exist, their masses, the ways in which

[13] *M. Green and J. Schwarz, Anomaly cancellations in supersymmetric D=10 gauge theory and superstring theory,* Physics Letters B **149** *(1984), 117–122.*

[14] *P. Candelas, G. Horowitz, A. Strominger, and E. Witten, Vacuum configurations for superstrings,* Nuclear Physics B **258** *(1985), 46–74.*

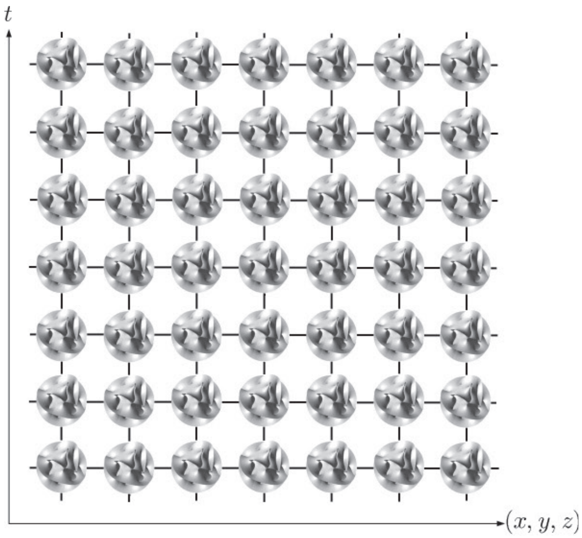


Figure 9. If string theory is correct, at any point in four-dimensional spacetime there's a hidden, six-dimensional Calabi-Yau space. **[Xianfeng (David) Gu and Xiaotian (Tim) Yin in *The Shape of Inner Space*. (Calabi-Yau images courtesy of Andrew J. Hanson, Indiana University).]**

they interact, and maybe even the constants of nature (see Figure 9).

In their attempts to derive the particles of nature, theoretical physicists rely on something called the Dirac operator. Analyzing the spectrum of this operator reveals the variety of particles that we might see. Based on the principle of separation of variables on this ten-dimensional spacetime, which is the product of the four-dimensional spacetime with the six-dimensional Calabi-Yau space, we know that part of the spectrum is contributed by the Calabi-Yau space. Particles with nonzero spectrum will be extremely large if the diameter of the Calabi-Yau space is very small. We do not expect to observe any of these particles, as they would appear only at incredibly high energies.

But particles with zero spectrum are potentially observable and can be calculated from the topology of the Calabi-Yau space. This gives you an idea of why the topology of this tiny, six-dimensional realm could play an important role in physics.

While Einstein had said the phenomenon of gravity is really a manifestation of geometry, string theorists boldly proclaimed that the physics of our universe is a consequence of the geometry of Calabi-Yau space. That's why string theorists were so anxious to figure out the precise shape of this six-dimensional space—a problem we're still working on today. (See Figure 10.)

Witten was eager to learn more about Calabi-Yau spaces. He flew from Princeton to San Diego to talk with me about how to construct them. He also wanted to know how many Calabi-Yau spaces there were for physicists to choose among. Initially,

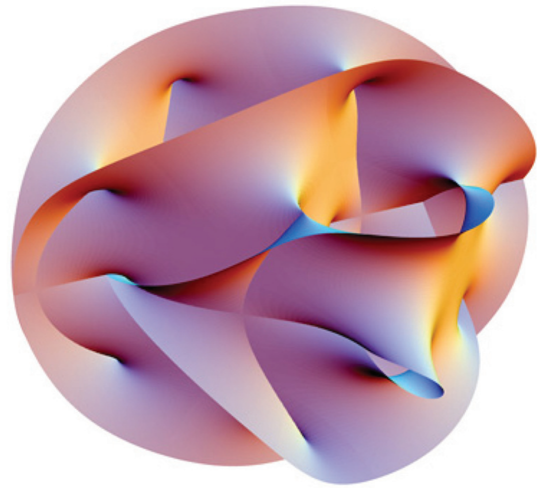


Figure 10. A two-dimensional cross-section of a six-dimensional Calabi-Yau space. **[Andrew J. Hanson/Indiana University.]**

physicists thought there might only be a few examples—a few basic topologies—which made the goal of determining the "internal" shape of our universe seem a lot more manageable. But we soon realized there were many more examples of Calabi-Yau spaces—many more possible topologies—than were originally anticipated. In the early 1980s, I guessed that there were tens of thousands of these spaces, and that number has grown considerably since then.

The task of figuring out the shape of inner space suddenly seemed more daunting, and perhaps even hopeless if the number of possibilities turned out to be infinite. The latter question has yet to be settled, although I have always thought that the number of Calabi-Yau spaces of any dimension is finite. That number is certain to be big, but I believe it is bounded. One reason for thinking that stems from a theorem by Kollár, Miyaoka, and Mori,[15] which showed that, for each dimension, the number of compact manifolds (or spaces) with positive Ricci curvature is indeed finite. Calabi-Yau spaces are compact as well—meaning they cannot extend to infinity—but they have zero Ricci curvature, rather than positive Ricci curvature, so they should be considered a "borderline" case. Normally, when something is proven true for spaces of positive curvature, it is likely to be true for spaces of nonnegative curvature, which would thus include Calabi-Yau spaces. Moreover, after two-and-a-half decades of investigating these spaces, we've found no hint of any method that would enable us to construct an infinite number of them. (See Figure 11.)

---

[15] *János Kollár, Yoichi Miyaoka, and Shigefumi Mori, Rational connectedness and boundedness of Fano manifolds,* J. Differential Geometry **36** (*1992), no. 3, 765–779.*

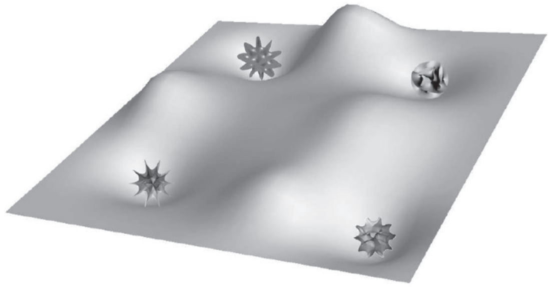


Figure 11. In string theory, the energy of empty space, also called the vacuum energy, can assume a vast number of possible values. The concept of the "landscape" of string theory was invented, in part, to illustrate the fact that the theory has many possible solutions—each corresponding to a different Calabi-Yau space, which gives rise to different physics. The notion of the string theory landscape is closely tied to the idea of a "multiverse". [Xianfeng (David) Gu and Xiaotian (Tim) Yin in *The Shape of Inner Space*. (Calabi-Yau images courtesy of Andrew J. Hanson, Indiana University.)]

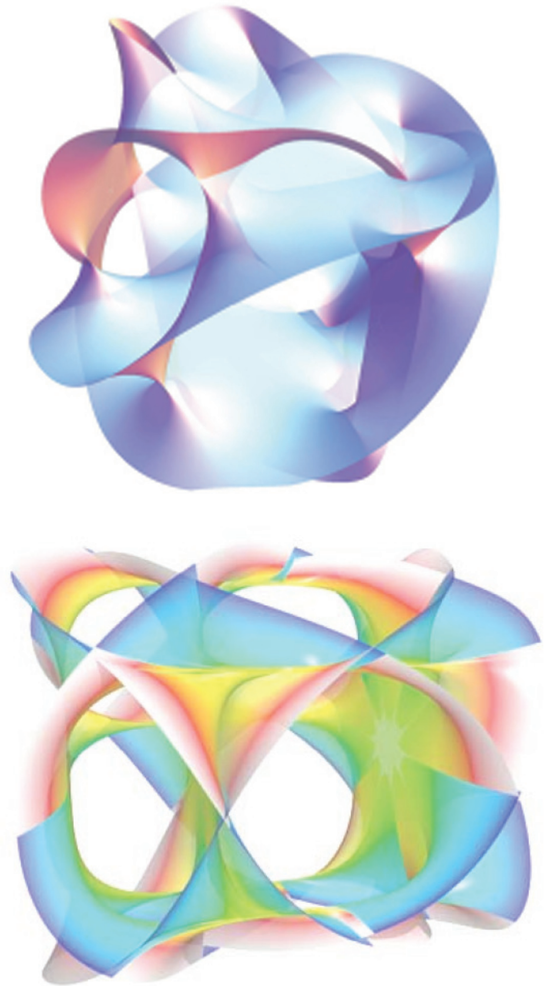


Figure 12. Physicists discovered that two Calabi-Yau spaces that look different and have distinct topologies can still lead to identical physics—a property they called "mirror symmetry". [Andrew J. Hanson/Indiana University.]

The excitement over Calabi-Yau spaces started in 1984, when physicists first began to see how these complex geometries might fit into their new theories. That enthusiasm kept up for a few years before waning. But interest in Calabi-Yau spaces picked up again in the late 1980s, when Brian Greene, Ronen Plesser,[16] Philip Candelas,[17] and others began exploring the notion of "mirror symmetry".

The basic idea here was that two different Calabi-Yau spaces, which had different topologies and seemed to have nothing in common, nevertheless gave rise to the same physics. This established a previously unknown kinship between so-called mirror pairs of Calabi-Yau spaces (Figure 12).

A conjecture proposed in 1995 by Strominger, Yau, and Zaslow offered insights into the substructure of a Calabi-Yau space.[18]

According to the so-called SYZ conjecture, a six-dimensional Calabi-Yau space can essentially be divided into two three-dimensional spaces. One of these spaces is a three-dimensional torus. First you take the torus and "invert" it, through an operation similar to switching its radius from r to $1/r$. When you combine the inverted torus with the other three-dimensional space, you'll have the mirror manifold of the original Calabi-Yau space. This conjecture provides a geometrical picture of mirror symmetry though it has only been proven for special cases and has not yet been proven in a general sense. (See Figure 13.)

The connection between mirror manifolds, which was uncovered through physics, proved to be extremely powerful in the hands of mathematicians. When they were stumped trying to solve a problem involving one Calabi-Yau space, they could try solving the same problem on its mirror pair. On many occasions, this approach was successful. As a result, mathematical problems of counting curves that had defied resolution, sometimes for as long as a century, were now being solved. (The German mathematician Hermann Schubert investigated many of these problems in the nineteenth

[16] *B. R. Greene and M. R. Plesser, Duality in Calabi-Yau moduli space,* Nuclear Physics B **338** *(1990), 15–37.*

[17] *Philip Candelas, Xenia C. De La Ossa, Paul S. Green, and Linda Parkes, A pair of Calabi-Yau manifolds as an exactly soluble superconformal theory,* Nuclear Physics B **359** *(1991), 21–74.*

[18] *A. Strominger, S. T. Yau, and E. Zaslow, Mirror symmetry is T duality,* Nuclear Physics B **479** *(1996), 243–259.*

century.) And a branch of mathematics called enumerative geometry was suddenly rejuvenated. These advances gave mathematicians greater respect for physicists, as well as greater respect for string theory itself.

Mirror symmetry is an important example of what we call a duality. It sheds light on the deep geometry of Calabi-Yau space. It has also helped us solve some very difficult questions of counting rational curves of various degrees on the quintic with five variables, which is a kind of Calabi-Yau space.

This problem, named after Schubert, dates back to the nineteenth century. Schubert showed that the number of degree-one rational curves on a quintic is 2,875. In 1986 Sheldon Katz found that there are 609,250 degree two curves.[19] Then around 1989 two Norwegian mathematicians, Geir Ellingsrud and Stein Strømme, found that the number of degree three curves—based on algebraic geometry techniques—was 2,683,549,425. Relying on a string theory approach, a group of physicists, led by Candelas, arrived at a different number, 317,206,375. The physicists, however, had used a formula that, up to then, had not been motivated by mathematical principles. As such, rigorous justification of that formula still awaited confirmation by mathematicians.

In January of 1990 I organized the first major meeting between string theorists and mathematicians at the urging of Isadore Singer. The event took place at the Mathematical Sciences Research Institute (MSRI) in Berkeley. At this meeting there was a somewhat tense debate regarding who was right, Ellingsrud and Strømme or the Candelas team. The discrepancy between the two camps lasted a few months until the mathematicians discovered a mistake in their computer code. After they corrected that error, their number agreed perfectly with that put forth by the physicists. And, ever since then, mathematicians have begun to appreciate the depth of the insight provided by the string theorists.

The episode also provided firm evidence that mirror symmetry had a mathematical basis. It took several years but, by the mid- to late 1990s, a rigorous mathematical proof of mirror symmetry—and a validation of the Candelas et al. formula—was finally achieved independently by Givental[20] and Lian-Liu-Yau.[21]

Conclusion

Before we get too carried away, we should bear in mind that string theory, as the name suggests, is just a theory. It has not been confirmed by physical experiments, nor have any experiments yet been designed that could put that theory to a definitive test. So the jury is still out on the question of whether string theory actually describes nature, which was, of course, the original intent. (See Figure 14.)

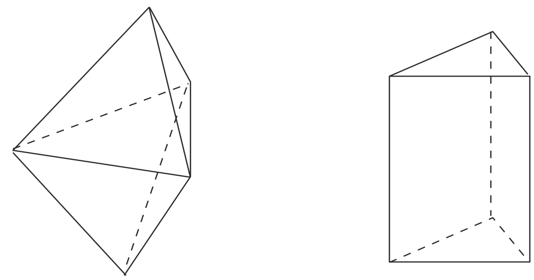


Figure 13. The double tetrahedron, which has five vertices and six faces, and the triangular prism, which has six vertices and five faces, are simple examples of mirror symmetry. These polyhedra can be used to construct a Calabi-Yau space and its mirror pair, although the details of this procedure can get rather technical. [Xiangfeng (David) Gu and Xiaotian (Tim) Yin in *The Shape of Inner Space*.]

On the positive side of the ledger, some extremely intriguing, as well as powerful, mathematics has been inspired by string theory. Mathematical formulae developed through this connection have proved to be correct, and will always remain so, regardless of the scientific validity of string theory. Although it is empirically unproven, string theory now stands as the only consistent theory that unifies the different forces. And it is beautiful. Moreover, the effort to unify the different forces of nature has unexpectedly led to the unification of different areas of mathematics that at one time seemed unrelated.

We still don't know what the final word will be. In the past two thousand years, the concept of geometry has evolved over several important stages to the current state of modern geometry. Each time geometry has been transformed in a major way, the new version has incorporated our improved understanding of nature arrived at through advances in theoretical physics. It seems likely that we shall witness another major development in the twenty-first century, the advent of quantum geometry—a geometry that can incorporate quantum physics in the small and general relativity in the large.

The fact that abstract mathematics can reveal so much about nature is something I find both mysterious and fascinating. This is one of the ideas that my coauthor and I have tried to get across in our book, *The Shape of Inner Space*. We also hope that the book gives you a description of how

[19] *S. Katz, On the finiteness of rational curves on quintic threefolds,* Compositio Math. **60** *(1986), 151–162.*

[20] *A. Givental, Equivariant Gromov-Witten invariants,* Int. Math. Res. Notices **13** *(1996), 613–663.*

[21] *B. Lian, K. Liu, and S. T. Yau, Mirror principle. I,* Asian J. Math. **1** *(1997), 729–763.*

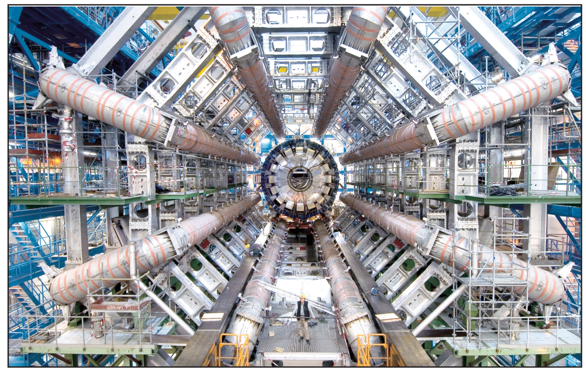


Figure 14. Experiments at the Large Hadron Collider at CERN in Geneva may reveal hints of extra dimensions or the existence of supersymmetric particles. Although such findings would be consistent with string theory, they would not prove that the theory is correct. (Courtesy of CERN.)

mathematicians work. They are not necessarily weird people, such as a janitor who solves centuries-old math problems on the side while mopping and dusting floors, as described in the movie *Good Will Hunting*. Nor does a brilliant mathematician have to be mentally ill or exhibit otherwise bizarre behavior, as depicted in another popular movie and book.

Mathematicians are just scientists who look at nature from a different, more abstract point of view than the empiricists do. But the work mathematicians do is still based on the truth and beauty of nature, the same as it is in physics. Our book tries to convey the thrill of working at the interface between mathematics and physics, showing how important ideas flow through different disciplines, with the result being the birth of new and important subjects.

In the case of string theory, geometry and physics have come together to produce some beautiful mathematics, as well as some very intriguing physics. The mathematics is so beautiful, in fact, and it has branched out into so many different areas, that it makes you wonder whether the physicists might be onto something after all.

The story is still unfolding, to be sure. I consider myself lucky to have been part of it and hope to stay involved in this effort for as long as I can contribute.

Gerhard Hochschild (1915–2010)

Walter Ferrer Santos and Martin Moskowitz, Coordinating Editors

In the mid-1940s and early 1950s, homological algebra was ripe for formalization, or to put it in Hochschild's own words—see his now classic review of the book *Homological Algebra* by Cartan and Eilenberg ([1])— "The appearance of this book must mean that the experimental phase of homological algebra is now surpassed."

From its topological origins in the work of Riemann (1857), Betti (1871), and Poincaré (1895) on the "homology numbers" and after 1925 with the work of E. Noether showing that the homology of a space was better viewed as a group and not as Betti numbers and torsion coefficients, the subject of homology of a space became more and more algebraic. A further step was taken with the appearance of the concept of a chain complex in 1929 as formulated by Mayer and in a different guise by de Rham in his 1931 thesis. In 1935 Hurewicz showed that the homology of an aspherical space depended only on its first homotopy group, hence defining implicitly the (co)homology of a group. In parallel, and purely from the viewpoint of algebra, the low-dimensional cohomology of a group had been considered earlier. For example, it appeared implicitly in Hilbert's Theorem 90 in 1897—known also to Kummer before—as well as in the study of so-called factor sets used to classify group extensions. It also occurred in other contexts—in the early work of Hölder (1893), Schur (1904), and Dickson (1906); and later Brauer (1928), Baer (1934), and Hall (1938). In 1941 H. Hopf gave an explicit formula for the second homology group in terms of a description of the first homotopy group using generators and relations which, according to Mac Lane, provided the justification for the study of group cohomology. The actual definition of homology and cohomology of a group first appears in the famous papers by Eilenberg and Mac Lane: first in the 1943 announcement [2] and later in 1947 in [3] in full detail. More or less simultaneously and independently, Freudenthal considered the same concepts in the Netherlands (c. 1944) and, in a different guise, Hopf was doing the same in Switzerland. In his 1944 paper, instead of using explicit complexes as in [3], Hopf uses free resolutions to define homology groups with integral coefficients, the concept of free resolution having been used in algebra since its introduction by Hilbert in his famous 1890 paper on invariant theory. For the above historical comments the authors followed closely the information appearing in Chapter 28, History of Homological Algebra by C. A. Weibel in [13].

While still a graduate student at Princeton, Hochschild submitted a paper for publication dealing with the study of the behavior of Lie algebras and associative algebras with respect to derivations. In the Introduction to [4]—which was published in 1942 shortly after he was drafted into the army at the end of 1941—he states: "These 'generalized derivations'…were found to be significant for the structure of an algebra. In fact we shall obtain a characterization of semisimple Lie algebras and semisimple associative algebras in terms of these generalized derivations."

Gerhard's dissertation committee, cochaired by Chevalley and Lefschetz, reports: "The thesis deals with certain important problems in Lie algebras

Walter Ferrer Santos is professor of mathematics at the Univ. de la República, Montevideo, Uruguay. He finished his thesis under Hochschild's direction in 1980. His email address is wrferrer@cmat.edu.uy.

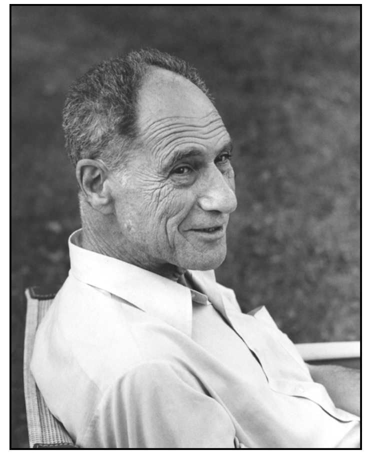
Martin Moskowitz is professor emeritus of mathematics at the City University of New York Graduate Center. He finished his thesis under Hochschild's direction in 1964. His email address is martin.moskowitz@gmail.com.

All photographs, unless otherwise noted, are courtesy of the Hochschild family.

and related questions in associative algebras. It contains in particular a highly interesting characterization of semisimple Lie algebras in terms of the operation of formal derivation. The thesis is highly worthy of publication as it contains many new results in addition to those indicated above. Furthermore, Hochschild set the problem himself and also did the research in an essentially independent way."[1] In modern terms Gerhard proved in his thesis that an associative algebra has the property that all its derivations are inner if and only if it is separable. The method he uses is basically homological, and with the tool of a separability idempotent, constructs from the given derivation the element that is used to characterize it as a conjugation. In these terms he was dealing with what is now called the first Hochschild cohomology group and proving its triviality. It still took Gerhard three years to publish a proof of the natural extension of his thesis results to a general cohomology theorem, and for that it was necessary first to construct an adequate cohomology theory. With that purpose in mind he generalized the complexes used in group cohomology to define what is now called Hochschild cohomology. Putting it in his own words: "The cohomology of an associative algebra is concerned with the m-linear mappings of an algebra into a two-sided module…A linear mapping…analogous to the coboundary operator of combinatorial topology and leading to the notion of 'cohomology group' has been defined by Eilenberg and Mac Lane (unpublished)…The present paper is concerned primarily with the connections between the structure of an algebra and vanishing of its cohomology groups"—see the Introduction to [5]. All these aspects of Hochschild cohomology, as well as its applications and many other topics, are treated in detail in the contribution by M. Gerstenhaber, "Hochschild's Work on Cohomology", that appears later in this article. In that contribution the author also describes the particular circumstances in which these first papers were written. Particularly interesting are his considerations concerning the back-and-forth interactions between the results of [5] and of [3]—e.g., concerning the concept of dimension shifting.

Paul Bateman contributed a note, "Gerhard Hochschild at Urbana (1948–58)", about the participation of Hochschild in the early development of the Department of Mathematics at the University of Illinois at Urbana-Champaign in the late 1940s and 1950s. That was an extremely fruitful period of Gerhard's professional as well as personal life. He married Ruth Heinsheimer in 1950—then a mathematics graduate student at UIUC—and his daughter and son were born in 1955 and 1957, respectively. Some relevant aspects of his mathematical work during this period are described in the following works.

In the contribution by John T. Tate, "Memories of Hochschild, with a Letter from Serre", the author writes about his personal and mathematical interaction with Gerhard in the genesis of the cohomological perspective of class field theory. He also adjoins a letter by Serre describing the process that led to the construction of the so-called Hochschild-Serre spectral sequence.



Gerhard Hochschild at his daughter Ann's wedding, 1978.

There are many mathematical objects carrying Gerhard's name. In another contribution to this memorial, Andy Magid, in "The Hochschild-Mostow group", reviews this concept (named in that fashion by Lubotzky in 1979), which appeared initially under the name of the "group of proper automorphisms of $R(G)$", $R(G)$ being the algebra of representative functions of the group G. This construction appeared in a series of papers by these authors published between 1957 and 1969. G. Hochschild and G. D. Mostow together wrote seventeen papers in different subjects. This very rich mathematical collaboration started while both were members of the Institute for Advanced Study in the academic year 1956–1957. Dan Mostow, in "Gerhard Hochschild as Collaborator", writes a very personal and illustrative note on their personal and mathematical interaction. One of its landmarks is the important paper on the invariant theory of unipotent groups [10]. Another is their theorem on faithful representations of real and complex connected Lie groups which is a global extension of Ado's theorem on Lie algebras (see the contribution to this memorial by M. Moskowitz).

The subject of representative functions is also dealt with in the interview that Pierre Cartier gave to one of the authors, which appears later. In particular, Cartier mentions the influence that his view of Tannaka duality and the concept of Hopf algebras had in this line of research. This is also explicitly spelled out in the introduction to [6], in which Hochschild writes: "We are concerned with the analogues for Lie algebras of the problems centered around the Tannaka duality theorem…The analogue of the Tannaka theorem for semisimple Lie algebras was established by Harish-Chandra in 1950. More recently P. Cartier has sketched (without proofs) a general duality

[1] *We thank the librarians of the Seeley G. Mudd Manuscript Library, Princeton, NJ, and Hochschild's family for providing access to Hochschild's records at Princeton University.*

theory for algebraic groups and Lie algebras which absorbs Harish-Chandra's result."

Cartier—as well as Tate in his article—also comments on the not-too-well-known interaction of Gerhard with the Bourbaki group, which began in the early 1950s when he attended three of the group congresses.[2]

The crucial institutional role he played in the development of mathematics at U. C. Berkeley from the 1960s on is described by Calvin Moore in "Gerhard Hochschild at Berkeley" in this article; in particular he describes in detail the institutional effort made by the department under the direction of J. Kelley (known by Gerhard since they served together at the Aberdeen Proving Ground) to recruit senior mathematicians in order to "aggiornare" the department to new mathematical developments.

Another result that has Hochschild's name attached to it is described by Bertram Kostant. In his contribution, "Hochschild Memorial", he relates from a very personal perspective the very close interaction they had as colleagues at that time at Berkeley. In particular he mentions the paper "Differential forms on regular affine algebras" that they wrote together with Alex Rosenberg (see [8]). This result, which now is known as the "HKR theorem", has played a very important conceptual role in the development of noncommutative geometry.

Concerning the ascribing of names to mathematical concepts and theorems, Gerhard used to say: "The personal names attached to mathematical objects are in general wrong." In this regard he insisted throughout his life that Hochschild cohomology should be called algebraic cohomology and that maybe it would be fairer to use that name for the rational cohomology of algebraic groups, as introduced in [7].

Concerning his interaction with colleagues at the Berkeley mathematics department, the contribution by G. Bergman, "Some Inadequate Recollections of Gerhard", gives a very personal description of Gerhard's personality.

Two of his students and then colleagues give us their personal viewpoint of Gerhard's role as an advisor and later mentor and friend throughout their mathematical careers. A constant subtheme in all the contributions, and in particular in these two, separated by more than twenty years, is a deep appreciation of Gerhard's personality that went together with, but often transcended, his mathematical influence. These two notes are by N. Nahlus, his last student (who finished in 1986), "Gerhard Hochschild as My Advisor and Friend", and M. Moskowitz, who finished in 1964, "Some Reminiscences".

Finally, with the help of Hochschild's family files, the science writer and Gerhard's son-in-law, James Schwartz, in "Gerhard Hochschild's Early Years: A Biographical Sketch", reconstructs the sometimes painful but very eventful early years of Gerhard's life until he sailed from Cape Town to New York in mid-1938 to begin Ph.D. studies at Princeton.

We conclude this introduction by addressing certain details not mentioned in the various contributions.

For one of the leading algebraists of his generation, his choice of courses at Princeton is rather peculiar.

1938/39: Calculus of variations, I.A.S. (Mayer); Elementary theory of functions of a real variable (Bohnenblust); Continuous groups (Eisenhart); Advanced theory of functions of a real variable (Bochner); The theory of relativity (Robertson); Continuous groups (Eisenhart).

1939/40: Applications of the theory of functions of a complex variable (Strodt); Riemannian geometry (Eisenhart); Topological groups (Chevalley); Algebraic geometry (Chevalley); Applications of analysis to geometry (Bochner); Riemannian geometry (Eisenhart).

1940/41: Applications of analysis to geometry (Bochner); Probability and ergodic theory, I.A.S. (Halmos and Ambrose); Differential equations (Chevalley); Research and work on dissertation under the direction of Chevalley—two semesters; Advanced theory of functions of a real variable (Bochner); Ergodic theory, I.A.S. (von Neumann).

An interesting story of his days at Princeton is the following: during the first lectures of Chevalley's course on differential equations the room was packed with people curious to know what he had to say on this subject. But at the end only three people remained: Hochschild, von Neumann, and Weyl.[3]

His writing style has been described by some of his colleagues as crystal clear and sometimes as "relentless". In the review of Gerhard's book *The Structure of Lie Groups*, which is nowadays

[2]*In accordance with the Bourbaki files provided to the editors by J.-P. Serre from Viviane le Dret, Hochschild participated at the following instances: the congress at Pelvoux-le-Poet (June 25 to July 8, 1951), foreign visitors: Hochschild and Borel, "cobayes": Cartier and Mirkil; the congress at Pelvoux-le-Poet (June 25 to July 8, 1952), foreign visitors: Borel, De Rham, and Hochschild; at the congress at Murols (August 17 to 31, 1954), foreign visitors: Hochschild and Tate, Honorable foreign visitors: Iyanaga and Yoshida; efficiency expert Mac Lane, "cobaye": Lang.*

[3]*A chronicler of Princeton's mathematical department in that period describes Chevalley as playing an "endless game of Go". Gerhard developed then a lasting passion for the game, acquiring approximately the level of a seventh kyu.*

considered a classic "fast and deep" introduction to the subject, Hirzebruch states: "It's amazing the extent to which the author achieved his goal to enable a self contained reading to someone who only knows the basics of multi-linear algebra, group theory, set theoretic topology and calculus," mentioning in particular his eighteen-page treatment of Tannaka duality that starts from scratch.

His originality was not limited only to style. One of the main ingredients of the singularity of his mathematics is his methodological consistency, even though that consistency did not always generate the approval of his colleagues. This is illustrated by some of the comments concerning his approach to algebraic groups in [9] and [11], in which the author "relentlessly" and almost exclusively used the Hopf algebra perspective in the development of the theory. Some of his colleagues thought that this viewpoint detracted from the geometric content of the results.

The adjective "relentless" could perhaps also be applied to his teaching style. In the introduction to his not-too-well-known monograph "A second introduction to analytic geometry", dedicated to his son Peter when he was a high school student, and in a direction surely orthogonal to the current trends in mathematical teaching, he says: "What follows is an examination of the basic geometrical features of Euclidian three-space from the view of rigorous mathematics…[and] our program here involves algebra and analysis as much as it involves geometry."

In his theory and practice of teaching, one also finds a tendency to include aspects of what is called "applied mathematics", and that could be considered somewhat surprising in someone deeply involved in the development of the more abstract areas of pure mathematics. In a letter to the *Notices of the AMS* published in July 2009, writing about calculus teaching, he says: "The educational potential of computers can be illustrated […] by elementary examples from classical mechanics construct[ing], by simple numerical integration, orbits like that of the earth around the sun […and…] explor[ing] paths generated when the acceleration depends in various ways on position, velocity, time, and path length from the origin." He bases these convictions on the courses he took in 1934 as an undergraduate in South Africa, where "in 'applied mathematics' […] you learned to formulate simple settings from classical mechanics in terms of differential equations [while] the introductory courses in formal calculus were as discouraging then as they are now."

Throughout his life he had a strong passion for photography. That hobby, which he began when he was a boy in Berlin, enabled him to obtain part-time work as a photographer's assistant in South Africa, a job that turned out to be extremely helpful under the difficult financial circumstances he found himself in while a student. Later in life, and especially after retiring, he dedicated many of his days to photography. In this article we show some pictures illustrative of his work.

References

[1] H. Cartan and S. Eilenberg, *Homological Algebra*, Princeton Univ. Press, Princeton, NJ, 1956.

[2] S. Eilenberg and S. Mac Lane, Relations between homology and homotopy groups, *Proc. Nat. Acad. Sci.* **29** (1943), 155–158.

[3] ———, Cohomology theory in abstract groups. I, *Ann. of Math.* **48** (1947), 51–78.

[4] G. Hochschild, Semi-simple algebras and generalized derivations, *Amer. J. Math.* **64** (1942), 677–694.

[5] ———, On the cohomology groups of an associative algebra, *Ann. of Math.* **46** (1945), 58–67.

[6] ———, Algebraic Lie algebras and representative functions, *Illinois J. Math.* **3** (1959), 499–523.

[7] ———, Cohomology of algebraic linear groups, *Illinois J. Math.* **5** (1961), 492–519.

[8] G. Hochschild, B. Kostant, and A. Rosenberg, Differential forms on regular affine algebras, *Trans. Amer. Math. Soc.* **102** (1962), 384–408.

[9] G. Hochschild, *Introduction to Affine Algebraic Groups*, Holden-Day, Inc., San Francisco, CA, 1971.

[10] G. Hochschild and G. D. Mostow, Unipotent groups in invariant theory, *Proc. Nat. Acad. Sci. U.S.A.* **70** (1973), 646–648.

[11] G. Hochschild, *Basic Theory of Algebraic Groups and Lie Algebras*, Graduate Texts in Mathematics, 75, Springer-Verlag, New York, 1981.

[12] J.-P. Serre, *Local Fields*. Graduate Texts in Mathematics, 67, Springer-Verlag, New York, 1979.

[13] C. A. Weibel, History of homological algebra, in *History of Topology*, I. M. James (ed.) Elsevier, Amsterdam, The Netherlands, 1999.

Short Biography of Gerhard Hochschild

Gerhard Paul Hochschild was born on April 29, 1915, in Berlin, of a middle-class Jewish family. He completed gymnasium there, and, as a consequence of the Nazi takeover in Germany, he emigrated together with his brother to Cape Town in South Africa in 1933, where he took a B.S. degree in science in 1936 and a M.S. in mathematics in 1937. Before beginning Ph.D. studies at Princeton University, he worked as a junior lecturer at the University of Cape Town during the 1937–38 academic year. He completed his thesis, entitled *Semisimple algebras and generalized derivations* and directed by Claude Chevalley, at Princeton in 1941.

After defending his thesis, he was appointed as a part-time instructor and research assistant at Princeton University for the academic year 1941–42 starting in September, but in November he was drafted into the U.S. Army and was mostly stationed at the Aberdeen Proving Ground. In June 1942, he became a naturalized citizen, and three years later, after the war was over, he left the Army to take a part-time position for a semester—November 1945 to June 1946—as an instructor at Princeton University. Two of his papers on what later was to be called Hochschild cohomology list his address as Aberdeen.

Heiner Hochschild and his two sons. Gerhard stands at his left, c. 1925.

Gerhard was a Benjamin Peirce Instructor at Harvard University during the academic years 1946–48 and in September of that year took a position at the University of Illinois at Urbana-Champaign. He spent the academic year 1951–52 visiting Yale University, 1955–56 visiting the University of California at Berkeley, and 1956–57 as a member of the Institute for Advanced Study at Princeton. Gerhard met Ruth Heinsheimer while in Urbana and they married in July 1950. Their daughter Ann was born in 1955 and their son Peter in 1957. Gerhard remained at UIUC until September 1958, when he moved to Berkeley as a professor of mathematics. He retired from Berkeley in 1982 and continued teaching until 1985.

He died peacefully at home on July 8, 2010, in El Cerrito, where he raised his family and lived during his years at Berkeley.

James Schwartz

Gerhard Hochschild's Early Years: A Biographical Sketch

Gerhard, the younger son of Heiner and Lilli, was born in Berlin in 1915. His father, who was a patent attorney with a degree in engineering, nurtured a love of science and engineering in both of his sons. At the age of nine, Gerhard's childhood took an abrupt turn when his mother was diagnosed with a lung ailment and was encouraged by the family doctor to seek a cure in a Swiss sanatorium. Reluctant to be parted from her young son, Lilli, with the support of the same doctor, became convinced that Gerhard shared her affliction and would benefit from a similar cure. Consequently, both mother and son were sent to Switzerland, she to Davos and he to a nearby "Kinderheim" in Arosa.

James Schwartz is a writer and, most recently, the author of In Pursuit of the Gene: From Darwin to DNA, *published by Harvard University Press. His email address is* jamesschwartz1@mac.com.

To the young boy, life in the sanatorium was a form of imprisonment, but Gerhard's spirit was not broken. In one incident reported by a staff member of the Kinderheim, Gerhard sold books and a treasured stamp collection given to him by his parents in order to raise money to buy himself a dog.[4] However, circumstances soon again conspired against the young boy. Far from the comfort of home and without the support of his father and brother, Gerhard was forced to witness at first hand his mother's gradual descent into mental illness, as Lilli began to suffer from delusions and gradually drifted further and further into her own world. After two years in Switzerland, Lilli was transferred to a mental asylum in Germany, where she was later murdered by the Nazis, and Gerhard returned alone to his father and brother in Berlin.

The tragic loss of his mother imprinted him with an acute sense of the fragility of life and at the same time seemed to instill in him a fierce determination to shape his own destiny. Back in Berlin, he entered gymnasium, where he found the German curriculum for the most part tedious and oppressive and developed a lifelong skepticism about formal education. Specializing in doing the minimum amount of work necessary to pass his courses, Gerhard nonetheless maintained his passion for learning and also pursued other interests, including photography and hiking. Though he found most of his high school teachers petty and tyrannical, there was one exception: Herr Doctor Flatow, a mathematics teacher. Five years later, when he was a university student in Cape Town, he wrote Flatow to express his gratitude: "I still remember with pleasure our hours of mathematics in school, and am so grateful to you for interesting me in mathematics."

Meanwhile, Germany itself was tottering on the verge of economic ruin as the National Socialists vied for power. Some seventy-five years after the fact, Gerhard still vividly remembered a particularly threatening incident. He had picked up his light-haired, fair-skinned friend Eva from school, and the two of them were walking home when a young Nazi roared up to them on a motorcycle. In a menacing voice, the Nazi boy said, "A Christian girl like you should not be with a dirty Jew." Gerhard, who had noticed that the Nazi was carrying a gun, avoided eye contact, and he and Eva managed to walk on without further engagement.

With Hitler's assumption of power in the spring of 1933, Gerhard's father made immediate plans to send his sons to safety in South Africa. Because it was impossible to send money out of the country, the boys were forced to earn their own way, and shortly after his arrival in Cape Town

[4] *This incident and other events described in this sketch were gleaned from correspondence that Gerhard saved.*

in May of 1933, Gerhard found employment as a photographer's assistant. Over the following years his photographs appeared in various Cape Town newspapers.

Meanwhile, however, he was trying to find a way to enroll at the University of Cape Town. His father, who had now himself emigrated to Paris and had no access to his money in Germany, was still unable to help. However, Gerhard received money for his university expenses from the Hochschild Family Foundation, which had been established with remarkable prescience in 1924 by a cousin of his grandfather's, Berthold Hochschild, to aid members of the extended family in times of need. By January of 1934, Gerhard had been accepted at the University, with just enough money to pay the tuition. Supplementing his job in the photography studio with private tutoring in math, he was able to earn enough to cover his modest living expenses. Around this time, he began to frequent a well-known circle of political activists, artists, and academics that met weekly at the home of Dr. Abdul Hamid Gool and his wife Zainunnissa (known as Cissie), a highly educated political organizer who founded the National Liberation League in 1935 and would go on to serve on the Cape Town City Council for thirteen years. Gerhard must have felt at home among these free thinkers, people of all races and political persuasions, meeting in defiance of the rigid social conventions of Cape Town.

At the University, Gerhard studied physics and applied mathematics, receiving his bachelor of science degree in 1936. The following year he completed a master of science degree in pure mathematics. To Flatow, his high school mathematics teacher, he described his interests as follows: "I plan to specialize in tensor calculations and in the basis of modern relativity theory and 'geometrized mechanics' and then pure mathematics, differential geometry and certain parts of the theory of differential equations. I think the ideal middle ground for me is pure and applied mathematics in which I am equally interested."

Later in his life, Gerhard spoke of the great debt he owed Stanley Skewes,[5] a lecturer (and later professor) in the mathematics department at Cape Town, who taught him in his undergraduate years and subsequently became his primary advisor and supporter. Skewes recommended him for a position as a junior lecturer in pure math, which enabled him to continue his studies from 1937 to 1938, and encouraged him to apply to the mathematics department at Princeton for further graduate work. When Gerhard sailed for America in the summer of 1938, Skewes saw him off. Gerhard remembered Skewes standing at the pier, calling out his final words of advice: Never doubt your own abilities.

[5] *Stanley Skewes was best known for his discovery in 1933 of what became known as the Skewes number.*

Murray Gerstenhaber

Hochschild's Work on Cohomology

Hochschild cohomology has become indispensable in pure algebra for its applications, among others, to representation theory and algebraic deformation theory, but it is emerging also as a new and valuable tool in physics, particularly quantum theory. It is all the more remarkable that the first two defining papers ([10], [11]) were written in 1945 and 1946, not at any prestigious academic institution nor, in fact, at any academic institution at all but at the Aberdeen Proving Ground, Maryland, where Hochschild did his military service during World War II. Despite this semi-isolation, Hochschild was aware of simultaneous yet unpublished work by Eilenberg and Mac Lane on group cohomology, which Hochschild acknowledged in [10], and they in turn acknowledged and adopted a fundamental result of [10] when their paper [3] finally appeared in 1947. In [10] Hochschild defined the complex that bears his name: If A is a k algebra and M an A bimodule (a concept first made explicit in [10]), then let $C^n(A, M)$ be the module of k multilinear maps $A \times \cdots \times A$ (n times) $\to M$ (or linear maps $A^{\otimes n} \to M$) with coboundary map $\delta : C^n \to C^{n+1}$ given, for $F \in C^n$, by

$$\begin{aligned}\delta F(a_1, \ldots, a_{n+1}) = a_1 F(a_2, \ldots a_{n+1}) \\ + \sum_{i=1}^{n} (-1)^n F(\ldots, a_i a_{i+1}, \ldots) \\ + (-1)^{n+1} F(a_1, \ldots, a_n) a_{n+1}.\end{aligned}$$

(Here $C^0(A, M)$ is just M.) Then $\delta\delta = 0$, and one can define cocycles, coboundaries, and cohomology groups in analogy with simplicial cohomology theory, except that here, as Hochschild proves in [10], if one knows $H^1(A, M)$ for all M then all higher cohomology groups are, in principle, already determined. (This fundamental "dimension shift" theorem, best understood in terms of resolutions that Hochschild had already mastered by [11], is cited in [3].) Accordingly, Hochschild described his theory as a "truncated" one (ending at H^1), whereas in fact he had discovered the fundamental fact that one must consider *all* modules over the object whose cohomology one is studying, not just the trivial module, as in the case of simplicial or group cohomology, or as originally in Lie cohomology. (What may be the first explicit consideration of Lie cohomology with coefficients in an arbitrary module seems to be in [17].) In fact, simplicial cohomology is actually a special case of

Murray Gerstenhaber is emeritus professor of mathematics at the University of Pennsylvania. His email address is mgersten@math.upenn.edu.

Hochschild cohomology in the sense that to any simplicial complex Σ and coefficient ring k there is naturally associated a k algebra $A = A(\Sigma, k)$ such that the simplicial cohomology $H^*(\Sigma, k)$ is canonically isomorphic to the Hochschild cohomology $H^*(A, A)$; cf. [6].[6]

Both of these are rings (the latter known to Hochschild in the more general context of pairings between modules), and the isomorphism is actually one of rings. What was not yet known to Hochschild was the "Gerstenhaber algebra" structure (cf. [4]) carried by $H^*(A, A)$, which has become useful in physics. In particular, $H^*(A, A)$ is commutative (in the graded sense), so the commutativity of $H^*(\Sigma, k)$ may be viewed as a consequence of this more general theorem. (Every cohomology theory must, however, be viewed on its own terms; the Steenrod operations, for example, are not generally present in Hochschild cohomology. In fact, the graded Lie structure of $H^*(A, A)$ is an obstruction to their existence; in $A(\Sigma, k)$ the Lie multiplication vanishes identically.)

Hochschild's original interest in, and development of, his cohomology seems to have begun with the observation that Wedderburn's third structure theorem is a consequence of the following: If $H^2(A, M) = 0$, then any "singular extension" $0 \to M \to B \to A \to 0$, i.e., one in which M is an ideal of B where the product of any two elements is zero (and which is therefore naturally a bimodule over A), must split; it follows by induction on the index of nilpotence of the radical that, if $H^2(A, M) = 0$ for all M, then any Artinian algebra B with "semisimple part" $A = B/J (= \text{radical of } B)$ has the property that the sequence $0 \to J \to B \to A \to 0$ also splits. Hochschild showed that, for finite-dimensional algebras A over a field (the only kind then generally considered), the condition that $H^1(A, M)$ vanish for all M (and hence that all higher cohomology groups of A also vanish) was equivalent to the classical definition of separability of A. This cohomological criterion continues to hold for the Auslander-Goldman definition of separability [1], namely that A be projective in the category of A bimodules, where now one may allow any (commutative, unital) coefficient ring k. (Either criterion immediately implies, and is equivalent to, the existence of a separability idempotent, the construction of which is frequently the easiest way to prove separability.) The intimations of this are already present in Hochschild's first paper [9], which appeared in 1942, the year he got his Ph.D. from Princeton.

Hochschild saw applications for his cohomology in many places. André Weil had introduced cohomology into class field theory, and Hochschild (after an earlier paper on class field theory in 1949) collaborated with Nakayama in 1951 to rederive some of Weil's results and go even further [15]. Simultaneously, Hochschild was interested in Lie groups and algebras and in algebraic groups. Two papers produced in collaboration with Serre in 1953 have become classics ([16], [17]). The first, extending work of Roger Lyndon, introduces the Hochschild-Serre spectral sequence to study the relation between the cohomology of a group, that of a normal subgroup, and of the quotient; the second applies the same techniques to Lie algebras. By 1956 Hochschild had published his fundamental paper [12] introducing the relative Tor and Ext, the importance of which is indicated by the length of the review by Henri Cartan. (In fact, Hochschild cohomology is a relative theory—one can compute the Hochschild cohomology of a k algebra using resolutions, but algebra and module "morphisms" must be understood as ones that split when considered simply as k module morphisms.)

It is not clear when it was first recognized that Hochschild cohomology could be computed relative to any algebra separable over the coefficient ring. This is not difficult to prove (once it is known) using projective resolutions and, in turn, sometimes makes Hochschild's original complex into an effective computational tool; it is the essential step in proving that simplicial cohomology is a special case of Hochschild cohomology. Expressed in terms of Hochschild's original complex for a k algebra A and bimodule M, if S is a k subalgebra of A, then the S relative cochains $F \in C^n(A, M)$ are those where, for all $a_1, \dots, a_n \in A$, all $s \in S$, and all $i = 1, \dots, n-1$, one has

$$F(\dots, a_i s, a_{i+1}, \dots) = F(\dots, a_i, s a_{i+1}, \dots),$$
$$F(s a_1, \dots, a_n) = s F(a_1, \dots, a_n),$$
$$F(a_1, \dots, a_n s) = F(a_1, \dots, a_n) s,$$

and where F vanishes whenever any argument is in S. These form a subcomplex of the usual Hochschild complex, and if S is separable over k, then the inclusion induces an isomorphism of cohomology.

In the midst of his work on Lie groups (later partly in collaboration with G. D. Mostow), Hochschild joined with Bertram Kostant and Alex Rosenberg, publishing [14]. This contains the celebrated HKR theorem, which in its simplest form (and stripped of the unnecessary hypothesis that the coefficient ring k be a perfect field) asserts that, if A is a finite separable algebraic extension of a polynomial ring $k[x_1, \dots, x_n]$, then $H^*(A, A)$ is just the exterior algebra over k generated by the derivations of A.

Hochschild's last paper explicitly devoted to cohomology theory, [13], appeared in 1974; his

[6] *S. D. Schack, my former student, friend, and collaborator in some of the works mentioned here, died on February 9, 2010.*

last published work, a text with a somewhat philosophical bent intended for beginning graduate students, appeared in 1983.

There is much that Hochschild did not know about his own cohomology, and he probably greatly underestimated (as did most) the impact that it would have, but fortunately he lived long enough to see many important developments. One was the recognition that $H^2(A, A)$ was the module of infinitesimal deformations of A with $H^3(A, A)$ containing the obstructions (see [5]), and that by extending Hochschild cohomology to presheaves of algebras the same idea could be applied to view at least the formal aspects of the Froelicher-Nijenhuis-Kodaira-Spencer deformation theory of analytic manifolds as special cases of Hochschild cohomology (see [7]). Hochschild cohomology was introduced into quantum theory in the groundbreaking paper of Bayen, Flato, Frønsdal, Lichnerowicz, and Sternheimer [2]. They showed that the Poisson bracket on the algebra of functions on phase space should be viewed as an infinitesimal deformation of that algebra and that quantization could be viewed as (or, alternatively, result from) deformation of the algebra using the given Poisson bracket as infinitesimal. Phase space being symplectic, this led to the question of whether every symplectic manifold could be similarly quantized, subsequently proven by Dewilde and Lecomte and ultimately to the question of whether every Poisson manifold could be quantized. The affirmative answer to this much more difficult question was part of Kontsevich's Fields Medal-winning work. This work used in an essential way L_∞ algebras (strong homotopy Lie algebras) and indirectly A_∞ algebras (associative algebras up to homotopy), basic concepts due to Stasheff. These, too, have their cohomology and deformation theories, patterned after Hochschild. Deformation quantization, introduced in [2], has sometimes been referred to as capturing the bronze medal in quantization, after the Hilbert space operator approach (which in a way formalizes and is equivalent to both the Heisenberg and Schrödinger approaches) and Feynman's approach by path integrals. It avoids some of the troublesome infinities, and recent work, in particular by Dito and by Stasheff in homological physics, suggests that we have so far seen only the very tip of the iceberg—Hochschild cohomology will ultimately prove as important a tool in physics as it has already been in pure algebra. The universe, it seems, is not flat, not commutative, and in important aspects not even associative, but it does respect Hochschild cohomology.

Hochschild steadfastly rejected the term "Hochschild cohomology", insisting always on "algebraic cohomology" and correcting you when you slipped. He was generous, once offering to give up his office to Oscar Goldman, who was starting on a year's leave at Berkeley at a time when no visitors' offices were available. Time will surely reveal many more applications of Hochschild's fundamental ideas, and were he present he would disclaim credit; nevertheless, I think he would be pleased.

References

[1] M. Auslander and O. Goldman, The Brauer group of a commutative ring, *J. Algebra* **4** (1960), 220–272.

[2] F. Bayen, M. Flato, C. Frønsdal, A. Lichnerowicz, and D. Sternheimer, Deformation theory and quantization I, II, *Ann. Phys.* **111** (1978), 61–110, 111–151.

[3] S. Eilenberg and S. Mac Lane, Cohomology theory in abstract groups, I, *Ann. of Math.* **48** (1947), 51–78.

[4] M. Gerstenhaber, The cohomology structure of an associative ring, *Ann. of Math.* **78** (1963), 267–288.

[5] ———, On the deformation of rings and algebras, *Ann. of Math.* **79** (1964), 59–103.

[6] M. Gerstenhaber and S. D. Schack, Simplicial cohomology is Hochschild cohomology, *J. Pure and Appl. Alg* **30** (1983), 143–156.

[7] ———, Algebraic cohomology and deformation theory, *Deformation Theory of Algebras and Structures and Applications* (M. Hazewinkel, M. Gerstenhaber, eds.), [8], 11–264.

[8] Michiel Hazewinkel and Murray Gerstenhaber, editors, *Deformation Theory of Algebras and Structures and Applications*, Kluwer, Dordrecht, 1988, Proceedings of NATO Advanced Study Institute, 'Il Ciocco', Castelvecchio-Pascoli, Tuscany, Italy, June 1–14, 1986.

[9] G. Hochschild, Semi-simple algebras and generalized derivations, *Amer. J. Math.* **64** (1942), 677–694.

[10] ———, On the cohomology groups of an associative algebra, *Ann. of Math.* **46** (1945), 58–67.

[11] ———, On the cohomology theory for associative algebras, *Ann. of Math.* **47** (1946), 568–579.

[12] ———, Relative homological algebra, *Trans. Amer. Math. Soc.* **82** (1956), 246–269.

[13] ———, Lie algebra cohomology and affine algebraic groups, *Illinois J. Math.* **18** (1974), 170–176.

[14] G. Hochschild, B. Kostant, and A. Rosenberg, Differential forms on regular affine algebras, *Trans. Amer. Math. Soc.* **102** (1962), 384–408.

[15] G. Hochschild and T. Nakayama, Cohomology in class field theory, *Ann. of Math.* **55** (1952), 348–366.

[16] G. Hochschild and J.-P. Serre, Cohomology of group extensions, *Trans. Amer. Math. Soc.* **74** (1953), 110–134.

[17] ———, Cohomology of Lie algebras, *Ann. of Math.* **57** (1953), 591–603.

Paul Bateman

Gerhard Hochschild at Urbana (1948–58)

Gerhard Paul Hochschild, an algebraist of the highest caliber, died July 8, 2010, in El Cerrito, California. His fields of interest included cohomology theory for algebras, algebraic groups, and Lie algebras. He was on the staff of the University of Illinois at Urbana-Champaign from 1948 to 1958. In 1958 he accepted an offer from the University of California at Berkeley, a position he held until his retirement. In 1979 he was elected to the National Academy of Sciences. In 1980 he was awarded the Leroy P. Steele Prize of the American Mathematical Society.

Gerhard Hochschild was born April 29, 1915, in Berlin, Germany. After the Nazi takeover in the early 1930s he suffered considerable harassment from Hitler Youth. Fortunately, his extended family was widely distributed geographically. Thus in due course he became a student at the University of Cape Town in South Africa, from which he received a B.S. in 1937 and an M.S. in mathematics in 1938. He then entered graduate school at Princeton University. In 1941 he produced an outstanding Ph.D. thesis under the supervision of Claude Chevalley. This was entitled *Semisimple algebras and generalized derivations* and was subsequently published in the *American Journal of Mathematics*, vol. 64 (1942), pp. 677–694.

Gerhard with wife Ruth on his right—partying at Urbana, c. 1952.

In 1941 Hochschild was drafted into the U.S. Army. He spent three years in the Army, most of it at the Aberdeen Proving Grounds in Maryland. In the army he found it desirable to use his middle name, Paul, rather than the more Teutonic name Gerhard. After his military service, Hochschild held a Benjamin Peirce Instructorship at Harvard University from 1946 to 1948. In 1948 Gerhard was appointed to an assistant professorship at Illinois. He was promoted to associate professor in 1950 and to full professor in 1952. During his ten years on the Illinois staff, Hochschild had three leaves of absence. He was a visiting professor at Yale for the academic year 1951–52, a visiting professor at Berkeley for the academic year 1955–56, and a member of the Institute for Advanced Study at Princeton for the academic year 1956–57. The Institute membership was supported by a Guggenheim Fellowship and by a sabbatical leave at half pay from the University of Illinois.

During his service at the University of Illinois, Gerhard taught a graduate course every semester. As someone who audited one of these courses, I can report that his lectures were very thoroughly prepared and well presented. Personally, I found Hochschild to be a very helpful consultant on matters related to algebra and algebraic number theory. While at Urbana Gerhard supervised the following three Ph.D. dissertations: George Francis Leger (1951), *On cohomology theory for Lie algebras*; Kung-Sing Shih (1953), *Cohomology of associative algebras and spectral sequences*; Ronald Alvin Macauley (1955), *Analytic group kernels and Lie algebra kernels.*

Reinhold Baer's return to Germany in 1956 and Gerhard Hochschild's departure for Berkeley in 1958 were both serious blows to the algebraic side of the Illinois mathematics department; however, the loss of Hochschild was a more serious blow in that he was at the top of his game mathematically in 1958, whereas Baer was near the end of his career in 1956. The two men differed in another respect: Baer's departure from Nazi Germany in the 1930s was almost painless, but Hochschild's definitely was not. In fact, although the two men were close friends in Urbana, Gerhard made it clear to Reinhold that he would never travel to Germany to visit him.

A story that is very illustrative of Gerhard's personality is the following: while Baer was on sabbatical, he asked Hochschild to take care of one of his students, Arno Cronheim. At the end of the process Arno wanted to give some mention of Hochschild in his thesis, but Gerhard insisted that he not do so and prevailed. The close and attentive relationship that Gerhard had with his students is illustrated by the following citations appearing in the acknowledgments in two of his students' theses.[7]

Shih says: "The author wishes to express his heartiest thanks to Prof. G. Hochschild for the warm encouragement, for the privilege of reading the manuscript of the paper [2][8] while it was not yet in print, and for many helpful suggestions generously given him throughout the preparation of this paper."

Macauley says: "The author takes this opportunity to express his most sincere gratitude

Paul Bateman is emeritus professor of mathematics at the University of Illinois at Urbana-Champaign. His email address is bateman@math.uiuc.edu.

[7] *We thank the staff at the Reference, Research, and Government Information Services, UIUC Library, for promptly providing this very useful information about this period of Hochschild's activities.*

[8] *The mentioned paper is G. P. Hochschild and J.-P. Serre, Cohomology of group extensions,* Trans. Amer. Math. Soc., *Vol. 74, 1953, pp. 110–134.*

to Professor G. P. Hochschild, who offered and gave more aid and encouragement in the preparation of this thesis than could reasonably be expected of any advisor and friend. Indeed, Professor Hochschild's patience has withstood an arduous test."

The quality and diversity of Hochschild's mathematical work during the period of his stay at Urbana is quite remarkable. Some of the topics studied in the period are: extensions and representations of Lie groups, cohomology theories, relative homological algebra, number theory, spectral sequences, theory of restricted Lie algebras, simple algebras, and more. His landmark work on the cohomological methods in class field theory appeared in three papers during that period; also, the two papers on the so-called Hochschild-Serre spectral sequences date from that time. The first two of the series of papers on representative functions, written jointly with G. D. Mostow, appeared in the years 1957 and 1958.

It was in Urbana that Gerhard met his wife, Ruth Heinsheimer, who, like Gerhard, was born in Germany. She and her mother escaped Germany in early 1939, first settling in Paris and then fleeing to a small village in the Pyrenees before sailing for New York from Lisbon in February of 1941. Ruth graduated from Bryn Mawr College in 1947 and then enrolled in the graduate program in mathematics at the University of Illinois at Urbana-Champaign, where she obtained an M.A. in mathematics in 1948. When Gerhard arrived as an assistant professor, she was working under the direction of R. Baer. They got acquainted then, and she and Gerhard were married in July 1950.[9] When they left for Berkeley in 1958, Ruth had also finished an M.A. degree in French literature. Their daughter Ann was born in 1955 in Urbana and their son Peter in Princeton in 1957.

John T. Tate

Memories of Hochschild, with a Letter from Serre

Gerhard Hochschild was my first friend in the mathematical world after my student days. Though his world outlook was pessimistic, it was usually expressed with humor, and in personal relations he was very generous, positive, and outgoing. I have many happy memories. Gerhard and his wife Ruth were fun to be with.

Our paths crossed often in the early 1950s. Our mathematical discussions at that time were mainly about the then quite new theory of cohomology of groups and its application to class field theory. Hochschild was the first to advocate this application in his 1950 *Annals* paper on local class field theory. The even greater importance of cohomology in the global theory became clear from André Weil's construction of the global Weil group as a group extension of a Galois group $G_{K/k}$ by the idele class group C_K made with a "canonical class" $\alpha_{K/k}$ in $H^2(G_{K/k}, C_K)$, but Weil used cohomology only because he had to and then as little as possible. He was not interested in using it to simplify proofs, nor in determining the exact structure of the groups $H^n(G_{K/k}, C_K)$. It was Hochschild and Nakayama, in their joint 1952 *Annals* paper, who determined the structure for $n = 1, 2$ in reworking global class field theory in terms of cohomology. Their work and Weil's inspired the Artin-Tate seminar of 1951–52 in Princeton. Later I showed that the results of Hochschild and Nakayama for $n = 1, 2$ imply purely algebraically that the cup product with the canonical class gives isomorphisms $H^{n-2}(G_{K/k}, \mathbb{Z}) \tilde{\to} H^n(G_{K/k}, C_K)$ for all n, a disappointment in that it shows that the higher-dimensional cohomology groups give no new arithmetic information.

The Hochschild-Serre spectral sequence was another preoccupation of Gerhard at that time. When I asked Serre[10] for the story behind his joint papers with Hochschild, he sent the following letter:

Paris, 3/11/10

Cher Tate,

J'ai surtout connu Hochschild en 51/53, à l'époque des "Hochschild-Serre". Voici comment ça s'est passé:

En septembre 1950, un peu avant de clarifier ce qui allait être ma thèse, j'ai vu que les suites spectrales de Leray s'appliquaient aussi à la cohomologie des extensions de groupes. C'était d'ailleurs presque évident vu ce qu'avaient déjà fait Cartan-Leray: ils avaient montré que, si $X \to Y$ *est un revêtement galoisien de groupe* Γ*, il y a une suite spectrale qui part de* $H^\bullet(\Gamma, H^\bullet(X))$ *et aboutit à* $H^\bullet(Y)$*. [Cette suite spectrale est souvent appelée maintenant "de Hochschild-Serre"— je n'y peux rien.] Si* $1 \to H \to G \to \Gamma \to 1$ *est une extension de groupes, on applique ça à l'action de* Γ *sur* E_G/H*, où* E_G *est un fibré universel pour* G*. On trouve directement ce*

John T. Tate is professor of mathematics, Sid Richardson Foundation Regents Chair (No. 4) Emeritus, University of Texas at Austin, and Perkins Professor Emeritus, Harvard University. His email address is `tate@math.utexas.edu`.

[9] *They both enjoyed very much those early years of their relationship at Urbana, and, frequently in his later years, Gerhard mentioned nostalgically the loss of that close group of friends that included not only mathematicians but also some people in literature [eds.].*

[10] *Jean-Pierre Serre is honorary professor at the Collège de France, Paris, where he held the chair "Algèbre et Ègéométrie" from 1956 to 1994. His email address is* `serre@noos.fr`.

qu'on veut. Je m'exprimais en termes plus algébriques dans la Note, mais cela revenait au même. Je citais Lyndon en ajoutant "on remarquera l'analogie de cette démonstration avec celle employée par R. C. Lyndon", affirmation très gratuite car nos démonstrations étaient complètement différentes (et Lyndon ne connaissait pas les suites spectrales).

Au début de l'année suivante (février-mars-avril?) je suis parti faire du ski à Serre-Chevalier avec Josiane. C'est là que j'ai reçu ma première lettre de mathématicien étranger, celle de Hochschild. Il me disait qu'il avait vu ma Note et qu'il avait fabriqué une démonstration différente, par des calculs explicites de cochaines. Je crois me souvenir (je n'ai malheureusement pas gardé sa lettre) qu'il me proposait aussi de publier ensemble nos deux démonstrations. Je me souviens du très grand plaisir que m'avait causé sa lettre; j'étais malade (angine), et la lettre m'avait guéri! J'ai accepté cette collaboration. Il est probable que j'ai rédigé (en français) la première partie du texte: "General Methods", c'est-à-dire la méthode de ma Note. La version définitive du texte s'est faite lors de mon séjour à Princeton en janvier-février 1952: Hochschild m'a invité chez lui (il était à Yale), et j'ai passé deux ou trois jours avec lui, à lire et à réviser notre texte. Je lui ai fait adopter la méthode Bourbaki que tu connais bien: lecture ligne à ligne à haute voix. Il était un peu surpris, mais il a accepté. Ça nous a coûté un grand nombre d'heures, mais on y est arrivé.

Quelques commentaires mathématiques sur ce texte:

- 1 - La méthode explicite par filtration de cochaînes (celle que Hochschild avait fabriquée) est en fait très voisine de celle de Lyndon. Nous ne le savions pas, car Lyndon n'avait publié qu'une partie de sa thèse. De plus, Lyndon était essentiellement un topologue, et pour lui les seuls coefficients intéressants étaient les coefficients constants. Hochschild et moi nous intéressions à bien d'autres choses, comme tu sais.

- 2 - Il y a une petite erreur idiote (les erreurs sont rarement intelligentes …) dans notre exposé: nous parlons de $C^i(G/H, C^j(H,M))$, où C = cochaînes, comme si ça avait un sens. Or ça n'en a pas, car G/H n'opère pas sur les $C^j(H,M)$; ça n'a aucune importance car on peut interpréter $C^i(G/H, C^j(H,M))$ simplement comme des applications

$$G/H \times \cdots \times G/H \to C^j(H,M),$$

et l'opération de cobord est relative à H uniquement. Cette erreur a été signalée en 1981 (seulement!) par F. R. Beyl; tu trouveras la référence à la p. 587 de mes C. P. vol. I.

- 3 - Dans sa construction, Hochschild a choisi de mettre H en première position, et G/H en deuxième. Or, en Topologie (que ce soit Leray, ou ma thèse), on écrit les variables dans l'ordre $H(\text{base}, H(\text{fibre}))$ en mettant d'abord (à gauche) les variables qui représentent la base, et à droite celles qui représentent la fibre. Cela peut paraître un détail, mais c'est un détail qui a des conséquences quand on fait des calculs explicites. Suppose par exemple que G soit abélien libre de rang 2, que H soit de rang 1, et que l'on ait choisi des orientations de H et de G/H, i.e., des isomorphismes de ces groupes avec $\mathbb{Z}$. "La" suite spectrale donne un isomorphisme de $H^2(G)$ (à coefficients dans $\mathbb{Q}$, disons) avec $H^1(G/H, H^1(H))$ qui est visiblement $\mathbb{Q}$. Bien sûr, une orientation du sous-truc et une orientation du quotient donnent une orientation du tout. Mais quelle orientation? La théorie de Leray (ou de ma thèse) en donne une, et la théorie de Hochschild donne l'opposée. C'est désagréable. Et que donne le point de vue Grothendieckien: suite spectrale des foncteurs composés? C'est pire: il ne donne rien, car Grothendieck, dans Tôhoku, se borne à dire qu' "il existe" une suite spectrale sans préciser laquelle (elle dépend de la méthode employée). Ce n'est pas par hasard qu'il n'a jamais exposé la théorie des cup-produits dans les suites spectrales: il aurait eu besoin d'être plus précis.

Voilà. Excuse-moi de m'être un peu écarté de Hochschild! Quoi d'autre? Que j'ai fait en 1952 la connaissance de sa femme, Ruth, et que je l'avais trouvée charmante. Que notre article sur les algèbres de Lie ne nous a posé aucun problème; seul détail: Chevalley était referee pour les Annals *et voulait nous faire remplacer nos cochaînes alternées par de l'algèbre extérieure. Je l'ai envoyé paître (how do you say that in polite English, and in not-so-polite English?), en donnant l'argument que notre théorie s'appliquait à des algèbres de Lie de dimension infinie.*

J'ai revu Hochschild en 1954, quand il est venu avec toi assister à un congrès Bourbaki. Je l'ai sûrement revu plusieurs fois ensuite, mais je ne crois pas que nous ayons discuté sérieusement de maths: nous avions choisi des directions différentes.

Bien à toi
J.-P. Serre

In the last paragraph of his letter Serre writes that, in 1954, Hochschild attended a Bourbaki meeting with me. I remember that well. Here's how it happened. On my first trip to Europe, that summer before the ICM in Amsterdam, the Hochschilds invited me to visit them at their then favorite vacation spot, the Riederfurka, a mountain resort on the Riederalp, just north of Brig and south of the Aletsch glacier. It's a tranquil place with breathtaking views. (Google "Riederfurka" to find hundreds of pictures.) After a few days there I took, on Gerhard's recommendation, the train to Zermatt and a cog railway up to a lookout area for a magnificent view of the mountains on the Italian border, from the Matterhorn to Monte Rosa, the highest mountain in Switzerland, which Gerhard had climbed with a group earlier that summer. I then met him and Ruth, to tag along with them to a Bourbaki meeting in Murols. Our landlady there referred to Ruth as "the woman with the two men". I was a fan of Bourbaki. There I was, seeing him at work and meeting most of the younger members for the first time. These memorable new experiences in Europe were made possible by the Hochschilds. It's hard to express how much their friendship meant to me.

Gerhard had a great sense of humor. He informed me of Ruth's first pregnancy by a postcard with the formula $H(G,R) \neq 0$. He enjoyed hobbies. I remember one time in Urbana he was growing plants in his kitchen under a special light. A more permanent interest was photography. From time to time he took trips by car in the desert or in the mountains to capture their beauty on film. On such a trip he usually sent me the funniest or most absurd postcard he could find, with a brief comment. I tried to return this gesture, but he won our quirky postcard contest hands down.

After Gerhard moved to Berkeley I saw him less often, except during a visit there for the spring term and summer of 1963 that he arranged. Though our mathematical interests were not as close then as earlier, he was a great host as always. I remember many pleasant hours spent at his house in El Cerrito with its magnificent view from the living room across the bay to San Francisco and the Golden Gate bridge. I am sad that we were together so rarely after that time, for he was a true friend who made a real difference in my life, especially in my postdoctoral days.

Andy Magid

The Hochschild-Mostow Group

Gerhard Hochschild is well known to the many mathematicians who employ his eponymous homology theory or spectral sequence (the latter is also named for Serre). Another algebraic notion that bears his name, the Hochschild-Mostow group, is probably less familiar; it is my object in this section of this memorial article to share this beautiful and important construction with a wider audience.

The Hochschild-Mostow group is a functor from groups to complex pro-affine algebraic groups. More precisely, let G be an analytic group, an algebraic group, or a finitely generated group. Consider all the complex representations $\rho\colon G \to \mathrm{GL}_n(\mathbb{C})$, where ρ is also required to be analytic or algebraic if G is. The Hochschild-Mostow group $A(G)$ of G is a complex pro-affine algebraic group for which there exists a homomorphism $P\colon G \to A(G)$ such that for any representation $\rho\colon G \to \mathrm{GL}_n(\mathbb{C})$ as above there is associated a unique algebraic representation $\hat{\rho}\colon A(G) \to \mathrm{GL}_n(\mathbb{C})$ such that $\hat{\rho} = \rho \circ P$. Of course algebraic representations of $A(G)$, when preceded by P, yield representations of G; these turn out to be analytic or algebraic if G is. Thus the representation theory of G is the same as the representation theory of $A(G)$.

A pro-affine algebraic group, by definition, is an inverse limit, with surjective transition maps, of affine algebraic groups. Its coordinate ring is the corresponding direct limit of the coordinate rings of the groups in the inverse system; these are all commutative Hopf algebras, as is their direct limit. Any commutative Hopf algebra over a field is a direct limit of its finitely generated Hopf subalgebras. Over a characteristic zero algebraically closed field, the affine algebraic groups associated to these finitely generated Hopf subalgebras form an inverse system with surjective transition maps. So, over C, pro-affine algebraic groups and commutative Hopf algebras are simply dual. In the papers introducing and studying $A(G)$, the authors treat the Hopf algebra as the basic object.

Those authors, of course, are G. D. Mostow and Gerhard P. Hochschild. Their collaborative work on this topic, which was published in the *American Journal of Mathematics* between 1957 and 1969, stresses the concept of a representative function on the group G. By this is meant a function $f : G \to \mathbb{C}$ whose left (equivalently right, or both) translates by the elements of G span over $\mathbb{C}$ a finite-dimensional vector space. If G is analytic or algebraic, f is required to be so as well. An example of such a function is a matrix coordinate function of a representation $\rho : G \to \mathrm{GL}_n(\mathbb{C})$, and in fact every representative function arises from some such matrix representation.

The set of all representative functions on G is denoted $R(G)$. The authors show it to be a Hopf algebra and hence associated to a pro-affine algebraic group as above. This latter is, of course, $A(G)$. In fact, the authors introduce $A(G)$ more directly: G acts on $R(G)$ as right translations, and then $A(G)$ can be seen to be the group of all $\mathbb{C}$-algebra automorphisms of $R(G)$ which commute with all these translations (the group of proper

Andy Magid is George Lynn Cross professor of mathematics at the University of Oklahoma. His email address is amagid@ou.edu.

automorphisms of $R(G)$, in the authors' original terminology).

The theory, therefore, can be expressed strictly in terms of the algebra $R(G)$ of representative functions on G and the group of proper automorphisms of this algebra. Notice that in this formulation neither Hopf algebra nor pro-affine group methods are required, a fact today's readers of the papers can appreciate as did those of the 1950s and 1960s.

One of the significant accomplishments of the original papers was the description of $A(G)$ in the case in which G is an analytic group. It turns out in this case that $A(G)$ is a semidirect product $H \rtimes T$ where T is a pro-torus and H is an analytic group that has the structure of an algebraic variety such that left translations of H by elements of H are morphisms (the right translations need not be morphisms). It should be intuitively clear how these notions—pro-torus and left algebraic group—are intended. In fact, they are much simpler to explain in terms of the algebra $R(G)$, and this is what Hochschild and Mostow do: they show how to write $R(G)$ as a tensor product $R \otimes Q$ where R is an finitely generated subalgebra of $R(G)$ stable under right translations and Q is the group algebra of an infinite-dimensional $\mathbb{Q}$ vector space.

The description of $A(G)$ in the case where G is affine algebraic is much simpler: $P\colon G \to A(G)$ is an isomorphism. The case where G is a compact topological group and the representative functions are continuous and real, although it doesn't fit into the context surveyed here, also yields an isomorphism, which Hochschild demonstrates, for example, in *The Structure of Lie Groups*, where he points out that this is a way to understand the Tannaka duality theorem.

More generally, the Hochschild-Mostow group is linked with the Grothendieck-Saavedra theory of Tannakian categories: the category C of finite-dimensional complex G modules is a tensored abelian category, and $\mathrm{Hom}_G(-, R(G))$ can be seen to be a fiber functor on C. Its tensor automorphisms, then, can be seen to be the group of proper automorphisms of $R(G)$, namely $A(G)$.

The case where G is finitely generated is harder than both the analytic and algebraic cases, although its investigation has proven to be very fruitful. This has been done by a number of authors using a number of names, usually some variant of "pro-algebraic completion" for $A(G)$. The terminology "Hochschild-Mostow group" was introduced by Alexander Lubotzky in his thesis (Bar-Ilan University, 1979, in Hebrew), where he used it to point out the connection between the Tannaka duality property and the congruence subgroup property for discrete groups. Lubotzky and his students and collaborators (including myself) have continued the study of $A(G)$ for G finitely generated to the present day.

And to end on a more personal note: in the 1970s I had stumbled across left algebraic groups in the characteristic p context in trying to understand universal étale covers of affine algebraic groups in positive characteristic. A helpful reviewer of a research proposal pointed me toward the complex left algebraic groups of Hochschild and Mostow's work. In studying that work in the geometric language I favored I was able to make some additional progress for complex analytic groups. One of Hochschild's former students took me with him to see Gerhard during an AMS meeting in San Francisco, and eventually this resulted in my spending a sabbatical at Berkeley for the spring quarter of 1980. I was in an office right down the hall from Gerhard. We met in the late afternoon nearly every day to discuss mathematics and other topics. Although Gerhard was already then, thirty years ago, the age I am now, his energy and enthusiasm were remarkable, as well as his generosity with his time for junior colleagues. I believe it was then that he told me (although it could have been a couple of years later when he came to a conference at the University of Oklahoma) that during World War II, when he had been stationed at Ft. Sill in Oklahoma, he, along with the other noncitizen soldiers in his unit, had been taken to the local county courthouse for naturalization. Ever since, I have proudly claimed that Gerhard was a citizen of Oklahoma. Of course, he was a citizen of the world, and all of us who came to know him personally and mathematically are proud of that connection.

G. D. Mostow

Gerhard Hochschild as Collaborator

Gerhard Hochschild arrived in Princeton in September 1938 with a master's degree from Cape Town University, where he had majored in both math and physics. He had decided to drop physics; Gerhard said "I can raise and lower indices of tensors as well as the best physicists, but I find mathematics more satisfying." He chose Claude Chevalley for his thesis advisor. After three and a half years in Princeton and finishing his thesis, Gerhard had to go into the U.S. military service. He returned to Princeton for a semester after the war and in 1956 for a one-year visit to the Institute for Advanced Study.

I first became acquainted with Gerhard Hochschild at the Institute for Advanced Study. In those days at the Institute, everyone came to

G. D. Mostow is emeritus professor of mathematics at Yale University. His email address is `george.mostow@yale.edu`.

A typical Hochschild landscape photo.

tea, and members discussed their work with one another enthusiastically.

One cannot write about Gerhard comprehensively without mentioning his charisma. Some of his charisma resulted from his colorful criticism of the hypocrisies that abound in all large organizations. In the army, even though he was a recent immigrant to the United States, he impressed his fellow soldiers with the virtuosity of his profanity. I learned this from the famous geometric measure theorist Herbert Federer, who served in Gerhard's unit at Aberdeen Proving Grounds.

In general, he exhibited a tolerant viewpoint in his relations with people. As a teenager growing up in Berlin, he had suffered from the ignominies imposed on Jews—for example, he was once accosted by Nazi thugs and pushed around, with the police standing idly by. Although he was adamant about never returning to Germany, he did not allow his feelings to affect his personal relationships. For example, later he developed a lasting friendship with Professor Friedrich Hirzebruch and his wife that began when they visited the University of California at Berkeley in the early 1960s.

Gerhard had certain fixed standards that nothing could change. For example, in the many visits that I made to his photography lab, he showed me pictures of landscapes principally consisting of interestingly shaped stones colored gray. Never once did he show me a picture that included a person or that included color. He took many such pictures that I thought were repetitious, but to him they represented an effort to capture perfection. Anything short of that was a compromise that would disappoint him.

His striving for perfect rigor also is reflected in his textbook on Lie Groups for graduate students, which is "uncompromising in requiring austerity of thought", in the words of Gerhard's thesis advisor Claude Chevalley.

My mathematical collaboration with Hochschild began in 1957, when we were both members of the school of mathematics of the Institute. Our mathematical backgrounds were quite different. Gerhard had published papers on the theory of bimodules, cohomology groups of associative algebras, and the application of cohomology to number theory. My previous publications were on geometric aspects of Lie Groups and had virtually no overlap with his at that time. Also, our temperaments were very different, hardly predictive of a joint collaboration that produced seventeen papers.

Our collaboration resulted from the fact that Gerhard was interested in relating Tannaka duality to his earlier work on bimodules. At the time we began to work together, he was fascinated with the Tannaka duality theorem, which was carefully presented in the 1946 Claude Chevalley book *Theory of Lie Groups*. The only drawback was that the indirect definition of multiplication in the "dual" could have been more satisfactory.

Tannaka duality was initially intended to extend Pontryagin duality to a wider class of Lie groups. In order to give a satisfactory statement of Tannaka duality that is formulated in terms of standard mathematical objects, one needs to clarify some elementary definitions.

Let X be a set, G be a group, k be a field, and $F = F(X, k)$ be an algebra of functions on X with values in k. A *left action* of G on X is a map $\mu\colon G \times X \to X$ satisfying

$$\mu(a_2, \mu(a_1, x)) = \mu(a_2 a_1, x) \quad \text{for all } (a_1, a_2, x) \text{ in } G \times G \times X.$$

A *right action* of G on X is a map $\nu\colon X \times G \to X$ satisfying

$$\nu(\nu(x, a_1), a_2) = \nu(x, a_1 a_2) \quad \text{for all } (x, a_1, a_2) \text{ in } X \times G \times G.$$

For any left action μ on X, $f \in F$ and $a \in G$, let $(f.a)$ denote the function on X defined by

$$(f.a)(x) = f(\mu(a, x)).$$

Assume $f.a$ is in F for all f in F, a in G. Then the map $f \to f.a$ is easily seen to be a right action on F.

Similarly, for any right action ν on X, $f \in F$, and $a \in G$, $(a.f)$ denotes the function defined by

$$(a.f)(x) = f(\nu(x, a)).$$

Assume $a.f$ is in F for all f in F, a in G. The map f to $a.f$ is easily seen to be a left action on F.

The maps $f \to f.a$ and $f \to a.f$ are called right and left translates of f, respectively.

The k-valued function f on G is called a *representative function* if the linear span of the set $\{f.a, a \in G\}$ of right translate functions is a finite-dimensional vector space over k.

It is an easy theorem that a k-valued function f is a representative function if and only if the left translates of f span a finite-dimensional vector space over k. A similar result is true for the span of the right translates and, furthermore, for the span of both translates.

Let Repr(G) denote the set of all representative functions on G; this is a ring. An automorphism of the ring Repr(G) is called a proper automorphism if it commutes with all right translations by G and fixes all the constant functions. For example, any left translation on Repr(G) is a proper automorphism.

Let $A(G)$ denote the set of all proper automorphisms. $A(G)$ is a group with multiplication given by composition.

Tannaka duality is equivalent to the assertion: if $k = \mathbf{R}$ and G is a compact Lie group, then $A(G)$ coincides with the group of all left translations of G.

This formulation makes it possible to derive many relationships. For example, if $k = \mathbf{C}$ then $A(G)$ is the "universal" complexification of G. Moreover, the ring Repr(G) is a Hopf algebra. Many interesting relations between G, Repr(G), and $A(G)$ can be observed. For example, these relations were useful to Alex Lubotzky in his study of discrete subgroups.

During our long collaboration, we worked out the various insights provided by the study of the pro–algebraic group $A(G)$. The functor $G \to A(G)$ was named the Hochschild-Mostow functor by Alex Lubotzky.

It gives me much pleasure to recall our years of collaboration and warm friendship.

Walter Ferrer Santos

Interview with Pierre Cartier

The present interview occurred while the author and Pierre Cartier were participating in the "Segundo encuentro de historia conceptual de la matemática" that took place November 22–27, 2010, Córdoba, Argentina.

Walter Ferrer: Professor Cartier, when did you meet Gerhard Hochschild for the first time?

Pierre Cartier: To the best of my recollection, it was in June 1951, at the end of my first year as a student at the École Normale Supérieure, Paris. I was invited by Henri Cartan and Samuel Eilenberg—both were my advisors for the year—to participate in one of the closed-door meetings of the Bourbaki group. This meeting took place in Pelvoux, a small resort town in the Alps, and there I met for the first time people like C. Chevalley, J. Delsarte, J. Dieudonné, and A. Weil, the founders of Bourbaki. The senior participants asked me to go and pick up Gerhard at the train station, where he had arrived on the night train. [11] In the meeting, I remember discussions about Lie groups, according to a draft written by Laurent Schwartz, and also on commutative algebra. Hochschild was very much interested in both.

WF: Can you tell me about his later participation in meetings of the Bourbaki group?

PC: According to the minutes of Bourbaki, he participated again in the meetings in June 1952 and August 1954. I was told that he participated in the 1954 congress accompanied by his wife Ruth and John Tate. On the light side, I was told by the participants that the innkeeper used to refer to the visitors as the "lady with the two Americans". I did not go to either of these meetings, but I heard, from Chevalley, about Hochschild's visit and his deep interest in the topics covered. In that period the group was very much interested in the subjects of commutative algebra (including the new homological methods of Serre and M. Auslander) and Lie groups. It was about that time that J.-P. Serre—by then a very active member of the group—published his two papers with Hochschild on what are now called Hochschild-Serre spectral sequences.

WF: Did you meet him afterward while he was at Urbana or Berkeley?

PC: I remember very well two of my visits with him. In the fall 1957, I was a member of the Institute for Advanced Study at Princeton—shortly after he left it. I had been invited by Dieudonné—who by that time had a position at Northwestern University—to visit the Chicago area, including Urbana. In Urbana I was very much impressed by Joseph Doob, the well-known probabilist, who served there until his retirement in 1978, and also by Gerhard Hochschild, who was on the faculty at that time. In those days there was a great interest in algebraic groups, and I had just participated in the famous Chevalley seminar, and we talked extensively about the subject. On this occasion, he handed me the first of his series of papers on representative functions.[12] That was just after I had published a short note on the Tannaka duality for algebraic groups in 1956,[13] and we talked at length about these topics from that perspective.

My next meeting with him was in Berkeley [in] 1984. He had just recently retired, but we still had many common mathematical interests.

Pierre Cartier is currently emeritus director at CNRS, France. He is affiliated with University Paris Diderot and IHES. His email address is `cartier@ihes.fr`.

[11] *Hochschild mentioned once to the author about his participation in the meeting, and the surprise that he felt when he saw the "very young boy with a Boy Scout look that went to pick me up at the station" later participating fully in the discussions of the group.*

[12] *This paper was the start of a long collaboration with G. D. Mostow.*

[13] *Cartier is referring to his paper "Dualité de Tannaka des groupes et des algèbres de Lie",* C. R. Acad. Sci. Paris, *vol. 242 (1956), pp. 322–325.*

I remember his pride when he showed me the miniature train—a very sophisticated device—that he had built in the basement of his house in El Cerrito. To me the train was a very symbolic illustration of his precise and accurate mind.

I remember that he attended the seminar on cyclic cohomology that I gave at MSRI on that occasion and that at the end of the day he took me to the airport as I was leaving for Asia. Since the plane was late, we could enjoy a wonderful sunset together.

WF: What was the influence of Hochschild's mathematics in your own personal work?

PC: At the time of our first contacts, I was deeply influenced by the methods of homological algebra, especially after some lectures by Henri Cartan and the publication of the now classic *Homological Algebra* by Cartan and Eilenberg. In the fall of 1955, having Mac Lane attending my lectures, I invented the cohomology theory of coalgebras. It was a dual version of Hochschild's work on what is now called Hochschild cohomology, a cohomology theory of algebras with coefficients on a bimodule. Then I was avidly reading all his papers on homological algebra, and I recall A. Weil mentioning to me very enthusiastically Gerhard's work with Nakayama on the homological methods in class field theory. Also, my thesis—defended in September 1958—was devoted to problems of Lie algebras and algebraic groups in characteristic p, and in the process of finishing it, his papers in this field were very useful. I would also like to mention that at the end of the 1950s I had been drafted into the French army and hence was unable to travel abroad for a period of almost three years. J.-P. Serre—who was regularly visiting the USA—was very often the link between Gerhard and myself.

WF: In many conversations Gerhard told me that you were the person who introduced him to the notion of a Hopf algebra. Can you tell me about this?

PC: My work on Hopf algebras was previous to my thesis and was developed in relation to the cohomology theory that I mentioned earlier, even if it did not appear explicitly in the thesis. I think that my major discovery in this direction was that, in order to apply the full power of Hopf theory to the realm of algebraic groups and Lie algebras, it was necessary to relax all kinds of restrictions that were customary in this theory, in particular the commutativity and the condition of being graded.[14] I suppose that, when we discussed his paper on representative functions in Urbana, I mentioned to him the possibility of using Hopf algebras in this setting.

WF: Is there any additional comment about Hochschild you would like to share with us?

PC: I would like to comment that, even though we were not in direct personal contact too frequently, we corresponded regularly, and throughout his career he sent me his reprints which I read avidly. On a more personal note, concerning his youth in South Africa, I remember very well that my mother in France had helped many German and Austrian Jews to escape the Nazi regime. For many years I was able to collect stamps from many countries like Canada, Israel, and South Africa, taken from the extensive correspondence she had with the emigres she had helped. Sometimes I wonder if some of the stamps came from Gerhard or from his family.

Books by Gerhard Hochschild

The Structure of Lie Groups, Holden-Day Series in Mathematics, San Francisco-London-Amsterdam: Holden-Day, Inc. (1965).

A Second Introduction to Analytic Geometry, San Francisco-Cambridge-London-Amsterdam: Holden-Day, Inc. (1968).

Introduction to Affine Algebraic Groups, San Francisco-Cambridge-London-Amsterdam: Holden-Day, Inc. (1971).

Basic Theory of Algebraic Groups and Lie Algebras, Graduate Texts in Mathematics, 75, New York-Heidelberg-Berlin: Springer-Verlag (1981).

Perspectives of Elementary Mathematics, New York-Heidelberg-Berlin: Springer-Verlag (1983).

Calvin Moore

Gerhard Hochschild at Berkeley

Gerhard Hochschild's connection with Berkeley dates to 1955, when he accepted a position as visiting professor of mathematics at the University of California, Berkeley, for the academic year 1955–56. When he arrived, he found a mathematics department that was very different from the Berkeley mathematics department of today or indeed from what it became in the early 1960s. It was a small department with a total of nineteen faculty members in all professorial ranks. The department had some very real strengths, including a distinguished group of statisticians and probabilists, but this group had split off into a newly formed, separate department of statistics in 1955.

[14]*I recall that Henri Cartan advised me in that respect not to "overbourbakaise" (P.C.)*

Calvin Moore is emeritus professor of mathematics at the University of California, Berkeley. His email address is `ccmoore@math.berkeley.edu`.

There were also strengths in a number of areas—analysis, including PDEs and functional analysis; computational number theory; and logic. But algebra, as well as geometry and topology, fields that were rapidly developing at the time, were seriously underrepresented among the faculty in 1955. The department was poised to grow substantially in the next few years, and the hope was, through this growth, to remedy these programmatic weaknesses. Inviting Hochschild, a prominent senior algebraist of considerable stature, to visit for the 1955–56 year was a first step toward this program. Hochschild did enjoy his year's visit.

However, from past experience, the department knew that it would encounter difficulty in attracting to Berkeley permanently senior faculty in these areas of weakness because of concern about isolation. Further, it would be difficult to attract outstanding junior faculty in these areas absent senior faculty. Nevertheless, the department succeeded in hiring three outstanding assistant professors in these areas in 1956—Emery Thomas, Bertram Kostant, and James Eells. The department, under John Kelley's leadership, decided on a strategy of hiring clusters of senior faculty in the underrepresented areas. In the fall of 1957 the department approached Hochschild and Maxwell Rosenlicht and offered them both full professorships at Berkeley to begin in 1958. Each was informed of the offer to the other, and the strategy was proven to be a success when both accepted, thus providing a core of senior algebraists at Berkeley.

A shack in the Bay Area, photograph by Hochschild.

The following year, this cluster strategy was applied in geometry and topology, with offers made to Edwin Spanier and Shiing-Shen Chern. Both accepted, with Spanier arriving in 1959 and Chern deferring arrival for a year because of prior plans. Knowing that Hochschild and Rosenlicht had already moved to Berkeley perhaps increased the likelihood that Chern and Spanier would accept these offers. Also, in 1960, Stephen Smale, Morris Hirsch, and Glen Bredon accepted appointments as assistant professors. By 1960 the number of faculty in professorial ranks had grown to forty-four from nineteen five years earlier, with a much improved balance of fields and a vigorous and vibrant intellectual atmosphere. Hochschild's appointment and his decision to come to Berkeley were among several key factors in this change.

Beginning a bit before he first visited Berkeley, Gerhard's research interests began to shift from the homology of associative algebras and applications of homological algebra to class field theory, to the study of Lie algebras and Lie groups, especially algebraic Lie algebras and Lie groups, their linear representations, and their cohomology, and Lie group and Lie algebra extensions. When he arrived permanently in Berkeley in 1958, Gerhard found in Bert Kostant someone with similar interests in Lie algebras and Lie groups, and this common interest led to a collaboration, with two published papers on differential forms and cohomology of Lie algebras. Kostant, however, was lured away by MIT in 1961. In that same year the author arrived as a brand-new assistant professor with interests in extensions and cohomology of topological groups. These common interests led to many discussions of these topics but not to any joint publications.

Over the next twenty-five years Gerhard produced a steady stream of important and fascinating papers on Lie algebras, Lie groups, their representations, and cohomology. Many of these were done in collaboration with Dan Mostow of Yale University and represented a career-long scientific collaboration and friendship. He also became interested in Hopf algebras and wrote several papers on them and their connections with Lie groups. Gerhard supervised the doctoral dissertations of 22 students at UC Berkeley, and overall in his career he had 26 doctoral students with 122 descendants, according to the Mathematics Genealogy Project. His achievements were recognized in his election to the National Academy of Sciences and to the American Academy of Arts and Sciences. In 1980 the American Mathematical Society awarded Gerhard its Steele Prize for work of fundamental or lasting importance, citing in particular five papers published from 1945 to 1952 on homological algebra and its applications. Gerhard replied that although he was deeply honored by the Society's consideration of his work for a prize, he was, for personal reasons, unable to accept the Steele award. A friend has commented that the reason was simply that Gerhard did not believe in prizes.

As a senior algebraist in the department, he was called on frequently for advice and counsel on departmental matters. His opinions and advice were wise and incisive and offered with his characteristic ironic wit. He also served as advisor and mentor for many junior faculty members in algebra, and his guidance was deeply appreciated by the many colleagues who sought it. He had, however, a lifelong aversion to and dislike of what he termed academic bureaucracy. One result of this was that he consciously, consistently, and with self-deprecating good humor avoided all attempts to convince him to assume any administrative positions such as chair or vice chair in the department.

Gerhard was a longtime smoker who, when he did give it up, continued for some time to carry around with him an unlit cigarette between his fingers and sometimes between his lips, perhaps as a memento of his former smoking days. He changed the cigarette occasionally when it became too decrepit. But he never lit it!

The university had a policy in place up until July 1, 1982, that required mandatory retirement of tenured faculty members on July 1 following their sixty-seventh birthday. Effective July 1, 1982, this policy had been changed to require mandatory retirement on July 1 following the seventieth birthday. As Gerhard was born on April 29, 1915, he was by two months in the last cohort that was subject to the earlier mandatory retirement age. Gerhard saw this policy as academic bureaucracy at its worst. The end result was that he retired on July 1, 1982, and entered the university's phased retirement program for three years, teaching part time until retiring fully on July 1, 1985.

During his years in Berkeley, Gerhard became increasingly interested in landscape photography, pursuing this hobby with a deep and abiding commitment. Entirely self-taught, he relied on reading books on photography. He was particularly attracted to the desert landscape of the U.S. southwest. He would periodically go off on expeditions by himself, with his camera gear, which included a Hasselblad 4×4 and later a view camera, driving thousands of miles looking for just the right scene and just the right lighting, sometimes staying away for a month. His favorite site was in southeastern Utah, although Alaska was also a destination of his expeditions, and he also photographed the San Francisco Bay. The famous California photographer Ansel Adams was his model and his hero, and Gerhard's work does remind one of some of the work of Ansel Adams. Gerhard was encouraged by friends to have a show featuring his work, but he declined all such efforts. His photography occupied him for decades, but toward the end of his life, his health did not permit him to go off on these long expeditions.

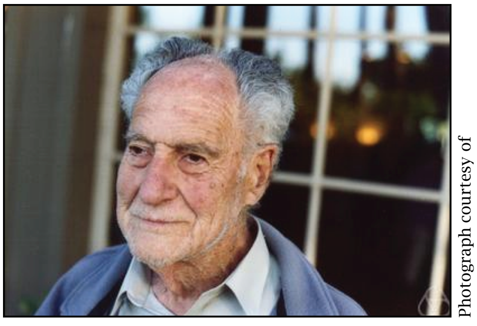
Gerhard died peacefully at home after a long and satisfying life on July 8, 2010, at the age of ninety-five with his daughter Ann at his bedside. He is survived by his daughter Ann, his son Peter, and two grandchildren. His beloved wife Ruth predeceased him in 2005.

Bertram Kostant

Hochschild Memorial

In 1956 I accepted an offer from UC Berkeley for an assistant professorship. About five years later I made an agonizing decision to leave Berkeley and accept an offer for a full professorship at MIT. One of the many reasons this decision was so painful to me was that it would severely diminish my close relationship with Gerhard Hochschild.

Hochschild arrived in Berkeley (I believe) in the late 1950s, and right from the beginning we recognized in each other kindred spirits. Whenever I came to the department I looked forward to spending time with him, either in his smoke-filled office or over lunch. Any and every topic, mathematical or otherwise, was up for discussion. Even when we strongly disagreed on some topic, he exuded so much charm and likeability that I found it impossible to become upset with him.



Photograph courtesy of George Bergman.

Gerhard in 2003.

Mathematically we collaborated on two papers about which I will shortly comment. Aside from these papers, we both became interested in the newly developing field of algebraic groups. We focused our attention on the 1956–58 Séminaire C. Chevalley on the Classification des groupes de Lie algébriques. However, in order to read the output of this Séminaire, we both needed to learn some basic algebraic geometry. To do this we alternated in lecturing to each other, using as a basic text Chevalley's book *Fondements de la Géométrie Algébrique*. Happily, this was a successful effort.

Our first joint paper, coauthored with Alex Rosenberg, was entitled *Differential forms on regular affine algebras*. It appeared in *TAMS* **102** (1962), No. 3, 383–408. The main result of the paper (the HKR theorem) is still highly cited and played an important role in the development of cyclic cohomology. The second paper proved that, for complex reductive homogeneous spaces, the de Rham cohomology can be computed using only holomorphic differential forms. It was cited by A. Grothendieck in a work establishing a very interesting, far more general theorem.

Bertram Kostant is emeritus professor of mathematics at the Massachusetts Institute of Technology. His email address is kostant@math.mit.edu.

Hochschild disliked ceremony and academic glorification of any kind. I understand it took a great deal of arm-twisting for him to accept membership in the National Academy of Sciences. Even so, he refused to cooperate and fill out the necessary forms that went with membership. Hochschild cohomology and homology are central objects in modern algebra. Nevertheless, he enjoyed making light of his own fundamental discoveries and all the fuss made about them. In other matters as well, he seemed to take pleasure in swimming upstream against the flow of academic behavior. I must say that this kind of rebelliousness resonated with me, but he was much more courageous than I was. At any rate my friendship with him was one of the happiest experiences of my life.

George M. Bergman

Some Inadequate Recollections of Gerhard

I wish I had known Gerhard better, mathematically and personally.

When, while a senior at Berkeley, I got my first mainstream mathematical result (an answer to an old ring-theoretic question), I went to Professor Hochschild, and he helped me put it into good form for publication. When I came back to Berkeley as a faculty member four and a half years later, Gerhard was a friendly presence, and over the years, he made many little helpful comments on drafts of my papers.

He liked to talk pessimistically: "If we were really happy, of course, we wouldn't be doing mathematics." (I think this was typical of the impact of Freud on many people of my father's generation.)

Courtesy of Martin Moskowitz.

A computer-generated picture presented by Gerhard to Martin Moskowitz.

As Berkeley's mathematics department photographer, I inform each of my colleagues, when five years have passed since the last photograph I've taken of them, that it is time to do another. In recent decades, Gerhard would respond with "You are recording the course of senile decay, Bergman?" But he never resisted letting me take the picture.

He had an interest in photography himself, and one time, when I brought him outside to re-photograph him, he held up a large envelope in which he had gotten some material from Kodak and wanted me to include it in the picture. I didn't know why, but I complied. Unfortunately, my photo didn't include the whole envelope; when I showed him the picture, he chided me for having left out the part showing the product name: *Ultra Filter*.

Dennis Sullivan came here to speak in 2008, long after Gerhard had stopped coming by. He was disappointed not to see him at his talk. He commented, "I wonder whether he knows that people eat Hochschild cohomology for breakfast these days?"

Looking through a birthday collection for Anthony Joseph in the library not long ago, I noticed a contribution written in Latin. One section was about the "Complexus de Rham-Koszul-Hochschildianus". I emailed Gerhard and let him know that he had been Latinized.

I sometimes thought that if, as a retiree, I was eventually required to share my office, I would ask whether the person I shared it with could be Hochschild. Though he was no longer coming in frequently, the times when he did would be a pleasure. But that was not to be.

George Bergman is emeritus professor at the Graduate School at the University of California, Berkeley, Department of Mathematics. His email address is gbergman@math.berkeley.edu.

Martin Moskowitz

Some Reminiscences

I met Gerhard in 1962, when I took qualifying exams at UC Berkeley and he was chair of my Algebra Committee for that exam. When the results of the exam were in, I asked him if he would agree to be my thesis advisor. He did, and as an example of his generosity, he put off a sabbatical to do it.

Several of his students would meet Gerhard once a week, after which he would take us for coffee on the north side. He would pay. (In fact, many years later, when he had already retired and I was fully employed, he still insisted on paying!) At one of those meetings I discovered a gap in my thesis (which involved locally compact abelian groups and so every statement had a dual). I told him I would try to fill it for the following week. When I presented this, he asked why didn't I do the dual and proceeded to tell me the story of a Jewish mother who gave her son two ties for his birthday. The next time he visited he dutifully wore one of them. His mother asked "Didn't you like the other one?" My colleague, Ray Hoobler, who was a student of Gerhard a few years later, told me that when Gerhard first took him on, he gave him a ride home and had Ray terrified as he frequently took both hands off the wheel, gesticulating wildly as he enthusiastically told Ray about possible thesis topics.

Martin Moskowitz is emeritus professor of mathematics at the City University of New York. His email address is martin.moskowitz@gmail.com.

When I completed my dissertation in 1964, Gerhard simply informed me that I was going to Chicago. He said the weather wasn't good, but the mathematics was, so that's where I was going. Many years later he observed that, in the 1960s, we were in a kind of golden age when research was very active and universally respected. It was the only time in his memory when mathematics wasn't underfunded.

When I returned to Berkeley some years later, he mentioned that he had been a member of Bourbaki. He claimed that, when he arrived for his first session in Paris, he asked the cab driver to take him to the Eiffel Tower "because that was the only thing I knew how to say in French". Later I learned that he spoke excellent French.

He also mentioned that, as a young man, he was at the Institute for Advanced Study working on class field theory. There would be tea every day at 3:00, and he would meet Andre Weil, who would ask about his progress. After several months he solved the problem he was working on and rushed to Weil's office to tell him about it. As he opened the door, Weil said, "What you are about to tell me is in Nakayama's paper of 1941." Gerhard then wryly remarked "if it doesn't kill you it will make you stronger" (I believe this is, more or less, a quote from Nietzsche).

At some point in the 1970s Gerhard was put on the committee to select the new instructors at Berkeley and given literature from the administration for guidance, which included affirmative action policies. He called the dean and told him he couldn't do this because ethnic and racial criteria have no place in mathematics. Having seen Nazis up close and personal and having had the difference between "Jewish" and "Aryan" mathematics made clear to him, he could not, in turn, consider racial/ethnic criteria in selecting new instructors. The dean then argued that there is a difference between "negative racism", which the Nazis practiced, and the current policy, whose purpose was to have a positive outcome. Gerhard did not regard this as adequate and resigned from the committee.

I was in Berkeley and participated in a Festschrift for Gerhard on the occasion of his sixty-fifth birthday. As it happened, that was exactly the time he was made a member of the National Academy of Sciences. He asked me "Is there any way to get out of this?" and I responded, "the only way is to die."

In 1998 I visited Berkeley on sabbatical. Once there I asked the department for Internet access and was told this would cost \$50 for the semester, which I paid. Then I went down to the math library and asked about library use. I was told this would cost \$100 for the semester, but that it also included Internet access. I naively said fine, I just paid \$50 for that and so I would be happy to pay another \$50 and have both, but the answer was no! The first fifty was paid to the math department and the hundred goes to the library. When I mentioned this to Gerhard, he offered to send them a check for \$100 "to shame them into relenting." I told him not to bother because one can't shame people who have no shame.

I'm personally directly knowledgeable about only a few of Gerhard's many and excellent papers. Among them are a series with Dan Mostow on faithful representations of real and complex Lie groups, which globalize Ado's theorem and which, because of their importance and trenchant character, I mention here. The generalities concerning representative functions are dealt with in Andy Magid's discussion in the present article.

Theorem. Let G be a connected real or complex Lie group.

In the real case G has a faithful finite dimensional smooth representation if and only if its radical and a Levi factor have such a representation. In the complex case G has a faithful finite-dimensional holomorphic representation if and only if the radical does (since a complex semisimple group always has a faithful representation). If G is either real or complex with a faithfully represented Levi factor and a simply connected radical, then G has a faithful finite-dimensional smooth (resp. holomorphic) that is unipotent on the nilradical.

Gerhard's other articles that I'm familiar with are *Automorphisms of Lie algebras* and his paper on faithfully representing a Lie group together with its automorphism group (1978 *Pacific Journal*, his last published paper). This played a role in something I did with Fred Greenleaf, which appeared in his Festschrift (1980 *Pacific Journal*). There is also an unpublished manuscript on lattices of the early 1980s which, although the methods are quite different, had some influence on my paper in *Math Zeit.* 1999.

After his retirement, Gerhard engaged heavily in photography, taking beautiful images during his many trips to the deserts and forests in Canada, Arizona, New Mexico, and elsewhere. He also got involved in computer-generated images. Among these were fractals. He gave my wife and me several of these stunning images in color which we framed and hung. Finally, Gerhard's work has had an enduring effect on many younger mathematicians. I give two examples. Hossein Abbaspour, my coauthor on our book, *Basic Lie Theory*, (2007 and dedicated to Gerhard), who works in low-dimensional topology, remarked to me that Hochschild cohomology is pervasive in his subject and that "Hochschild is all over my mathematical life." Moreover, in a 2009 dissertation entitled *Cohomological Aspects of Complete Reducibility of Representations*, Yannis Farmakis, âŁ a student of mine, proved, among other things, the following theorem: Let G be a locally compact group, H a closed subgroup, and ρ a continuous representation of G on a real or complex Banach space V. If G/H is compact and has finite volume and $\rho|H$ is completely reducible, then ρ itself is completely reducible. The proof is based on ideas of "injectivity" and "injective resolution" of a continuous module V developed by Hochschild-Mostow in their seminal paper *Cohomology of Lie groups*, which was needed in order to take into account the additional structure (differentiability and integrability) present in the G module V.

Nazih Nahlus

Gerhard Hochschild as My Advisor and Friend

As an advisor, Hochschild was always a wonderful friend. Modest and sincere as a mathematician and as a person, he has had an enormous effect on my life which I will never forget.

I took Hochschild's year-long course on Lie groups in 1980–81. It was a pleasure to follow his beautiful lectures. I decided to ask him whether he would agree to be my advisor. Hochschild replied that, since he was about to retire, it would be preferable for me to work with a younger person, but fortunately for me he agreed to consider it. However, he would make no promises until he saw the results of the qualifying examination. Prior to taking the exam I told Hochschild that I guessed and then proved the cancellation laws for finite-dimensional Lie algebras over a field. At first, he seemed doubtful about this result, but the following day, he told me that my observation follows from the theory of groups with operators.

Although I could have written my thesis exclusively on Lie groups and Lie algebras, Hochschild advised me to learn algebraic groups and Hopf algebras as well. When I needed a recommendation of my teaching for job applications, I told Hochschild that a senior faculty colleague had lost my file after I had been his teaching assistant for three quarters. To my delight, Hochschild immediately made a phone call and in a very deep voice "requested" him to "find his file now!" In 1986 I asked Hochschild whether he was satisfied with the results of my thesis (since I had freed it from the restriction "up to coverings"), he joked by saying that only proving the Riemann hypothesis would impress him. He also advised that, after the Ph.D., one should find one's own path in research.

Nazih Nahlus is professor of mathematics at the American University of Beirut. His email address is `nahlus@aub.edu.lb`.

Students of Gerhard Hochschild

George Leger Jr., University of Illinois at Urbana-Champaign (1951)

Kung Shih, University of Illinois at Urbana-Champaign (1953)

Ronald Macauley, University of Illinois at Urbana-Champaign (1955)

Andrzej Białynicki-Birula, University of California, Berkeley (1960)

Donald Osteberg, University of California, Berkeley (1960)

Byoung-Song Chwe, University of California, Berkeley (1961)

James Ax, University of California, Berkeley (1961)

William Giles, University of California, Berkeley (1962)

George Rinehart, University of California, Berkeley (1962)

Martin Moskowitz, University of California, Berkeley (1964)

Leonard Ross, University of California, Berkeley (1964)

Theodore Tracewell, University of California, Berkeley (1964)

Siegfried Grosser, University of California, Berkeley (1965)

Bostwick Wyman, University of California, Berkeley (1966)

Gert Almkvist, University of California, Berkeley (1966)

Raymond Hoobler, University of California, Berkeley (1966)

Richard Mateosian, University of California, Berkeley (1969)

Howard Stauffer, University of California, Berkeley (1969)

David Johnson, University of California, Berkeley (1971)

Farshid Minbashian, University of California, Berkeley (1972)

John Reinoehl, University of California, Berkeley (1975)

Brian Peterson, University of California, Berkeley (1976)

Walter Ferrer Santos, University of California, Berkeley (1980)

Rolf Farnsteiner, Universität Hamburg (1982)

John Ryan, University of California, Berkeley (1984)

Nazih Nahlus, University of California, Berkeley (1986)

However, I felt at that time that I needed one more bit of direction. This was graciously given by Andy Magid, who encouraged me to work on pro-affine algebraic groups by suggesting a very interesting problem related to the Hochschild-Mostow theory. Consequently, when I visited Hochschild in the summer of 1993, he was very happy with my research progress.

On my sabbatical visit to Berkeley in 1998–99, Hochschild told me that my visit helped him to keep his office another year. Although by then he was out of mathematics, it was greatly inspiring, and I am grateful for those weekly meetings during which he would listen to my ideas and make very general comments.

Hochschild also had a great sense of humor. For instance, when I told him about my concerns about cholesterol, he replied: "do not worry, it will eventually go to zero!" He was also interested in reading books on theoretical physics, even though, as he commented to me, the underlying mathematics in such books for "the general reader" is always brought up in the maximally denigrating way!

Concerning his books, Hochschild's GTM book in 1981, *Basic Theory of Algebraic Groups and Lie Algebras*, is impressive on many levels. It is entirely self-contained, assuming no knowledge beyond the first year of graduate study in algebra. His treatment of commutative algebra, algebraic geometry (leading to coset varieties), and Lie algebras could serve as excellent introductions to such topics. This book covers a great range of material in about 260 pages. Moreover, it is written with maximal clarity by one of the great authorities of the century. Similar comments can be made concerning his book *The Structure of Lie Groups*, starting with Tannaka duality for compact groups, basics of covering spaces and manifolds, and many other topics.

The 1904 St. Louis Congress and Westward Expansion of American Mathematics

David E. Zitarelli

The emergence of a professional cadre of mathematicians in the midwestern part of the United States in the 1890s has been well documented. (See Chapter 7 of [1] for details.) One of the primary factors in this development was the Chicago Congress of 1893. A similar transformation took place the next decade centered on the 1904 St. Louis Mathematics Congress (StLMC). This time the AMS played a central role in formulating the mathematics program, as well as in conducting its annual summer meeting in conjunction with the Congress, thus reflecting the growth and consolidation of the American mathematics research community that had occurred in the intervening eleven years.

Just as the Chicago Congress signaled the movement of American mathematics to the Midwest, the StLMC extended this expansion to what was then considered the southwestern part of the United States. The StLMC serves as a developmental milestone in the westward expansion of an emerging community of American mathematicians during the years 1900–1910. The advances in both parts of the country were spearheaded by a few key figures from one or two universities. For the StLMC, this meant Washington University and the University of Missouri, whose histories reveal an evolving mission from teaching to teaching plus research. A spinoff of both congresses was the formation of sections within the AMS that permitted individuals in areas distant from New York City to engage actively with others of similar interests.

David E. Zitarelli is associate professor of mathematics at Temple University. His email address is david.zitarelli@temple.edu.

The Louisiana Purchase Exposition

St. Louis was teeming with activity a century after having gained fame as the starting point for the Lewis and Clark expedition in 1803. To commemorate the centennial of the Louisiana Purchase, the city hosted a World's Fair that attracted almost twenty million visitors during its seven-month run. The 1904 Olympic Games were also held in St. Louis in conjunction with the Fair, but the Games were only nominally international due to the prohibitive cost of sailing from Europe, and as a result 525 of the 681 athletes were American.

Like the well-known Columbian Exposition of 1893, the Louisiana Purchase Exposition hosted a series of academic congresses, and an administrative board was established in the latter part of 1902 to plan and coordinate all activities. This six-person committee was chaired by Nicholas M. Butler, the president of Columbia University in New York City, and included three other university presidents: William R. Harper (Chicago), R. H. Jesse (Missouri), and Henry S. Pritchett (MIT). After holding several meetings, the administrative board settled upon 156 separate congresses that attracted more than 100,000 delegates.

The largest assembly, the International Congress of Arts and Science (ICAS), boasted a "participating attendance…in the neighborhood of ten thousand" [2, p. 546]. The ICAS sponsored a series of lectures on scientific and literary topics connected around the theme "Progress of Man since the Louisiana Purchase" during the week of September 19–24, 1904. Because of its size, the ICAS required all twenty-nine lecture halls and meeting rooms on the campus of Washington University.

The Canadian-born Simon Newcomb (1835–1909) was selected as president of the ICAS. Described as "the dean of American scientific circles, whose eminent services to the Government of the United States and whose recognized position in foreign and domestic scientific circles made him particularly fitted to preside over such an international gathering of the leading scientists of the world" [3, p. 12], Newcomb devoted twenty months to the ICAS. The classification scheme placed mathematics with philosophy. Mathematics was divided into three sections: 1) algebra and analysis, 2) geometry, and 3) applied mathematics.

The ICAS explicitly sought to inject an international flavor by supplying "funds sufficient to secure the participation of the leading scientists of the world" [2, p. 545]. As early as November 1901, when William Harper was the preferred candidate to head the administrative board, he was informed, "You will be permitted to travel as you may deem it necessary, at home and abroad…If in your opinion it shall be necessary, in order to secure the participation in the Congresses of certain noted delegates, their expenses will be paid from their homes to St. Louis, and return, and borne while they are in St. Louis in attendance upon the Congresses."[1] It was suggested that $200,000 be set aside for this purpose, an impressive sum that underscores the desire to offer an internationally attractive program.

Once Columbia President Nicholas Butler was installed as chair of the administrative board, the three paid executive officers—Newcomb plus two vice-presidents—sailed to Europe to invite leading scholars to participate. Newcomb was charged with securing such scientists, mostly from France, in mathematics, physics, astronomy, biology, and technology. This predates what the Rockefeller Foundation charged G. D. Birkhoff to do some twenty years later for an entirely different reason.

It was arranged for international delegates to be welcomed in New York City by a special reception committee that facilitated the clearance of luggage and provided fitting entertainment. Several speakers proceeded to St. Louis at once, but the great majority went directly to the University of Chicago, where they were entertained during the week preceding the Congress by President Harper. In St. Louis foreign participants were greeted by a reception committee whose charge was "to meet all incoming trains and conduct the members of the Congress personally to their stopping-places, and assist them in all matters of detail" [3, p. 22]. Individuals were housed in a university dormitory, but those with families were placed in homes.

Once international participation was settled, the ICAS moved to the domestic component: "The necessity was now very evident that our strongest men of science must be induced to take part, in order to compare favorably with the leading minds which Europe is sending" [3, p. 18]. Such a prideful charge may have applied to other areas of study, particularly the earth sciences, but surely the state of mathematics in America trailed behind that in Europe in 1904. Furthermore, an ICAS memo read [3, p. 10]:

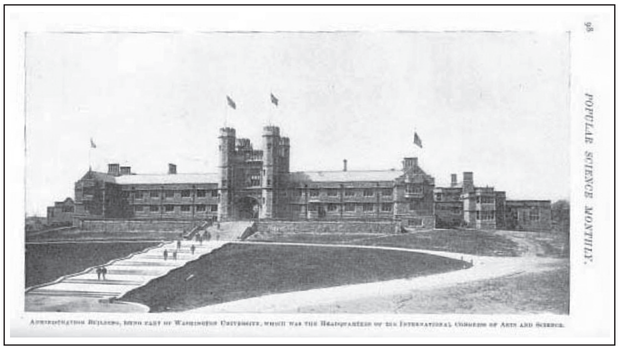
> The Committee deems it of the utmost importance to secure the advice and assistance of learned societies in this country in perfecting the details of the proposed plan, especially the selection of speakers and the programme of work in each section. It will facilitate the latter purpose if such societies be invited and encouraged to hold meetings at St. Louis during the week immediately preceding…the General Congress.

For mathematics, that could only mean the AMS—it was then the only American professional organization of mathematicians. Communication between the ICAS and AMS was abetted by the fact that AMS President Thomas S. Fiske was a faculty member at Columbia University, whose president was chair of the administrative board.

The *Bulletin of the AMS* served as a beacon for alerting the rapidly increasing community of North American research mathematicians to the event beforehand, beginning with a note in the December 1903 issue [4]. One month later the journal revealed that Gaston Darboux, Ludwig Boltzmann, and Henri Poincaré had accepted invitations to deliver addresses [5]. Émile Picard was soon added to the roster. The June 1904 issue of the *Bulletin* heralded the complete list of eight invited speakers, adding Maxime Bôcher (Harvard), Edward Kasner (Columbia), Heinrich Maschke (Chicago), and James Pierpont (Yale) [6]. This list provides

Simon Newcomb (center) and ICAS officers.

[1] *David R. Francis to William R. Harper, November 23, 1901. Office of the President. Harper, Judson and Burton Administrative Records, Box 42, Folder 16, "Expositions 1903 Louisiana Purchase Exposition, St. Louis, 1899-1905."*



Administrative Building, Washington University.

insight into those perceived as among the leading mathematicians in the country at the time. It is notable that Edward Kasner was the only speaker with a doctorate from an American institution.

As requested, the AMS held its annual summer meeting in conjunction with the Congress, with AMS headquarters located at the Inside Inn on exposition grounds.

AMS Meeting

As requested, the burgeoning AMS, whose membership of 464 had nearly doubled since the Chicago Congress, held its eleventh annual summer meeting on the Friday and Saturday before the Congress opened on Monday. Altogether, thirty-nine AMS members attended, a figure that did not count Henri Poincaré or Gino Fano, who were "present by special invitation" [7, p. 55]. In addition, another ten presenters who did not belong to the Society were in attendance, as were perhaps five others who attended the St. Louis Congress.

Henri Poincaré headed a program of twenty-one different speakers who delivered twenty-four lectures in two-hour sessions held at 10 a.m. and 2 p.m. both days. In contrast with modern meetings, no two addresses ran concurrently, as all lectures were delivered in the library at Washington University. Poincaré's talk was an investigation into the geodesics on a convex surface that was one in a series of important papers on his research into periodic solutions of the three-body problem. Per his custom, he asserted a conjecture: there must be at least three such geodesics. (At the time it was known only that a minimum of one must exist.) Also following his custom, Poincaré provided geometric insight that emboldened such a pronouncement. Maurice Fréchet (France) and Francis S. Macaulay (England) submitted papers but did not attend, so E. H. Moore read both.

Five highly regarded Americans submitted papers for the AMS meeting, three associated with Chicago and two with Harvard. Leonard Dickson and Oswald Veblen were two of E. H. Moore's earliest Ph.D. students; both were on his staff during 1904–05. Dickson delivered two lectures on group theory. Gilbert Bliss, the third member of the Chicago group, read Veblen's paper outlining a proof of the Jordan curve theorem. Veblen had only recently completed his dissertation under Moore but remained behind in Chicago. Bliss had graduated under Oskar Bolza four years earlier; he was on the faculty at Missouri for only the year 1904–05. At the AMS meeting he also presented his own results in a lecture that listed necessary and sufficient conditions for a certain function from the calculus of variations to be integrable. The two Harvard mathematicians, both holding doctorates from German universities, Maxime Bôcher (Göttingen) and E. V. Huntington (Strasbourg), read papers on the foundations of mathematics.

There were three mathematics professors at Washington University in St. Louis in 1904–05, yet none participated actively in the AMS summer meeting. Alexander Chessin attended but did not deliver a paper, even though he had published regularly up to that time. His colleagues Calvin Woodward and George James were probably present but were not yet AMS members so were not listed in the AMS report. On the other hand, mathematicians from the University of Missouri were actively engaged in organizing the meeting and delivering papers. Earle Hedrick, a Ph.D. student of David Hilbert who had come to Missouri from Yale one year earlier, was intimately involved in almost all aspects of the tandem AMS and Congress events. In addition to lecturing twice on distinct topics at the AMS meeting, Hedrick publicized his university's collection of models. See [7] for more details on this exhibit.

The set of physical models had been constructed mostly by the little-known Louis Ingold (1872–1935), who had obtained a bachelor's degree from Missouri in 1901 and a master's in 1902 for the thesis "Geometry of four dimensions". He spent the next year taking courses at the University of Chicago, rejoined the Missouri faculty from 1903 to 1905, and took a leave of absence for 1905–1906 that resulted in a Ph.D. under Heinrich Maschke in 1907.

Another speaker at the AMS meeting from the University of Missouri was Lewis Darwin Ames (1869–1955), who lectured on topics related to the Jordan curve theorem. Ames had been an undergraduate student at Missouri before enrolling in the graduate program at Harvard. He joined the Missouri faculty in 1903 while completing his dissertation under William Fogg Osgood shortly before the St. Louis Congress began, becoming Osgood's first Ph.D. student. Another notable American mathematician to present a paper was Henry White, the Klein protégé who spoke on quartic and quintic surfaces that admit infinitesimal collineations.

Four speakers addressed the American specialty of group theory: G. A. Miller (then at Stanford, later a mainstay at Illinois) spoke about a theorem of

Burnside on subgroups of abelian groups, W. B. Fite on successive commutator subgroups, and J. W. Young on congruence subgroups of modular groups. John Wesley Young (1879–1932), associated with Dartmouth from 1911 to 1932, probably wrote his dissertation under William Benjamin Fite (1869–1932), who was then at Cornell but later moved to Columbia. Ida May Schottenfels (1869–1942), whose activity at the turn of the century was second only to that of Charlotte Angas Scott among women mathematicians in America [8], spoke about generators for substitution groups and Galois field groups.

There were two other American speakers. James Byrnie Shaw (1866–1948, Millikin University), who discussed linear associative algebras, had received his Ph.D. in 1893 from Purdue University, which did not award another doctorate in mathematics until 1939. He was ranked among the top ten most active members of the Chicago Section up to the time it was subsumed by the AMS in 1923 [9]. Finally, Harry Schultz Vandiver (1882–1973), then a twenty-one-year-old high-school dropout (from the celebrated Central High School in Philadelphia), had already established a reputation based on research carried out with another prodigy, G. D. Birkhoff. The first degree Vandiver ever earned was an honorary doctorate that Pennsylvania bestowed upon him in 1946 (at age sixty-three). His paper at the AMS meeting was on reduction algorithms for the solution of linear equations over a finite field. Details of all these works can be found in the *Bulletin* report of the meeting [7].

St. Louis Congress

Although no mathematics *per se* took place during the opening ceremonies of the International Congress of Arts and Science on Monday, two presentations are germane. Jean Gaston Darboux, the perpetual secretary of the Academy of Sciences in Paris, spoke briefly in his capacity as honorary vice-president for France. His remarks recalled an American statesman from an earlier era. "Since the time of Franklin, who received at the hands of France the welcome which justice and his own personal genius and worth demanded, most affectionate relations have not ceased to unite the scientists of France and the scientists of America" [3, p. 28].

Simon Newcomb delivered the initial scientific address in his role as ICAS president. Although he was sixty-nine years old at the time, Newcomb's vitality could be attested by his hiking trek to a chalet high up the side of the Matterhorn the following year. His talk, "The evolution of the scientific investigator", drew upon a lifetime of experience in the sciences that included one stint as president of the AMS (1897–1898) and another as founding member and first president (1899–1905) of the American Astronomical Society. Newcomb described his remarks as an "inquiry into the logical order of the causes which have made our civilization what it is to-day" [10, p. 136]. In order to compare the inventor with the investigator, he called upon the analogy between an oak tree and its acorn—the qualities of the great oak are wonderful to behold, but the real wonder lies concealed in the acorn. "While giving all due honor to the great inventors, let us remember that the first place is that of the great investigators" [10, p. 137].

The formal program of lectures began the next morning at 10 o'clock when Division A, Normative Science (consisting of mathematics and philosophy), assembled for a joint session. The plenum lecture by mathematical philosopher Josiah Royce, "The sciences of the ideal", began, "I am required to explain what scientific interests seem to me to be common to the work of the philosophers and of the mathematicians…. The mathematicians are becoming more and more philosophical. The philosophers, in the near future, will become, I believe, more and more mathematical" [11, p. 151]. Royce's remarks appeared two weeks later in *Science*, the popular weekly journal published by the American Association for the Advancement of Science [11].

Immediately following Royce's lecture, the two disciplines separated, with mathematicians moving to a nearby lecture hall for the first of the four sessions. Henry S. White (Northwestern), chair of the first one, introduced the two speakers in turn, Maxime Bôcher (Harvard) and James Pierpont (Yale), both of whom presented forty-five-minute addresses of a highly general character, Bôcher on "The fundamental conceptions and methods of mathematics" and Pierpont on "The history of mathematics in the nineteenth century". The addresses were published in tandem two months later in the *Bulletin* [12], [13].

While this session was devoted to an overview of mathematics, each of the other three considered specific subfields. A sidebar lists the program of speakers and officers for all four sessions. The sessions on subfields included a secretary responsible for taking detailed notes that would form the basis for the formal *Proceedings* of the Congress, which stated, "Great care was exerted in selecting the chairmen … as they must be men of international reputation and conceded strength. For the secretary-ships younger men of promise and ability were selected, chiefly from university circles" [3, p. 19]. This quotation shows an early recognition of the critical importance of advancing the careers of young workers such as G. A. Bliss and Thomas Holgate by linking them with established scholars such as E. H. Moore and M. W. Haskell.

Each session devoted to a subfield was allotted three hours: a forty-five-minute address on fundamental conceptions and methods, a fifteen-minute period for questions and comments, a forty-five-minute address on the present state of the specialty,

Émile Picard with E. H. Moore and Heinrich Maschke.

another fifteen-minute period for audience response, and an hour for "supplementary papers". (A sidebar lists all supplementary papers.)

Whereas Tuesday's session had featured American speakers by design, the other three included international celebrities. The session on algebra and analysis, held two days later, was chaired by E. H. Moore, whose participation provided a direct link to his own Chicago Congress eleven years earlier. Émile Picard (Sorbonne) opened the program with a lecture delivered in French, "Sur le développement de l'analyse mathématique et ses rapports avec quelques autres sciences"; it appeared in two parts that October and November [14]. An authorized translation by G. B. Halsted (then at Kenyon College), "On the development of mathematical analysis and its relations to some other sciences", appeared in *Science* one month after the Congress ended [15].

The other principal address, "On present problems of algebra and analysis", was delivered by Klein protégé Heinrich Maschke, who had been on the faculty at the University of Chicago since its opening in 1892. According to the AMS report he delivered "an extended survey of the present state of the theory of invariants of quadratic differential forms in n independent variables, an intensive study of differential parameters or the Biegungsinvarianten of surfaces, and included an overview of [his] papers in the *Transactions* of this Society" [16, p. 359]. The entire address is reproduced as [17].

The official report from the Congress waxed enthusiastic about this session: "The Section of

Speakers and Officers

Division A—Normative Science
Hall 6, September 20, 1904, 10 a. m.–11 a.m.

Speaker: JOSIAH ROYCE, Harvard University
"The sciences of the ideal"

Department 2—Mathematics
Hall 7, September 20, 11:15 a. m.–1 p.m.
Chairman: Henry S. White, Northwestern University

Speakers: Maxime Bôcher, Harvard University: "The fundamental conceptions and methods of mathematics"; James P. Pierpont, Yale University: "The history of mathematics in the nineteenth century"

Section A. Algebra and Analysis
Hall 9, September 22, 10 a.m.–1 p.m.
Chairman: E. H. Moore, University of Chicago;
Secretary: G. A. Bliss, University of Missouri

Speakers: Émile Picard, The Sorbonne, Member of the Institute of France: "Sur le développement de l'analyse mathématique et ses rapports avec quelques autres sciences" ("On the development of mathematical analysis and its relations to some other sciences"); Heinrich Maschke, University of Chicago: "On present problems of algebra and analysis"

Section B. Geometry
Hall 9, September 24, 10 a.m.–1 p.m.
Chairman: M. W. Haskell, University of California
Secretary: Thomas J. Holgate, Northwestern University

Speakers: Gaston Darboux, Perpetual Secretary of the Academy of Sciences, Paris: "Étude sur le développement des méthodes géométriques" ("A study of the development of geometric methods"): Edward Kasner, Columbia University: "The present problems of geometry"

Section C. Applied Mathematics
Hall 7, September 24, 3 p.m.–6 p.m.
Chairman: Arthur G. Webster, Clark University
Secretary: Henry T. Eddy, University of Minnesota
Speakers: Ludwig Boltzmann, University of Vienna: "The relations of applied mathematics"; Henri Poincaré, The Sorbonne, Member of the Institute of France: "L'état actuel et l'avenir de la physique mathématique" ("The principles of mathematical physics")

Supplementary Papers

Section A. Algebra and Analysis

1. G. A. Miller (Stanford), "Bearing of several recent theorems on group theory"
2. James Byrnie Shaw (Millikin), "Linear associative algebra"
3. M. W. Haskell (Berkeley), "The reduction of any collineation to a product of perspective collineations"
4. M. B. Porter (Texas), "On functions defined by an infinite series of analytic functions of a complex variable"
5. Edward V. Huntington (Harvard), "A set of postulates for real algebra comprising postulates for a one-dimensional continuum and for the theory of groups"
6. J. I. Hutchinson (Cornell), "Uniformizing of algebraic functions"
7. E. R. Hedrick* (Missouri), "Generalization of the analytic functions of a complex variable"

Section B. Geometry

1. Harris Hancock (Cincinnati), "Algebraic minimal surfaces"
2. H. F. Blichfeldt (Stanford), "Concerning some geometrical properties of surfaces of revolution"
3. George Bruce Halsted (Kenyon), "Non-Euclidean spherics"
4. Arnold Emch (Colorado), "The configuration of the points of inflexion of a plane cubic and their harmonic polars"
5. H. P. Manning (Brown), "Representation of complex variables in space of four dimensions"
6. G. A. Bliss* (Missouri), "Concerning calculus of variations"
7. L. W. Dowling (Wisconsin), "Certain universal curves"

Section C. Applied Mathematics

1. Henry T. Eddy* (Minnesota), "The electromagnetic theory and the velocity of light"
2. Alexander Macfarlane (Ontario), "On the exponential notation in vector analysis"
3. James McMahon (Cornell), "On the use of N-fold Riemann spaces in applied mathematics"

* Submitted but not read.

Algebra and Analysis attracted wide interest and caused many supplementary papers on various topics to be submitted" [3, p. 531]. Henry White's AMS report supplied abstracts of five of the seven shorter communications in this meeting and provided a bibliographic reference for another [16].

The final two sessions on mathematics were held on Saturday, beginning with one on geometry. Curiously, Gaston Darboux's address was translated into English in two different versions and published in two different venues: "A study of the development of geometric methods", translated by G. B. Halsted and published in *Popular Science Monthly* [18] and "A survey of the development of geometric methods" by Henry Thompson and published in the *Bulletin* [19]. We have been unable to determine why different translations were undertaken by two different mathematicians. Darboux's work had previously appeared in the original French version [20].

The other chief address on geometry was delivered by Edward Kasner (1878–1955), who was only twenty-six years old at the time but had earned his Columbia Ph.D. five years earlier. After obtaining his doctorate Kasner followed the prevalent American custom of sailing to Göttingen for a year of postgraduate study, chiefly so he could attend lectures by David Hilbert and Felix Klein. Upon his return to the United States he remained at Columbia for the rest of his life. One of his best known works is the coauthored book (with former student James Roy Newman) in 1940, *Mathematics and the Imagination*, which surveyed the entire field of mathematics. Newman wrote, "I had the good fortune to attend several of his courses as a graduate student, and, like many others, I owe to him a true awakening of interest in mathematics and an appreciation of its rare excellence" [21, p. 1994]. Kasner's paper at the St. Louis Congress, "The present problems of geometry", was described by future Fields medalist Jesse Douglas as "a comprehensive summary and formulation of the status of the subject at that time" [22, p. 190]. The paper examined several major unsolved problems [23].

The concluding session on applied mathematics ran from 3 p.m. until 6 p.m. Given the penchant in North America for pure mathematics, it is not surprising that both lectures on applied topics were delivered by Europeans. The chair, Arthur G. Webster (Clark University), and the first speaker, Ludwig Boltzmann (Vienna), were physicists. Boltzmann's lecture was translated from German by Saul Epsteen (Chicago) as "The relations of applied mathematics". In his opening remarks Boltzmann lamented the gulf separating theoretical physicists such as himself from experimentalists [24, p. 591].

Henri Poincaré, the final speaker, drew the largest audience. His lecture, "L'état actuel et l'avenir

Henri Poincaré

Photo courtesy of the Smithsonian Institution Libraries, Washington, D.C.

de la physique mathématique" [25], was translated in two separate versions: "The principles of mathematical physics" in the conference proceedings by G. B. Halsted [26] and "The present and the future of mathematical physics" in the *Bulletin* by J. W. Young [27]. Once again we have no explanation for seemingly duplicate efforts. Pages are cited from the *Bulletin* because it is more easily accessible.

Poincaré opened his remarks with four questions. "What is the present state of mathematical physics? What are its problems? What is its future? Is it about to change its orientation?" [27, p. 240]. Regarding these questions he stated, "It is easy to ask; difficult to answer" [*Ibid*.]. With Einstein's *annus mirabilis* less than a year away, the answer to the third question was somewhat different from what Poincaré might have imagined, although his remarks at the St. Louis Congress attest to the fact that he came very close to discovering the theory of special relativity. Darrigol [28] provides a recent, balanced account of the controversy surrounding the discovery of special relativity.

This time the official account reported merely, "Three short papers were read in the Section on Applied Mathematics" [3, p. 622]. Moreover, Henry White's AMS report [16] listed only one of the three short papers that followed Poincaré's address.

Official activities for the overseas participants did not end with Saturday's sessions. After the Congress concluded on Sunday, the foreign speakers boarded a train for Washington, D.C. to attend an official reception hosted by President Theodore Roosevelt and another reception at which Simon Newcomb held court. From there they hopped aboard another train for Boston, where Congress vice-president Hugo Münsterberg hosted a reception at Harvard. Finally, the exhausting itinerary called for the celebrities to proceed to New York for a farewell dinner at Columbia hosted by the Association of Old German Students. Only then did the speakers set sail for home.

Washington University and the University of Missouri

The AMS meeting and the St. Louis Mathematics Congress took place on the new campus of Washington University, and mathematicians from the University of Missouri were instrumental in both gatherings. Here we outline the histories of these institutions through the first decade of the twentieth century to illustrate the southwestern movement of the change in the primary mission of leading institutions from low-level teaching to upper-level mentorship *plus* research.

Washington University was founded in 1853 by Unitarian minister William Greenleaf Eliot Jr. and one of his parishioners, Missouri State Senator Waymon Crow. Though quite different individuals, Crow and Eliot shared a desire to establish an educational enterprise to provide "powerful civilizing forces that could tame the diverse, fast-growing population" of St. Louis [29, p. 7]. Ads for the new school reflected an early emphasis on mathematics, promising a course of instruction that "will embrace mental and written Arithmetic, Algebra, Reading, Grammar, Declamations, and if desirable writing and spelling" [29, p. 11]. Before daytime classes started in 1856, the Board of Trustees appointed Joseph J. Reynolds (1822–1899) as Eliot Professor of Mathematics, Mechanics, and Civil Engineering. An 1843 graduate of West Point, Reynolds later gained distinction as a combat veteran of the Mexican War and the U.S. Civil War.

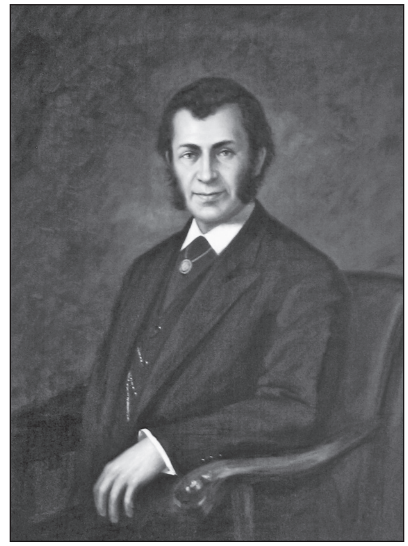
But mathematics gained a much stronger foothold in the fledgling university when its first chancellor was brought aboard in 1859. Joseph Gibson Hoyt (1815–1862) was a Yale graduate and Greek scholar who had been professor of mathematics and natural philosophy at the exclusive Phillips Exeter Academy from 1840 to 1858 before taking up his post at Washington University. His choice for the chair of mathematics and astronomy was William Chauvenet (1820–1870), an 1840 Yale graduate who became the principal founder of the Naval Academy in 1845 at age twenty-four. Chauvenet remained at Navy until being recruited by his Yale classmate Hoyt. Described as someone who "had a charming personality, was a skilled musician and was so broadly cultured in all things that he filled well his position as leader of a humanistic institution" [30, p. 1], Chauvenet wrote seminal works on geometry, spherical trigonometry, and astronomy that were especially known for clear exposition. As a result, when the Mathematical Association of America established a prize for exposition in 1925, it named the award in his honor. (To date three Washington mathematicians have won the Chauvenet Prize—Guido Weiss (in 1967), Kenneth I. Gross (1981), and Steven G. Krantz (1992)—the most of any university in the country.)

Washington University reeled with decreasing enrollments and financial support during the U.S. Civil War but rebounded under the leadership of Chauvenet until his untimely death in 1870. Harvard graduate Calvin Milton Woodward (1837–1914) was then hired as Nathaniel Thayer Professor of Mathematics and Applied Mechanics, as well as Washington's first dean, but he became so actively involved in the development of vocational education in the school's Polytechnic Institute that he contributed very little to mathematics. The subject then languished for the next six years until the appointment of John Krom Rees (1851–1907), who put the university on the map by establishing (with Woodward) standard time for that region. But their collaboration was short-lived, as Rees remained at Washington only five years before returning to his alma mater, Columbia. In 1888 he was one of the six charter members of the New York Mathematical Society.

The departure of Rees in 1881 was the catalyst for hiring two mathematicians who would become leading administrators at other institutions, Henry Smith Pritchett (1857–1939) and Edmund A. Engler (1856–1918). The new additions made extensive use of a small observatory on campus to collaborate with the U.S. Coast and Geodetic Survey in sending time signals to towns and rail lines from the Appalachians to the Rocky Mountains. Pritchett left Washington in 1897 to become head of the U.S. Coast and Geodetic Survey. He then accepted the presidency of MIT, a post he held until 1906; as noted above, he was one of six members of the administrative board. Engler was awarded a Ph.D. in mathematics by Washington University in 1892. The department did not bestow another doctorate until the mid-1930s, when the émigré Gabor Szegö directed four dissertations; it would be another twenty years before Ph.D.s were produced on a regular basis. Engler left Washington in 1901 to accept the presidency of Worcester Institute. Many of the plaster-and-string models he constructed were exhibited in Washington's mathematics department through the middle of the twentieth century and are now stored in the Engineering School.

Along with a rapidly increasing population in St. Louis during the 1890s, there emerged a group of inhabitants the university courted: "Part of the original vision of the institution was that it was to be a place for the wealthy mercantile class of the city to send their children for refinement and erudition" [31, p. 1]. So in 1899 the decision was made to move the campus from its downtown location to a large tract of land that ultimately resulted in the present Hilltop Campus. Funding was secured to erect several buildings over the next three years, but a sudden financial crisis squashed plans for construction of a new library, physics building, athletic grounds, and gymnasium. The University needed an immediate infusion of $600,000. And that is when the World's Fair came to the rescue.

David Rowland Francis (1850–1927), an 1870 graduate, was president of the Louisiana Purchase Exposition. Mayor of St. Louis from 1885 to 1889, governor of Missouri from 1889 to 1893, and U.S. Secretary of the Interior from 1896 to 1897, Francis saw the opportunity to extend the fairgrounds beyond its Forest Park location while helping his alma mater at the same time. He arranged for the Exposition to lease the land and new buildings and to set aside funding for constructing three more buildings. Moreover, the contract stipulated that if the intended start date of the World's Fair was postponed beyond its intended time of 1903, the Exposition would provide additional funds toward construction of a fourth new building. David Francis remains an example of a highly successful political figure who negotiated in a way that benefitted the city of St. Louis, the World's Fair, and Washington University.



William Chauvenet

Portrait of William Chauvenet, anonymous, n.d., 30" x 40", Mildred Lane Kemper Art Museum.

In the meantime, the face of Washington mathematics had changed perceptibly with the 1901 hiring of G. O. James and A. S. Chessin. Little is known about either one. George Oscar James (1873–1932) received his Ph.D. from Johns Hopkins in 1899; although no official dissertation advisor is listed, the blending of differential equations with hypersurfaces suggests that it was written under Thomas Craig. James served as chair at Washington from 1918 to 1932.

Alexander Sawéljevitsch Chessin was the more accomplished of the two. Born in St. Petersburg, Russia (in either 1865 or 1866 according to different sources), Chessin received a Doctor of Philosophy degree from the University of St. Petersburg and was then sent by the Russian government to Italy on a special mission. A few years later he earned a civil engineering degree from the Polytechnic School in Zurich. Chessin came to the United States to attend the Chicago Mathematics Congress in 1893. After offering a course at Harvard and assisting Simon Newcomb with planetary tables in Washington, D.C., he joined the Johns Hopkins University faculty. However, a note in the July 1898 *Bulletin* revealed, "Professor Simon Newcomb has resumed his professorship of mathematics at the Johns Hopkins University. Associate Professor A. S. Chessin has resigned his position" [32, p. 555]. Chessin returned to Russia from 1899 to 1901 yet maintained a New York City address with the AMS before succeeding Edmund Engler at Washington University in the fall of 1901.

Chessin has proved to be an elusive character. He published at least eighteen papers between 1894 and 1905 and was one of three founders of the Southwestern Section of the AMS in 1906, but he left Washington University after the spring 1907 semester. Notes in the *Bulletin* indicate that he lectured at three eastern colleges after that

William W. Hudson

and attended AMS meetings in New York through October 1912. The 1910 census cites his "birth about 1867" and lists an address in New York City, but, curiously, he was not included in the next decennial census even though a court document from 1922 ruled against him in a patent suit over the gyroscope. That is the last we hear about Chessin, with no mention of him and no paper by him in any subsequent mathematical publication.

At the time of the World's Fair, then, the mathematics department at Washington University consisted of A. S. Chessin, George James, and Calvin Woodward. Now we turn to the University of Missouri, located in Columbia, about 125 miles from St. Louis. Like Washington University (WU hereafter), the University of Missouri (UM) started out as a private college, dating its founding from 1839, when the private Columbia College was converted to the public University of the State of Missouri. UM thereby became the first public university in the United States west of the Mississippi River. UM's mathematics fortunes began with its first president, John Hiram Lathrop (1799-1866), a former professor of mathematics. During the antebellum period mathematics was taught by William W. Hudson, who was also in charge of astronomy. Hudson contributed no new mathematics, rather devoting his time to administrative tasks that included two stints as president of the institution, the first in an acting capacity. In the meantime UM also hired mathematics tutors to teach introductory courses.

During the period of Reconstruction, 1865–1877, both UM and WU recovered from dwindling enrollments and financial support caused by the Civil War. Whereas the WU faculty included C. M. Woodward, J. K. Rees, H. S. Pritchett, and E. A. Engler through the 1880s, UM made only one appointment in mathematics, Joseph Ficklin (1833–1887), who headed the department from 1865 until his death in 1887. Although Ficklin's primary interest was astronomy, he wrote numerous low-level textbooks for American schools.

The change in the mission at UM came from Richard H. Jesse (1853–1921), whose tenure as president of the university, 1891–1908, was described in the authoritative history of UM as follows [33, p. 355]:

> President Jesse's discrimination in the recruiting of new members of the faculty so as to secure men of intellectual competency as well as teaching and administrative ability became so well known that in future years people looked back upon his presidency as the Golden Age of the University.

Jesse inherited a respectable mathematician, William Benjamin Smith (1850–1934), who had come to UM with a Ph.D. from Göttingen in mathematics and physics. However, Smith left within the first two years of Jesse's presidency.

Jesse's appointments in mathematics over the next ten years were hardly "golden", but that changed in 1902 when he brought Arthur Byron Coble (1878–1966) to campus with a fresh Ph.D. from Johns Hopkins under Frank Morley. Coble returned to Hopkins after only one year, but Jesse trumped even this defection by appointing Earle Hedrick and L. D. Ames in 1903, G. A. Bliss in 1904, O. D. Kellogg and W. D. A. Westfall in 1905, and Otto Dunkel in 1907. This faculty ranked among the very best in the country! Earle Raymond Hedrick (1876–1943), Oliver Dimon Kellogg (1878–1932), and Wilhelmus David Allen Westfall (1879–1951) had all earned Ph.D.s under David Hilbert at Göttingen, and Gilbert Ames Bliss (1876–1951) had obtained his Chicago Ph.D. under Oskar Bolza and Otto Dunkel (1869–1951) his Harvard Ph.D. under Maxime Bôcher. This means that the UM mathematics department at the time of the St. Louis Congress in 1904 included Hedrick, Ames, and Bliss. In addition, Louis Ingold, whose work on constructing physical models for the Congress has already been cited, was an instructor at the time; his Chicago Ph.D. under Heinrich Maschke provided yet another link between UM and Göttingen. Bliss was recruited to Princeton the next year, 1905, in connection with the preceptorial scheme devised by Woodrow Wilson and carried out by Henry Fine. Yet, when the third section of the AMS was founded, the UM faculty included Hedrick, Ames, Kellogg, Westfall, and Dunkel.

Southwestern Section

The founding of the Southwestern (SW) Section of the AMS can be viewed as the culmination of a decade of the western expansion in the American mathematical landscape. The idea of a section of the AMS emerged in 1896 when a group of mathematicians in the Chicago area led by E. H. Moore petitioned the AMS to hold two official meetings annually. This induced the Council of the AMS to approve the formation of the Chicago Section in 1897. That idea resonated with a group of West Coast mathematicians who had been attending meetings of the San Francisco Academy of Sciences and founded the San Francisco Section in 1902.

The idea for a third section seems to have been planted when a half dozen mathematicians from the St. Louis area attended the April 1906 meeting of the Chicago Section with the aim of establishing their own group within the national organization.

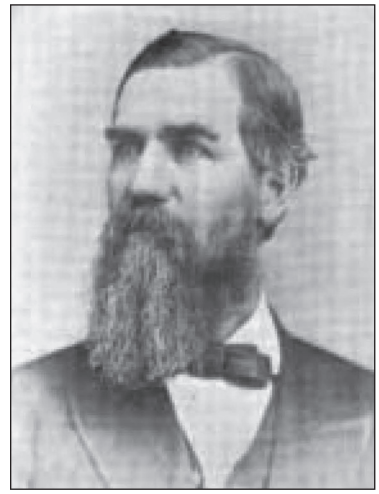
The minutes from that meeting record, "A resolution was introduced by E. H. Moore and unanimously carried, expressing the very earnest hope of the Chicago Section that it may be found possible to establish a strong section of the Society which shall hold meetings at some convenient center in the Southwest" [34, p. 435]. In December 1906 this resolution and presentations made by Earle Hedrick impelled AMS leaders to authorize the formation of the Southwestern Section [35]. Therefore it seems that E. H. Moore not only originated the notion of a section but played a pivotal role in helping his Missouri colleagues spread it to other parts of the country.

The groundswell of support for the Southwestern Section encouraged its leaders to launch activity even before gaining official approval. Minutes from the annual AMS meeting held December 1906 in New York City record briefly, "The organization of a new Section, to be known as the Southwestern Section of the Society, was authorized by the Council" [36, p. 262]. However, four weeks before official authorization, the section sponsored a "preliminary meeting" at the University of Missouri. To underscore the continuing connection with Chicago, "Professor E. H. Moore was asked to preside as honorary chairman of the meeting for the afternoon session.... At the conclusion of the meeting a motion was passed expressing the thanks of the members to all who had assisted in the formation of this section, especially to Professor E. H. Moore" [37, p. 218].

The SW Section held its first regular meeting in November 1907 in St. Louis. (Today's Central Section of the AMS is essentially a union of the Chicago and SW Sections.) The enthusiasm for this initial southwestern endeavor can be seen by comparing its attendance of thirty AMS members with the thirteen who were listed for the San Francisco Section meeting in September as well as the thirty-three and thirty who attended the spring Chicago Section meetings in 1907 and 1908, respectively. For further evidence, twenty-eight members attended the meeting in New York in October 1907, whereas, the attendance at the AMS annual summer meeting held the previous month at Cornell had been forty-seven.

With the University of Missouri and Washington University serving as the section's initial focal points, it is not surprising that its first two meetings were held on their campuses and that their departments were the best represented. Chicago Section leaders continued active participation in the new Section, with Herbert Slaught attending the second meeting. He and three others from that meeting—B. F. Finkel (Drury College), Earle Hedrick and Otto Dunkel (both at Missouri)—would play critical roles when the MAA was founded in 1915.

Another sign that Missouri and Washington University supplied the SW Section's initial leadership can be seen in the slate of officers. Earle Hedrick was elected chair at the preliminary meeting; in our view he should be regarded as the principal founder of the SW Section. Alexander Chessin was elected secretary at this meeting and chair at the regular meeting, where Oliver Kellogg (Missouri) was elected secretary. Kellogg held this position from 1907 to 1918, ending only when he was assigned to teach at the U.S. Coast Guard Academy in Connecticut during World War I; at the end of the war he was appointed to a lectureship at Harvard, where he remained for the rest of his life.



Joseph Ficklin

Conclusion

Was the St. Louis Mathematics Congress a success? On the one hand, the *Proceedings* reported, "not financially, nor was there ever a thought that it would be. Probably not more than seven thousand persons outside of St. Louis came primarily to attend the Congress, and their admission fees were a bagatelle" [3, p. 42]. On the other hand, those same *Proceedings* boasted, "the Congress was an unqualified success and of enduring reputation" [3, p. 42]. The "enduring reputation" was due to the prompt publication of the *Proceedings* and the worldwide journals in which individual papers appeared. Unlike the organizers of the Chicago Congress, the St. Louis directors had made arrangements beforehand for Houghton, Mifflin and Company to publish the *Proceedings*. The official final report from the St. Louis World's Fair concluded, "The Exposition of 1904 was a brilliant success in every respect. ... The papers of these congresses ...will find their way into the libraries of the world and will be treasured there" [2, p. 552]. Seven of the eight papers from the mathematics sessions were published within six months of the Congress, and two journals produced special issues devoted to the international exposition. The *Bulletin des Sciences Mathématique*s published the original papers of all three French speakers in the first part of its volume for 1904, and *The Popular Science Monthly* devoted its November 1904 issue to scientific papers presented at the meeting, including an edited version of Simon Newcomb's opening address [10].

Henry White's official report on the St. Louis Congress for the AMS included abstracts for most of the supplementary papers and supplied bibliographic details for others. It too was upbeat. "One purpose of the directors of the Congress was certainly realized—the conceptions of science as an organic whole, and of the community of interest, the necessary interdependence, of all special divisions of science were fitly expressed and strikingly enforced by this unique gathering" [16, pp. 360–361].

Three elements differentiate the Chicago and St. Louis Congresses. One was the participation—indeed, the very existence—of a national professional organization of mathematicians, the AMS. Another was participation by foreign scholars. Both congresses featured leading international figures, but only the St. Louis Congress explicitly supported speakers from abroad with attractive financial inducements. A third distinguishing characteristic was the publication of the proceedings. Although the 1893 event helped launch the New York Mathematical Society into a national organization that published its proceedings because no private publisher could be found, just eleven years later at least a dozen publishing houses vied to bring the papers into print. However, whereas the 1893 World's Fair exerted critical influence on the mathematics department at Chicago and ultimately throughout the United States, its 1904 successor seems to have had limited effect.

Nonetheless, the nine-day combined AMS meeting and St. Louis Congress was the centerpiece of the (south)-westward expansion of mathematics in America. Henry White reported, "The auditors … numbered between 60 and 70" [16, pp. 358–359]. Along with the emergence of research universities and the founding of an AMS section, these meetings paint a picture of an American community of mathematicians that was moving westward with increasing numbers and prestige.

We end with two sets of open questions that seem worthy of further investigation:

1) What list of mathematicians was considered for inclusion in the St. Louis Congress, both domestic and international? Why was German participation so minimal?

2) What, if any, lasting effect did the StLMC have on its participants? Were the published papers cited in subsequent works by established researchers or young workers?

Acknowledgment

The author is appreciative for helpful comments by Alan Gluchoff, Albert C. Lewis, and a cast of referees on earlier versions of this article. He thanks Temple University for the Research and Study Leave that provided him with uninterrupted time to carry out this research.

Photo credits

Simon Newcomb and ICAS officers and Administrative Building, Washington University: *Congress of Arts and Science: Universal Exposition, St. Louis, 1904*, Howard J. Rogers, author, Houghton, Mifflin and Company, 1905; Émile Picard with E. H. Moore and Heinrich Maschke: *Popular Science Monthly* **66** (November 1904); Henri Poincaré: Courtesy of the Smithsonian Institution Libraries, Washington, D.C.; William Chauvenet: Anonymous, Portrait of William Chauvenet, Mildred Lane Kemper Art Museum, gift of Dr. and Mrs. Benjamin Strong, 1988; Joseph Ficklin: *A Genealogical History of the Ficklin Family*, compiled by Walter Homan Ficklin, The W. H. Kistler Press, Denver, CO, 1912; William Hudson: Plate 3 of *A History of the University of Missouri*, Frank Stephens, author, University of Missouri Press, 1962.

References

[1] Karen H. Parshall and David E. Rowe, *The Emergence of the American Mathematical Community, 1876–1900: J. J. Sylvester, Felix Klein, and E. H. Moore*, Amer. Math. Soc., 1994.

[2] David R. Francis, *The Universal Exposition of 1904*, Louisiana Purchase Exposition Company, 1913.

[3] Howard J. Rogers, *Congress of Arts and Science: Universal Exposition, St. Louis, 1904*, Houghton, Mifflin and Company, 1905.

[4] Anon, Notes, *Bull. Amer. Math. Soc.* **10** (1903), 158–163.

[5] Anon, Notes, *Bull. Amer. Math. Soc.* **10** (1904), 210–215.

[6] Anon, Notes, *Bull. Amer. Math. Soc.* **10** (1904), 471–479.

[7] Mellen W. Haskell and Henry S. White, The eleventh summer meeting of the American Mathematical Society, *Bull. Amer. Math. Soc.* **11** (1904), 55–68.

[8] Della D. Fenster and Karen H. Parshall, Women in the American mathematical research community: 1891–1906, in Eberhard Knobloch and David E. Rowe, *The History of Modern Mathematics, Volume III: Images, Ideas, and Communities*, Academic Press, 1994, pp. 229–261.

[9] Arnold Dresden, A report on the scientific work of the Chicago Section, 1897–1922, *Bull. Amer. Math. Soc.* **28** (1922), 303–307.

[10] Simon Newcomb, The evolution of the scientific investigator, in [3], pp. 135–147, and *Popular Science Monthly* 66 (1904), 92–96.

[11] Josiah Royce, The sciences of the ideal, in [3], pp. 151–170, and *Science*, October 7, 1904, 449–462.

[12] Maxime Bôcher, The fundamental conceptions and methods of mathematics, *Bull. Amer. Math. Soc.* **11** (1905), 115–135.

[13] James Pierpont, The history of mathematics in the nineteenth century, *Bull. Amer. Math. Soc.* **11** (1905), 136–159.

[14] C. É. Picard, Sur le développement de l'analyse mathématique et ses rapports avec quelques autres sciences, *Bull. des Sci. Math.* **28** (1904), 267–278, 282–296.

[15] C. É. Picard, On the development of mathematical analysis and its relation to some other sciences, in [3], pp. 497–517, and *Science* **20** (1904), 857–872.

[16] Henry S. White, Mathematics at the St. Louis Congress, September 20, 22, and 24, 1904, *Bull. Amer. Math. Soc.* 11 (1905), 358–363.

[17] Heinrich Maschke, On present problems of algebra and analysis, in [3], pp. 518–530.

[18] Gaston Darboux, A study of the development of geometric methods, *Popular Science Monthly* **66** (1905), 412–434; also [3], pp. 535–558.
[19] ______ , A survey of the development of geometric methods, *Bull. Amer. Math. Soc.* **11** (1905), 517–543.
[20] ______ , Étude sur le développement des méthodes géométriques, *Bull. des Sciences Math.* **28** (1904), 234–263.
[21] James R. Newman, *The World of Mathematics*, Vol. 3, Simon & Schuster, 1956.
[22] Jesse Douglas, Edward Kasner, 1878-1955, *Biographical Memoirs*, National Academy of Sciences, Washington DC, 1958, 179–209.
[23] Edward Kasner, The present problems of geometry, in [3], pp. 559–586; and *Bull. Amer. Math. Soc.* **11** (1905), 283–314.
[24] Ludwig Boltzmann, The relations of applied mathematics, in [3], pp. 591–603.
[25] Henri Poincaré, L'état actuel et l'avenir de la physique mathématique, *Bull. des Sciences Math.* **28** (1904), 302–324; and *The Monist* **15** (1905), 1–25.
[26] ______ , The principles of mathematical physics, in [3], pp. 604–622.
[27] ______ , The present and the future of mathematical physics, *Bull. Amer. Math. Soc.* **12** (1906), 240–260.
[28] Olivier Darrigol, The mystery of the Einstein-Poincaré connection, *Isis* **95** (2004), 614–626.
[29] Candace O'Connor, *Beginning a Great Work: Washington University in St. Louis, 1853-2003*, Washington University, 2003.
[30] W. H. Roever, *History of Mathematics at Washington University*, Roever Papers, Box 02, Olin Library, Washington University, 1947.
[31] Steven Krantz, An anecdotal history of the Washington University mathematics department, in Gary R. Jensen and Steven G. Krantz (eds.), *150 Years of Mathematics at Washington University in St. Louis*, Amer. Math. Soc., 2006, pp. 1–11.
[32] Anon, Notes, *Bull. Amer. Math. Soc.* **4** (1898), 554–558.
[33] Frank F. Stephens, A *History of the University of Missouri*, Univ. of Missouri Press, 1962.
[34] Herbert E. Slaught, The April meeting of the Chicago Section, *Bull. Amer. Math. Soc.* **12** (1906), 434–446.
[35] Raymond C. Archibald, *A Semicentennial History of the American Mathematical Society 1888–1938*, Amer. Math. Soc., 1938.
[36] Frank Nelson Cole, The thirteenth annual meeting of the American Mathematical Society, *Bull. Amer. Math. Soc.* **13** (1906), 261–274.
[37] A. S. Chessin, The preliminary meeting of the Southwestern Section, *Bull. Amer. Math. Soc.* 13 (1907), 218–223.

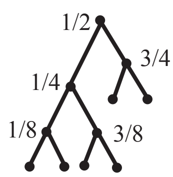
WHAT IS...
Thompson's Group?

J. W. Cannon and W. J. Floyd

Introduction

Richard J. Thompson's group T is the first known finitely presented infinite simple group. Hundreds of papers have been devoted to this group, to its two finitely presented companions $F \subset T \subset V$, and to related groups.

These groups describe transformations from one rooted binary tree to another. Such trees can be encoded by sequences of rational numbers: The root of the tree is represented by the dyadic fraction $1/2$. Each dyadic fraction $x \cdot (1/2)^k \in (0, 1)$ (x odd) is the unique *parent* of two dyadic *children*, namely, $(2x \pm 1) \cdot (1/2)^{k+1}$. A sequence $S = \{a_1 < \cdots < a_n\} \subset (0, 1)$ of dyadic fractions is called a *tree sequence of length* $n \geq 0$ if the parent of each $a_i \neq 1/2$ is also in S.



$\{1/8 < 1/4 < 3/8 < 1/2 < 3/4\}$

Exercise. Draw the tree associated with the tree sequence $\{1/8 < 1/4 < 1/2 < 3/4 < 13/16 < 7/8\}$.

One tree sequence $S(1) = \{a_1(1) < \cdots < a_n(1)\}$ is transformed into a second $S(2) = \{a_1(2) < \cdots < a_n(2)\}$ of the same length by the homeomorphism of $[0, 1]$ that fixes 0 and 1, takes $a_i(1)$ to $a_i(2)$, and is linear between. These homeomorphisms are the elements of F and are precisely the piecewise linear homeomorphisms with break points at dyadic rationals and slopes powers of 2.

Exercise. [See the section "Manipulating the Elements" in this article for hints to the solution of this nontrivial exercise.] Show that the group F is generated by the two homeomorphisms $X_0, X_1 : [0, 1] \to [0, 1]$, that linearly extend $\{0 < 1/2 < 3/4 < 1\} \to \{0 < 1/4 < 1/2 < 1\}$ and $\{0 < 1/2 < 3/4 < 7/8 < 1\} \to \{0 < 1/2 < 5/8 < 3/4 < 1\}$.

If we identify the endpoints of $[0, 1]$ to form a circle S^1, then F acts on S^1. We obtain T by adding one more generating homeomorphism $Y : S^1 \to S^1$, namely, $x \mapsto x + 1/2$, modulo 1.

The third of the Thompson groups, called V, acts on S^1, contains T, and adds one final *discontinuous* generator Z that fixes the half-open interval $[0, 1/2)$ and interchanges the half-open intervals $[1/2, 3/4)$ and $[3/4, 1)$.

Exercise. In what manner do T and V manipulate trees?

Origins

Matt Brin has called Thompson's groups F, T, and V *chameleons*. The reader may be interested in some of the subjects in which Thompson's groups have arisen: logic (R. J. Thompson), solvable and unsolvable problems in group theory (R. J. Thompson and R. McKenzie), homotopy and category theory (Peter Freyd and Alex Heller), shape theory (Jerzy Dydak and Harold M. Hastings), Teichmüller theory and mapping class groups (Robert C. Penner), dynamic data storage in trees (Daniel D. Sleator, Robert E. Tarjan, and William P. Thurston).

Properties of F

The group F does not fit easily into standard categories. It is non-Abelian and torsion free and contains a free semigroup on two generators, yet it contains no non-Abelian free subgroup. It is not a matrix group. Every subgroup of F is either finite-rank free Abelian or contains an infinite-rank free Abelian subgroup.

Exercise. Find a free Abelian subgroup of F of rank 2. Then find a free Abelian subgroup of F of infinite rank.

[Think of homeomorphisms with disjoint support.]

J. W. Cannon is Orson Pratt Professor of Mathematics at Brigham Young University. His email address is `cannon@math.byu.edu`.

W. J. Floyd is professor of mathematics at Virginia Tech. His email address is `floyd@math.vt.edu`.

For the specialist only, we mention that F is not hyperbolic, is not in the Kropholler hierarchy, and may or may not be automatic.

For the general reader, we will define the notion of *amenability* and explain the most famous unsolved problem about F, first stated by Ross Geoghegan: "Is F amenable?" Amenability arises from the Hausdorff-Banach-Tarski paradox, which states that the unit ball in Euclidean 3-space can be rigidly "torn" into finitely many pieces and then reassembled to form *two* copies of the unit ball. This paradox is possible precisely *because* the group G of rigid symmetries of 3-space is nonamenable.

A group G is amenable if it carries a left-invariant, finitely additive measure of total measure one that is defined on all subsets. Such measures exist in a group G if and only if each finitely generated subgroup H satisfies the following simple geometric condition: H has arbitrarily large finite subsets with relatively small boundary. More precisely, there are arbitrarily large finite subsets X of H for which an arbitrarily small fraction of the elements $x \cdot g$, with $x \in X$ and g a generator, lie outside of X.

Exercise. Show that free Abelian groups satisfy this geometric condition. Show that free non-Abelian groups do not.

[It is known that Thompson's group F contains many of the former and none of the latter. The Hahn-Banach theorem from real analysis was first proved in order to show that Abelian groups are amenable.]

At a recent conference devoted to the group a poll was taken. *Is F amenable?* Twelve participants voted "yes" and twelve voted "no".

Manipulating the Elements of Thompson's Group F

Let $S = \{a_1 < \cdots < a_n\} \subset (0,1)$ be a tree sequence. If $a_i = x \cdot (1/2)^{k_i}$ (x odd), then we call k_i the exponent of a_i.

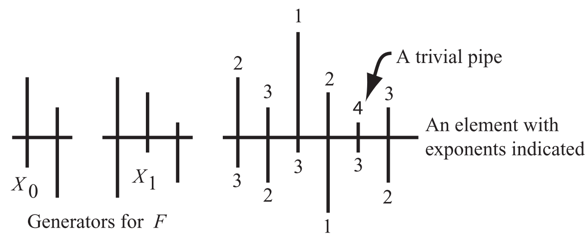
Problem. How can we tell that a sequence of exponents comes from a tree sequence?

Exercise. The sequence $\{k_1, \ldots, k_n\}$ of exponents completely determines the tree sequence.

The exercise is the basis of a geometric representation of the homeomorphism $h \in F$ transforming $S(1)$ into $S(2)$:

Let $I_1, \ldots, I_n$ denote n vertical intervals, called *pipes*, in the xy-plane, each crossing the x axis and ordered from left to right so that I_i represents the pair $(a_i(1), a_i(2))$. In the following diagram the area above the axis represents $S(1)$; the lower half represents $S(2)$. Each parent in $S(1)$ and $S(2)$ should be longer than its children.

Exercise. Relative heights determine exponents, upper and lower, and hence determine $S(1)$ and $S(2)$ and the homeomorphism h.

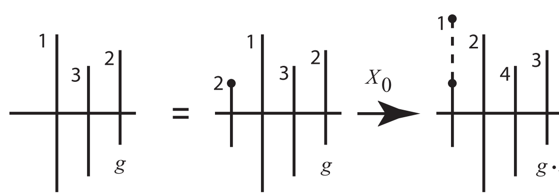


If a pipe is shorter on both ends than its nearest neighbors, then the pipe is called *trivial.*

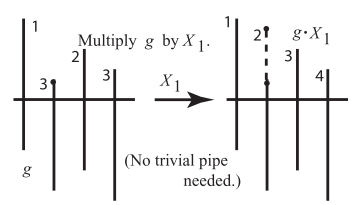
Exercise. The insertion or deletion of a trivial pipe does not change the homeomorphism (element of F) that is represented by the pipe system.

Exercise. A pipe system represents the identity homeomorphism if and only if the upper exponent sequence equals the lower exponent sequence.

A pipe system representing $g \cdot X_0^{\pm 1}$ or $g \cdot X_1^{\pm 1}$ can be formed from a pipe system for g simply by lengthening the upper portion of one pipe: the pipe of exponent 2 to the left of exponent 1 for X_0; the pipe of exponent 3 to the right of exponent 1 and to the left of exponent 2 for X_1. Before the lengthening, insert a trivial pipe in the correct position if necessary. (See the following diagrams.)



Multiply g by X_0: add a trivial pipe, and then promote that pipe to have upper exponent 1.



Problem. How should pipes be lengthened to multiply g on the left by $X_i^{\pm 1}$?

Exercise. Use these moves, their inverses, and the deletion of trivial pipes to reduce an arbitrary pipe system to the empty system (the identity).

Further Reading

See [J. W. Cannon, W. J. Floyd, and W. R. Parry: Introductory notes on Richard Thompson's groups, *L'Enseignement Mathématique*, **42** (1996), 215–256] for references. MathSciNet lists about 180 papers in which Thompson's groups play a major role. The papers of M. G. Brin, V. S. Guba, and M. V. Sapir are good sources for further references.

NORTHWESTERN
UNIVERSITY

Call for Nominations

Nemmers Prize in Mathematics

$200,000

Northwestern University invites nominations for the Frederic Esser Nemmers Prize in Mathematics to be awarded during the 2011-12 academic year. The award includes payment to the recipient of $200,000. Made possible by a generous gift to Northwestern by the late Erwin Esser Nemmers and the late Frederic Esser Nemmers, the award is given every other year.

Candidacy for the Nemmers Prize in Mathematics is open to those with careers of outstanding achievement in mathematics as demonstrated by major contributions to new knowledge or the development of significant new modes of analysis. Individuals of all nationalities and institutional affiliations are eligible except current or recent members of the Northwestern University faculty and recipients of the Nobel Prize.

The recipient of the 2012 Nemmers Prize in Mathematics will deliver a public lecture and participate in other scholarly activities at Northwestern University for 10 weeks during the 2012-13 academic year.

Nominations for the Frederic Esser Nemmers Prize in Mathematics will be accepted until December 1, 2011. Nominating letters of no more than three pages should describe the nominee's professional experience, accomplishments, and qualifications for the award. A brief *curriculum vitae* of the nominee is helpful but not required. Nominations from experts in the field are preferred to institutional nominations; direct applications will not be accepted.

Nominations may be sent to:

nemmers@northwestern.edu

or

Secretary
Selection Committee for the Nemmers Prizes
Office of the Provost
Northwestern University
633 Clark Street
Evanston, Illinois 60208-1119
U.S.A.

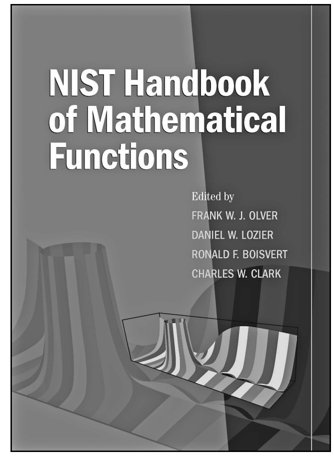
www.northwestern.edu/provost/awards/nemmers

Recipients of The Frederic Esser Nemmers Prize in Mathematics

John H. Conway
Simon Donaldson
Mikhael Gromov
Joseph B. Keller
Robert P. Langlands
Yuri I. Manin
Yakov G. Sinai
Terence Tao
Edward Witten

Handbooks of Mathematical Functions, Versions 1.0 and 2.0

Reviewed by Richard Beals



NIST Handbook of Mathematical Functions
Edited by Frank W. J. Olver, Daniel W. Lozier, Ronald F. Boisvert, and Charles W. Clark
Cambridge University Press, 2010
US$50.00, 966 pages,
ISBN: 978-05211-922-55

Who in the mathematical community uses handbooks of special functions, and why? And will the newest version make a difference?

By various objective measures, the handbook most used currently is the *Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables* [AS], universally known as "Abramowitz and Stegun" (A&S). Estimates of the number of copies sold range up to a million. Since 1997, when MathSciNet began compiling citation lists from papers reviewed in *Mathematical Reviews*, A&S has been acknowledged some 2,800 times, outdistancing other compendia by a factor of two (Gradshteyn-Ryzhik), three (Bateman Manuscript Project), five (Prudnikov-Brychkov-Marichev), and more.

So, more specifically, who has been using A&S? A check of a somewhat random list of forty analysts turned up a total of five such citations. Given the research areas and total number of publications, this turns out to be close to what one might predict. Per MSC major classification, the largest number of citations is in numerical analysis (313 as of mid-May), followed by partial differential equations (286). Fifteen classifications show one or fewer citations; manifolds and cell complexes is one of four classifications that show two citations. A more telling statistic is the ratio of papers to citations in each classification. It is no surprise that special functions leads, with about one citation per sixty books and papers. Areas in the one-in-200 to one-in-900 range include integral transforms, number theory, most of the applied mathematics areas, almost all the science classifications, dynamical systems, harmonic analysis, and differential and integral equations. (For manifolds and cell complexes the rate is about one in 12,500.)

This gives us a picture of who cites A&S. Why do they do so, apart from those who specialize in the subject of special functions? Although A&S contains material about combinatorics, which accounts for many of the number theory citations, the larger part is devoted to classical special functions. Most of these functions arose by proposing a model physical equation and separating variables in one coordinate system or another, thereby reducing the problem to a second-order ordinary differential equation such as Bessel's equation. We still often find that the simplest model of a given physical or mathematical problem leads to a classical equation and, therefore, a solution involving special functions. In ODE this includes turning points and some types of singularity. In PDE it includes problems of mixed type in aerodynamics and transport theory, hypoelliptic and degenerate elliptic problems, and weakly hyperbolic equations. An explicit solution of a model problem can point the way to an understanding of more general problems, allow for calculation of asymptotics, and so on—provided one has at hand enough information about the ingredients of the explicit solution. The list of such models continues to grow. Calculation of asymptotics also accounts for some of the usage in number theory.

Why and how might a successor to A&S be useful? Over half of the thousand pages of A&S are devoted to numerical tables (which is the reason that this writer eyed the Dover edition

Richard Beals is professor emeritus of mathematics at Yale University. His email address is `richard.beals@yale.edu`.

many times over many years before finally buying it). The ubiquity of computers and the Internet has made the tables largely obsolete. Most of the rest consists simply of lists of identities and formulas, some graphs, and some rather general references at the ends of chapters. There are competing works, but not as inexpensive, convenient, and easily available: Erdélyi et al. [EMOT] runs to three volumes, and Magnus et al. [MOS], the much more comprehensive successor to [MO], has long been out of print. But still, A&S is basically a cookbook. Some users must wonder whether and how the recipes hang together, where they come from, and how the formulas can be derived. (Such questions might even drive a late arrival to the subject to become involved in textbook writing.) There are recent textbooks and treatises, and though A&S is cited four or more times as often as any one of them, they may well be "used" more often. So, again, is a successor to the point?

A&S was the culmination of a decade-long project of the National Bureau of Standards, which has since been renamed the National Institute of Standards and Technology (NIST). A second decade–long project was undertaken under NIST auspices to update A&S. The result is a multimedia successor: the print and CD-ROM *NIST Handbook of Mathematical Functions* (NHMF) [OLBC1] and the online *Digital Library of Mathematical Functions* (DLMF) [OLBC2], edited by Frank W. J. Olver, Daniel W. Lozier, Ronald F. Boisvert, and Charles W. Clark.

It would take a genuine expert in special functions—or rather a committee of such experts—to give an adequate appraisal of this new effort. However, many of those who are most knowledgeable have been directly involved in the new production: four editors, ten associate editors, twenty-five validators, and twenty-nine authors (albeit with considerable overlap). Moreover, forty-seven members of NIST and fifty-one nonmembers are acknowledged by name as having "contributed to the project in a variety of ways." Therefore it has fallen to an amateur to discuss this production for the *Notices*.

Except for the chapters on constants and scales of notation and some of the material from the chapter on probability functions, all the nontabular content of A&S is incorporated in NHMF, generally in an expanded form. This includes the elementary functions and all the usual special functions, as well as Bernoulli and Euler polynomials and combinatorial analysis. The choice of additional material has been inspired by internal mathematical developments, by a broadening from classical analysis to related areas in algebra and number theory, and by such advances in mathematical physics as integrable models in continuum mechanics and statistical physics. There are new chapters on generalized hypergeometric functions, q–hypergeometric functions, multidimensional theta functions, Lamé functions, Heun functions, $3j$, $6j$, $9j$ symbols, Painlevé transcendents, and integrals with coalescing saddles.

The two methods chapters in A&S have been expanded to three: algebraic and analytic methods, asymptotic approximations, and numerical methods. In addition to definitions and brief summaries of standard facts from real and complex analysis, the first chapter introduces distributions and tempered distributions and gives a number of series and integral representations of the delta distribution. The second chapter is a comprehensive survey of old and new methods for asymptotics, with applications to differential and difference equations. The third chapter, on numerical methods, also contains new developments and is twice the size of the corresponding A&S chapter. The graphics are a major advance from what was feasible at the time of A&S, mostly three-dimensional views in color. (See, for example, the Bessel function graphs on pages 219–221.) Finally, the number of references is about 2,300, nearly an order of magnitude more than A&S, with much new work on asymptotics, approximations, location of zeros, and q–analysis.

All this suggests that NHMF will be a very useful replacement for A&S, with a wider audience. But, all in all, isn't it basically just another cookbook? The answer is yes, and no. Some cookbooks just have recipes, some instruct in the art of cooking, and some make your mouth water.

Consider the organization of a typical chapter. After a brief section on notation, there are sections on various functions, with subsections on definitions, graphics, representations and identities, zeros, integrals, sums, and asymptotics—very much in the spirit of A&S. Following this material is a section on applications—mathematical and physical. Sometimes brief, sometimes quite extensive, but generally very informative, these summaries indicate areas of use, with references. A section on computation contains brief discussions of methods, tables, and software, also with references. The final section contains general references for the chapter, followed by specific references, listed subsection by subsection. For each equation, either a specific reference or sketch of a derivation is given, sometimes noting corrections that need to be made in the source material.

NHMF positively invites browsing, in the methods chapters and throughout. The descriptions of applications and remarks on sources are a mine of information. Do you wonder what q-analysis is all about and where on earth it might be used? Do you want a quick view of combinatorics, Catalan numbers, Stirling numbers, and the like? Is there something you use a lot, and wonder if there is anything new to be learned about it? Are you intrigued by chapters with titles like "Integrals with

Coalescing Saddles" or "Functions with Matrix Argument"? If you have heard of—perhaps even used—Bessel functions, do you have any curiosity at all about Struwe functions and Heun functions? Do you know how the Chinese remainder theorem is used to facilitate numerical computations, or exactly how public key cryptography works? Are you surprised that a century-old topic like Painlevé transcendents has surfaced anew in a twenty-first-century handbook? Or a nearly two-century-old topic such as multidimensional theta functions? Would you like to see three-dimensional graphs of some familiar or less-familiar functions? It's all there, and more.

With a volume this large and ambitious—951 pages, double columned—it would be surprising to find nothing to second-guess, and perhaps even more surprising to find a review that does not indulge in some second-guessing … .

One of the goals of A&S was to further the standardization of notation, such as the use of M and U rather than Φ and Ψ for the Kummer functions. This remains a goal of NHMF. One innovation is particularly noted in the Mathematical Introduction: getting rid of the singularities of the hypergeometric function $F(a, b; c; x)$ by multiplying F by $1/\Gamma(c)$ to get $\mathbf{F}$:

$$\mathbf{F}(a, b; c; x) = \sum_{n=0}^{\infty} \frac{(a)_n (b)_n}{\Gamma(c+n)\, n!} x^n.$$

However, this choice is not used consistently in the relevant chapter. The sections on linear transformations and integral representations use $\mathbf{F}$, whereas those on quadratic transformations, differentiation formulas, and contiguous relations use F—even though the latter two sets of formulas simplify somewhat with $\mathbf{F}$. Similarly, in the confluent case, $\mathbf{M}(a, b, x) = M(a, b, x)/\Gamma(b)$ is introduced but not used throughout, and the companion possibility $\mathbf{U}(a, b, x) = U(a, b, x)/\Gamma(b-a)$ is overlooked entirely.

A less successful venture in A&S was to replace the conventional elliptic function indices k, k' by $m = k^2$ and $m_1 = (k')^2$, putting two chapters out of step with the rest of the world. NHMF returns to k, k' but continues to obscure the historic connection with integration of algebraic functions. The chapter on elliptic integrals systematically changes z to $\sin\phi$, while the chapter on Jacobi elliptic function begins by defining sn, cn, and dn in terms of θ functions.

The chapter on orthogonal polynomials in NHMF is much more extensive than the chapter in A&S. It now includes discrete orthogonal polynomials—not just the "classical" ones of Chebyshev, Charlier, Krawtchouk, and Meixner but all those in the Askey scheme, the additional continuous polynomials in that scheme, and all the q–versions as well. Unlike the orthogonal polynomial chapters in Erdélyi et al. [EMOT] and Magnus et al. [MO], [MOS], where the principal subdivision is by type of polynomial, the various sections here are each arranged by topic: orthogonality relations, series representations, recurrence relations, and so on. Looking for information on, say, Charlier polynomials, one starts with an index entry "*see* Hahn class …" and then has to insert C_n and various constants into schematic formulas spread over five pages. This Olympian view probably represents the way most experts see the subject, but those less expert may find it annoying. In a similar vein, some new notation is introduced to accompany some new normalizations, which are chosen so that in this version each of the classical discrete polynomials is exactly a generalized hypergeometric ${}_pF_q$. Nevertheless I found no mention of the older notations and normalizations. (A user-unfriendly approach is traditional in this area: see [Sz].)

While on the subject of notation and minor annoyances, I note that although the Mathematical Introduction to NHMF defines inf, sup, mod, and res, it does not define ph, which crops up later. It turns out that here, rather than referring to the concentration of hydrogen ions, ph replaces arg.

Quibbles aside, NHMF and the online version DLMF are a treasure for the mathematical and scientific communities, one that will be used and valued for decades. The organization, presentation, and general appearance are excellent. This beautiful book reflects credit on everyone and every organization involved: NIST; the National Science Foundation for funding; those who organized the project and obtained the funding; the advisors, editors, authors and validators; and Cambridge University Press. Above all, NHMF and DLMF are a monument to the efforts of the editor-in-chief, author of one chapter of A&S and author or coauthor of five chapters of this successor volume, Frank Olver.

A few final notes—for the history of the A&S project, see [Gr] and [BL]; for an early view of the DLMF/NHMF project, see Lozier [Lo] and for a later view [BCLO]; for two very personal viewpoints on handbooks and special functions, see Askey [As] and Wolfram [Wo]; for mathematical tables in general, see [CCFR]. And do look closely at the photograph and caption facing the title page of NHMF.

References

[AS] M. Abramowitz and I. Stegun, eds., *Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables*, Government Printing Office, Washington, D.C., 1964.

[As] R. Askey, Handbooks of special functions, in *A Century of Mathematics in America, part 3*, P. Duren, ed., American Mathematical Society, Providence, 1989, pp. 369–389.

[BCLO] R. F. Boisvert, C. F. Clark, D. W. Lozier, and F. W. J. Olver, A special functions handbook for the digital age, *Notices of the American Mathematical Society* **58**, no. 7 (2011).

[BL] R. F. Boisvert and D. W. Lozier, Handbook of mathematical functions, in *A Century of Excellence in Measurements, Standards and Technology*, D. R. Lide, ed., CRC Press, 2001, pp. 135–139.

[CCFR] M. Campbell-Kelly, M. Croarken, R. Flood, and E. Robson, *The History of Mathematical Tables: From Sumer to Spreadsheets*, Oxford University Press, 2003.

[EMOT] A. Erdélyi, W. Magnus, F. Oberhettinger, and F. G. Tricomi, *Higher transcendental functions, vol. I, II, III*, McGraw-Hill, New York, 1953.

[Gr] D. A. Grier, Irene Stegun, The "Handbook of Mathematical Functions", and the lingering influence of the new deal, *American Mathematical Monthly* **113** (2006), 585–597.

[Lo] D. Lozier, The DLMF project: A new initiative in classical special functions, in *Special Functions (Hong Kong, 1999)*, World Scientific Publishing, River Edge, NJ, 2000, 33-00.

[MO] W. Magnus and F. Oberhettinger, *Formulas and Theorems for the Special Functions of Mathematical Physics*, Chelsea, New York, 1949.

[MOS] W. Magnus, F. Oberhettinger, and R. P. Soni, *Formulas and Theorems for the Special Functions of Mathematical Physics*, Springer, New York, 1966.

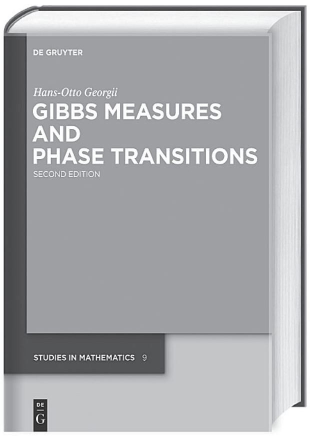
[OLBC1] F. W. Olver, D. W. Lozier, R. F. Boisvert, and C. W. Clark, *Digital Library of Mathematical Functions*, `http://dlmf.nist.gov/`.

[OLBC2] ——, *Handbook of Mathematical Functions*, Cambridge University Press, Cambridge, 2010.

[Sz] G. Szegő, *Orthogonal Polynomials*, American Mathematical Society, Providence, 1975.

[Wo] S. Wolfram, The history and future of special functions, `http://stephenwolfram.com/publications/recent/specialfunctions`.

DE GRUYTER STUDIES IN MATHEMATICS



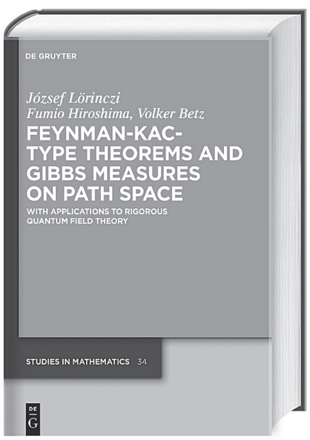
Hans-Otto Georgii

GIBBS MEASURES AND PHASE TRANSITIONS

2nd ext. ed. 2011. xiv, 542 pages. RRP € 119.95 [D]/*US$ 180.00
Hardcover ISBN 978-3-11-025029-9
eBook ISBN 978-3-11-025032-9
(De Gruyter Studies in Mathematics 9)

- Covers in depth a broad range of topics in the mathematical theory of phase transition in statistical mechanics
- Informs about the state of the art in several directions
- Accessible to a general readership of mathematicians with a basic knowledge of measure theory and probability
- Does not assume any prior knowledge of statistical mechanics

„This book is much more than an introduction to the subject of its title. It covers in depth a broad range of topics in the mathematical theory of phase transition in statistical mechanics and as an up to date reference in its chosen topics it is a work of outstanding scholarship. It is in fact one of the author‘s stated aims that this comprehensive monograph should serve both as an introductory text and as a reference for the expert.“ *Fredos Papangelou, Zentralblatt MATH*



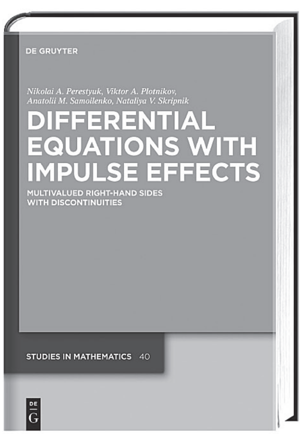
József Lörinczi, Fumio Hiroshima, Volker Betz

FEYNMAN-KAC-TYPE THEOREMS AND GIBBS MEASURES ON PATH SPACE

With Applications to Rigorous Quantum Field Theory

08/2011. Approx. x, 520 pages. RRP € 88.00 [D]/*132.00
Hardcover ISBN 978-3-11-020148-2
eBook ISBN 978-3-11-020373-8
(De Gruyter Studies in Mathematics 34)

This monograph offers a state-of-the-art mathematical account of functional integration methods in the context of self-adjoint operators and semigroups using the concepts and tools of modern stochastic analysis. These ideas are then applied principally to a rigorous treatment of some fundamental models of quantum field theory. In this self-contained presentation of the material both beginners and experts are addressed, while putting emphasis on the interdisciplinary character of the subject.



Nikolai A. Perestyuk, Viktor A. Plotnikov, Anatolii M. Samoilenko, Nataliya V. Skripnik

DIFFERENTIAL EQUATIONS WITH IMPULSE EFFECTS

Multivalued Right-hand Sides with Discontinuities

07/2011. xiv, 307 pages. RRP € 99.95 [D]/*US$ 150.00.
Hardcover ISBN 978-3-11-021816-9
eBook ISBN 978-3-11-021817-6
(De Gruyter Studies in Mathematics 40)

This monograph is devoted to the investigation of impulsive differential equations with set-valued and discontinuous right-hand sides. It is intended for researchers, lecturers, postgraduate students, and students of higher schools specialized in the field of the theory of differential equations, the theory of optimal control, and their applications.

DE GRUYTER

*for orders placed in North America. Prices are subject to change.
Prices do not include postage and handling.

www.degruyter.com

The Annotated Turing: A Guided Tour through Alan Turing's Historic Paper on Computability and the Turing Machine

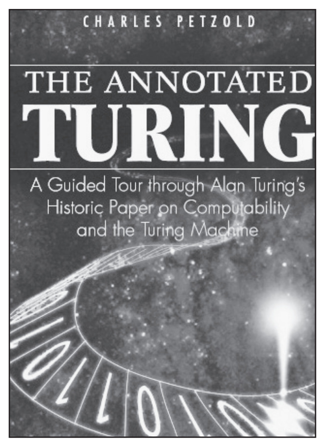
Reviewed by Richard J. Lipton

The Annotated Turing: A Guided Tour through Alan Turing's Historic Paper on Computability and the Turing Machine
Charles Petzold
Wiley Publishing, Inc., 2008
US$29.99, 384 pages
ISBN : 978-0-470-22905-7

This is a review of a "review" of the famous 1936 paper of Alan Turing. The "review" is the book by Charles Petzold entitled *The Annotated Turing: A Guided Tour through Alan Turing's Historic Paper on Computability and the Turing Machine.* I believe that Turing, with his use of diagonalization, might have liked the notion that this is a review of a review—but that is just speculation.

Turing's brilliant paper "On Computable Numbers, with Applications to the Entscheidungsproblem" created the modern notion of what it means to be computable: a number, a function—any object is considered computable if there is a machine that is able to compute it.

Turing was not the first to try to formally define the notion of computability, nor was he the last. But he undoubtedly found *the* **definition** *from the book*, to paraphrase Paul Erdős. Earlier definitions were given by Kurt Gödel, based on a suggestion of Jacques Herbrand, and another by Alonzo Church; later definitions were given by Andrey Markov and Emil Post, to name just two.



But Turing's definition, based on what we call Turing Machines (TMs) in his honor, is the right definition, the definition that is central to modern complexity. I cannot imagine the creation of the famous P=NP problem, for example, by Stephen Cook and Richard Karp without TMs. Turing's paper is truly a historic paper, as Petzold calls it.

Turing also introduced a beautiful problem, the Halting Problem. He proved that this natural problem had no solution. None. Without his definition of what is computable, it would have been impossible to prove that something cannot be computed. This happens throughout mathematics: for instance, without the notion of what it means to solve a polynomial equation by radicals, Niels Abel would have been unable to prove that the general equation of degree five is unsolvable. In a similar manner, Turing shows that there is no machine that can tell if an arbitrary other machine will halt or not, hence the name "Halting Problem".

Enter Charles Petzold, who is a famous technical writer and expert programmer. He has written an

Richard Lipton is professor and Frederick G. Storey Chair in Computing at Georgia Institute of Technology. His email address is rjl@cc.gatech.edu.

entire book of over three hundred pages on Turing's paper. Petzold's goal is nicely stated:

> Although the concept of the Turing Machine is well known, Turing's original 1936 paper is only rarely read. That's too bad, because the paper is not only a fascinating read but a milestone in the history of computing and 20th century intellectual thought in general.

I totally agree with his comment, and I would go further and argue that "rarely" is probably too weak. Nowadays the paper is almost never read.

Petzold's book is a clever mixture of background material that is needed to understand the notions used by Turing in the original paper. The obvious way to do this might have been to have an appendix with the original paper and commentary in the body of the book. But Petzold correctly surmises that few would turn to the appendix, thus defeating his whole purpose; he really wants us to *see* the Turing paper. He wants us to see Turing's paper with its old style; with its use of obsolete terminology, such as the notion "circle-free"—machines that keep printing output forever—with some long German phrases; and with typos too.

He achieves this by an interesting device: Turing's paper is "cut" into many small snippets, usually at most a few lines. These are typeset in the original fonts in gray boxes. Essentially the book is a snippet, comments by Petzold, a snippet, and so on. It reminds me a bit of Literate Programming due to Donald Knuth, only applied to a mathematical paper rather than to a program. Here is one snippet from the beginning of Turing's paper:

> According to my definition, a number is computable if its decimal can be written down by a machine.

Turing's writing is a combination. His general comments and discussion are beautiful and a pleasure to read. His discussion and explanation of the details are of necessity more concrete and sometimes a bit hard to follow. This is where Petzold's remarks are the most helpful.

One question is, Does Petzold's book solve the problem it set out to solve, getting people to read Turing? Does it really get people to read the original paper or do they tend to skip the snippets and read Petzold's commentary? I do not know. I found the snippets often to be an interruption in the flow, but others may have a different opinion.

Another question is, Does Petzold's book present the basic material of TMs and the Halting Problem in a readable manner? I believe the answer here is a resounding "yes". The background material for each snippet not only explains the next point but also supplies interesting context and history. This material is well written, as are his other books—his writing is crystal clear.

My last point concerns teaching and understanding the Halting Problem. To those who know the proof it is almost trivial. Assume there is a way to solve the Halting Problem: invoke the existence of a universal machine, add the diagonalization method of Georg Cantor, and get a contradiction. The proof is complete.

However, my experience in teaching this material over many years is that students follow the proof of the Halting Problem step by step, but many do not "get it". It could be me, but I have talked to many colleagues, and we agree that many students have trouble with this famous result. I think there are two major reasons the proof is hard for them to grasp: the proof uses "proof by contradiction" and there is something deep about the diagonalization method.

The reason I raise this point with respect to the book under review is that, for all its details, I still think the Halting Problem proof will be hard for many to follow. It has nothing to do with Petzold's writing, although perhaps the goals of seeing Turing's original paper and understanding the Halting Problem are not compatible. I wonder whether students will find the proof here easier or harder than the proofs in conventional textbooks. I just do not know.

There are several audiences for this book. For beginners this book might not be the best way to learn the basics of TMs and the Halting Problem, but such readers would nevertheless enjoy the careful and detailed commentary. Those who know this basic material will enjoy seeing Turing's paper flow by with the many comments and background material.

Why Do So Many Students Take Calculus?

Keith Stroyan

Calculus is one of the great achievements of the human intellect. It has served as the language of change in the development of scientific thought for more than three centuries. The contemporary importance of calculus includes applications in economics, psychology, and the social sciences and continues to play a key role in its traditional areas of application. Our students' interests and preparation are changing—see [B-Launch], [B-Focus], [S-Focus]—but calculus deserves a place in the curriculum of educated people in many walks of life, not only as technical preparation for careers in math and the physical sciences. Here I suggest a method to improve reasoning skills, promote teamwork, and capture the interest of a broad spectrum of college students. Student projects can engage students in realistic problems they find interesting but, more importantly, they can help students synthesize and apply the knowledge gained by working template exercises and can send a message that the subject can solve real problems.

My favorite calculus question is: Why did we eradicate polio by vaccination, but not measles? I like this question because it has real meaning and because effective use of computing can make it accessible at a beginning level. Under some reasonable assumptions [C:TLC, Ch.2], one can begin to describe the changes in the susceptible (s) and infectious (i) fractions of a large population undergoing the outbreak of a disease that confers immunity. If a person is infectious, say for eleven days, and the population is large and asynchronous, about 1/11th of the infectious recover daily. The model assumes that there is an average number of "close" contacts (c) each infectious person makes that could transfer the disease. Combining the daily contacts with the susceptible fraction gives an expression for daily new cases (contacts with immune people don't transfer the disease).

At first students use these expressions recursively to estimate the course of the disease in one-day steps, subtracting the recoveries and adding the new cases to the infectious group. Next we talk about recursively updating the model in shorter time periods and then talk about the limiting case of small time steps as a derivative. Machine computing allows us to calculate enough recursive steps to produce interesting graphs of a model epidemic lasting months. Once this is available we shift the class emphasis to trying to understand what the graphs tell us.

Students think about the measles-versus-polio problem and discover that the question boils down to a negative slope of the graph of infectious people. They need to rewrite the condition in terms of the model as "$s < 1/c$" and then compare the contact numbers "c" for different diseases ([S-Projects] and [S-D]). (A simple integral gives a "first order invariant" of the model, and this can be used

Keith Stroyan is professor of mathematics at the University of Iowa. His email address is `keith-stroyan@uiowa.edu`.

to measure the contact number c for real diseases.) When I teach calculus I have teams of students write a "lab report" or term paper describing their solution to the measles-versus-polio question beginning with a description of the model written in their own words. It is important that they recall how the model was built from simple ideas. I use a week of the course to show students how to write a technical report on a realistic problem and have a more independent project later.

Projects such as the herd immunity question allow students to think for themselves and write complete reasoned solutions. In my experience, most beginning calculus students are not ready to give technical proofs in the style of most calculus texts, but they can be encouraged to reason mathematically well beyond the level of template exercises by working on a larger problem that they find interesting. (The usual proofs most teachers know by heart are only "simple" and convincing once you understand the formulation in abstract function notation. See [Bos].) If students don't reason in some higher-level way about the material, the course tends to be reduced to template exercises and contrived "Story Problems". I believe a college course in math should move beyond this. (*The Far Side* captures the popular view of math in the "Hell's Library" cartoon in which all the books are "Story Problems".)

Most students at the University of Iowa take calculus for one semester or less (with AP credit), so I believe we should strive—in the first course—to really convince students that the subject speaks to their interests. A number of texts do this in different ways, such as [CinC], [C&M], [Smith-Moore], [Hilbert], [HarvardS and HarvardM], [Pengelley], and [Cohen], but I believe courses often fall short of showing students how calculus might affect their lives. It is easy to get sidetracked by algebra or trig skills and boil the course down to template exercises. That ends up reinforcing students' impression that math doesn't solve real problems.

Projects can have a profound impact on students because they "take intellectual ownership" of the problem. Most of my students can describe their projects a decade after they took the course. I wrote a book [S-Projects] with many projects (including some on pure math) to try to give every student something they find interesting. In these projects I try to keep the prerequisites simple, but always correct, science. I try to build on technical calculus topics developed in the course, and the assignments are timed to let students apply that new knowledge soon after it is encountered. We still have to do lots of "drill" and template exercises, but we don't stop there. My projects are less defined than some approaches that give more of a "road map". This takes more time but gives the students more responsibility. My goal for projects is to have students show themselves how calculus might affect their lives.

But using projects in a calculus course has drawbacks. Students don't write very well, and an instructor needs to help with both the math and students' explanations. I use "dual submission". The students submit a first draft that I mark up with comments and questions. They correct it and submit a final draft. I believe that process is an important part of helping them make clear arguments. It's hard work for all, but I find that it improves students' reasoning skills.

You need to give students a week or two from the shopping list of calculus topics to think about *their* problem. I reduced some of the usual topics to find the time. We followed 2,286 students in seven later courses that use calculus and found no harm in technical preparation [BYU on C:TLC page]. It has worked very well for faculty who are willing to use this method of helping students discover for themselves, "What good is it?"

I love the subject in many ways—it is hard not to admire Gauss's, "General investigations of curved surfaces" [Gauss] or the many other mathematical advances of calculus, but I believe the primary importance to most students is as a language of science—in their chosen discipline. (I include math projects for a tiny minority.) A beginning course in calculus should make this point in clear terms the students understand and develop themselves. I find that the projects of [S-Projects] or [Smith-Moore] begin to get students to use calculus to think for themselves and hope this will serve many students in their manifold careers. This is a good reason for so many students to take calculus. (See [NAA], [NS], [NNAA], [SN] for a recent contribution of basic calculus.)

References

[Bos] H. J. M. Bos, Differentials, higher-order differentials and the derivative in the Leibnizian calculus, *Archive for History of Exact Sciences* **14** (1974), no. 1, 1–90.

[B-Focus] David M. Bressoud, The changing face of calculus: First- and second-semester calculus as college courses, *MAA FOCUS*, November, 2004.

[B-Launch] ____ , *Meeting the Challenge of High School Calculus*, http://www.maa.org/columns/launchings/launchings.html.

[CinC] James Callahan, David Cox, Kenneth Hoffman, Donal O'Shea, Harriet Pollatsek, and Lester Senechal, *Calculus in Context, The Five-College Calculus Project*, W. H. Freeman & Co., New York, 1995.

[Cohen] Marcus Cohen, *Student Research Projects in Calculus*, MAA, 2009.

[C&M] William J. Davis, J. J. Uhl, and Horacio Porta, *Calculus and Mathematica*, http://www-cm.math.uiuc.edu/WhatIsCM.

[Gauss], Karl Friedrich Gauss, *General Investigations of Curved Surfaces of 1825 and 1827*, Translated with Notes and a Bibliography by James Caddall Morehead and Adam Miller Hiltebeitel, The Princeton University Library 1902, reprints available from The University of Michigan Libraries and Dover, Mineola, 2005.

[Hilbert] Stephen Hilbert, John Maceli, Eric Robinson, Diane Driscoll Schwartz, and Stan Seltzer, *Calculus, An Active Approach with Projects*, John Wiley & Sons, New York, 1994.

[Harvard S] Deborah Hughes-Hallett, William McCallum, Andrew M. Gleason, Andrew Pasquale, Daniel E. Flath, Douglas Quinney, Patti Frazer Lock, Wayne Raskind, Sheldon P. Gordon, Karen Rhea, David Lomen, Jeff Tecosky-Fledman, David Lovelock, Joe B. Trash, Brad G. Osgood, and Thomas W. Tucker, *Single Variable Calculus*, 3rd ed., John Wiley & Sons, Inc., New York, 2002.

[Harvard M] William McCallum, Deborah Hughes-Hallett, Daniel Flath, Brag G. Osgood, Andrew M. Gleason, Douglas Quinney, Sheldon P. Gordon, Wayne Raskind, Patti Frazer Lock, Jeff Tecosky-Fledman, David Mumford, and Joe B. Trash, *Multivariable Calculus*, 3rd ed., John Wiley & Sons, Inc., New York, 2002.

[NAA] J. W. Nadler, D. E. Angelaki and G. C. DeAngelis, A neural representation of depth from motion parallax in macaque visual cortex, *Nature* **452** (2008), 642–645.

[NNAA] J. W. Nadler, M. Nawrot, D. E. Angelaki, and G. C. DeAngelis, MT neurons combine visual motion with a smooth eye movement signal to code depth sign from motion parallax, *Neuron* **63** (2009), 523–532.

[NS] M. Nawrot and K. Stroyan, The motion/pursuit law for visual depth perception from motion parallax, *Vision Res.* **49** (2009), 1969–1978.

[Pengelley] Edward D. Gaughan, David J. Pengelley, Arthur Knoebel, and Douglas Kurtz, *Student Research Projects in Calculus* (Spectrum Series), MAA, 1992.

[Smith-Moore] David A. Smith and Lawrence C. Moore, *Calculus: Modeling and Application*, 2nd ed., 2010, `http://calculuscourse.maa.org/`.

[S-Focus] Keith D. Stroyan, The changing face of calculus: Engineering math at the University of Iowa, *MAA FOCUS*, February, 2006.

[S-Projects] ____ , *Projects for Calculus: The Language of Change*, `http://www.math.uiowa.edu/~stroyan/CTLC3rdEd/ProjectsCTLC/ctlcProjects.htm` (originally published by Academic Press, 1998).

[SN] Keith Stroyan and Mark Nawrot, *Visual Depth from Motion Parallax and Eye Pursuit*, submitted, 2010.

[SD] `http://demonstrations.wolfram.com/HerdImmunityForSmallpox/`.

[C:TLC] Keith Stroyan, *Calculus: The Language of Change*, `http://www.math.uiowa.edu/~stroyan/CTLC3rdEd/3rdCTLCText/ctlctoc.htm` (originally published by Academic Press, 1993 and 1998).

SCRIPTA MANENT

...written words endure

Journals in Flux

Peter J. Olver

Whither the academic journal? Publishers are scrambling to adapt to the new and rapidly evolving digital world. Libraries must balance declining resources with soaring prices and new bundled models of journal subscriptions. Meanwhile, management and investors are ever more nervous as tried-and-true economic models become obsolete. The mathematics community has reached a crossroads, requiring a full and frank discussion of the future role of journals in our profession.

The traditional published journal offered four primary benefits to the scientific community (see below for definitions): *enhancement*, *dissemination*, *archiving*, and *validation*. These formed the lure that, in the past, enabled publishers to sign on researchers to work pro bono (or even pay page charges) as authors, referees, and editors, while readers and libraries paid for material that the community freely supplied and evaluated.

By *enhancement* I mean the process of turning handwritten or, subsequently, typed manuscripts into polished, professionally typeset articles. With the ascendancy of TeX, the onus of enhancement has shifted to the author. Most journals now expect a LaTeX source file, adapted to their own peculiarities, with little or no editorial involvement. Some journals continue to copyedit papers, but they are now the exception. Thus, remarkably, publishers have managed to extend the free labor model to include most of their traditional enhancement functions.

Similarly, in the days of handwritten and typed manuscripts, *dissemination* of research to the

Peter J. Olver is professor of mathematics at the University of Minnesota, Minneapolis. His email address is `olver@math.umn.edu`.

wider community was an essential function of journals. Nowadays, preprints first appear on the `arXiv`, on university preprint servers, or on authors' personal websites, freely available to anyone with a sufficiently rapid and suitably uncensored Internet connection. In many fields, papers appear in journals, either electronic or print, as an afterthought, and those at the forefront of the subject have long since absorbed their contents. Fortunately, many publishers do allow authors to post at least the preprint versions of their works online, and authors and editorial board members should favor such journals. (And make sure to read the fine print: one publishing agreement I recently saw contains an unacceptable clause that appears to prevent authors from altering their personal or `arXiv` online version once the paper is submitted.)

Archiving of older material presents a different challenge, as many commercial publishers seek to profit from their past, limiting access to their archives to subscribers and thereby disadvantaging those without means or institutional support from being full members of the worldwide research community. Publishers may offer some level of near-term archival stability, but organizations and businesses can disappear, and previously accessible material, either paid or free, can be lost unless properly backed up by third parties. The rapid evolution and eventual obsolescence of hardware, software, and file formats compound the problem, and archivists face as yet unresolved difficulties with long-term electronic preservation of large volumes of material and prevention of data loss.

So, while enhancement, dissemination, and archiving all underlie the traditional journal system, to a large extent only validation persists as the reason for its continuation. By *validation*, I mean the confirmation of the correctness, originality, and status of a paper by its appearance in a refereed journal, which in turn helps validate its author's status insofar as hiring, promotion, grant funding, and salary rely (at least in part) on an individual's accumulated research output. But cracks in the system are starting to appear. In certain areas of applied mathematics, including computer vision, cryptography, and computer algebra, journals have been mostly superseded by prestigious conference proceedings, which are rigorously refereed and accept only a small percentage of contributions.

One increasingly contentious issue is journal ranking. While certainly not foolproof, the prestige of a journal is commonly regarded as confirmation of a paper's relative worth, especially by nonexperts. Publishers and administrators are consequently pushing citation-driven metrics such as the Impact Factor and its variants. Indeed, China now pays cash rewards for published papers, using a sliding scale based on the journal's Impact Factor [1]. But such metrics are known to be unreliable and, even worse, subject to abuse, motivating unscrupulous journal editors and publishers to artificially manipulate the Impact Factor and hence the supposed ranking of their journals [2]. While established researchers tend to have reasonably consistent estimates of journals' ratings (although this seems more true in pure than applied mathematics), those "not in the know" may easily be led astray, not to mention the administrators and bureaucrats who know nothing of the field.

Of course, while they are presumably correlated, a journal's ranking cannot unambiguously rank its individual contents, although reputation, selectivity, prestige of the editorial board, and stringency of the refereeing process do confer an implied status on the papers therein. On the other hand, too many high-profile researchers have been willing to lend their name to editorial boards without paying close attention to the journal's contents or operation; see [3] for a particularly egregious example. In 2010 the General Assembly of the International Mathematics Union (IMU) approved a document, *Best Current Practices for Journals* [4], prepared by its Committee for Electronic Information and Communication (CEIC). The document describes how well-run journals are managed through adherence to the fundamental principles of transparency, integrity, and professionalism, as well as detailing the rights and responsibilities of authors, referees, editors, and publishers.

Can the status of a paper be assessed, even without its appearance in a refereed journal? Quality evaluations in other contexts, say restaurants, might provide an answer. For a number of years, I've toyed with the idea of starting a "Michelin Guide" for math papers. Done right, with a rigorous refereeing process, this could completely supplant the validation provided by journals. Thus in one's vita one could point to having posted online, say in the `arXiv`, five one-star papers, three two-star papers, and one very rare three-star "Mathelin"-rated paper. Indeed, one can envision a variety of general-purpose guides with competing ratings, as well as specialized guides that would convey status within a particular field. The worth of each rating would depend on the reliability of the particular guide. Furthermore, unlike journals, these guides—like those for restaurants—could allow fluctuating ratings over time, as might happen when a once obscure, unrated paper suddenly provides the key to solving an important problem. Or, vice versa, a previously undetected error is found or the subject area falls out of favor. Less clear is how such a system could be practically instituted. (Michelin's original motivation was to sell more tires by encouraging car owners to drive to faraway restaurants, but eventually their guide and others became economically viable on their own merits.) *Math Reviews* was initially designed to play such a role, but most of its reviews nowadays are mere restatements of abstracts, and serious reviewing (except for the occasional book) has all but disappeared. The challenge is to devise a sound economic model for such scholarly guides, which ideally would include mechanisms for suitably compensating reviewers.

Finally, I feel compelled to say a brief word about the "dark side" of scientific publishing. I already noted journals artificially manipulating metrics such as the Impact Factor. More odious are predatory journals and conferences, which seek to profit from naïve and unscrupulous researchers through registration fees, pay-to-publish models, and the like [5]. Furthermore, the bane of plagiarism is more widespread than many of us acknowledge; see [6] for some recent cases in SIAM and my own website [7] for a personal experience that culminated in legal action and an official acknowledgment (as well as some remuneration) from the publisher. The community has been far too willing to overlook such abuses, which has only served to embolden the perpetrators. For instance, see [8] for an astonishing case of serial academic fraud in economics. Only full publicity, including naming names and, when appropriate, taking legal steps, will counter these insidious practices. Thus, while the electronic era has exacerbated older problems and created new ones such as citation-based metrics, it also provides a range of potentially powerful tools that can be employed to combat such nefarious influences on the profession.

The time is ripe for a radical rethinking of the traditional academic model for scholarly communication within mathematics. While many established researchers seem uninterested in or unwilling to fully come to terms with the rapidly shifting electronic publishing landscape, the community as a whole cannot afford to lull itself into a false sense of security. If we are not properly engaged, the future will be decided for us and, almost certainly, will not be to our liking.

Acknowledgments

The author is currently serving as chair of the CEIC and would like to thank its members and other colleagues, particularly Doug Arnold and David Mumford, for valuable input on earlier drafts. This column represents his personal views and not (except as noted) official CEIC or IMU policy.

References

[1] Shao Jufang and Huiyun Shen, The outflow of academic papers from China: Why is it happening and can it be stemmed?, *Learned Publishing* **24** (2011), 95–97. See also Phil Davis, Paying for impact: Does the Chinese model make sense? *The Scholarly Kitchen*, `http://scholarlykitchen.sspnet.org`, April 2011.

[2] Douglas N. Arnold and Kristine K. Fowler, Nefarious numbers, *Notices Amer. Math. Soc.* **58** (2011), 434–437.

[3] Retraction notice, *Applied Mathematics Letters* **24** (2011), 406.

[4] Best current practices for journals, *Notices Amer. Math. Soc.* **58** (2011), 62–65. See also `http://www.mathunion.org/fileadmin/CEIC/bestpractice/bpfinal.pdf`.

[5] Jeffrey Beall, "Predatory" open-access scholarly publishers, *The Charleston Advisor* **11**(4) (2010), 10–17.

[6] Douglas N. Arnold, Integrity under attack: The state of scholarly publishing, *SIAM News* **42**(10) (2009), 2–3.

[7] Peter J. Olver, *A case of serial plagiarism*, `http://www.math.umn.edu/~olver/plag.html`, February 2010.

[8] Ben R. Martin, Research misconduct—does self-policing work?, in *Confluence. Interdisciplinary Communications 2007/2008*, Willy Østreng, ed., Centre for Advanced Study, Oslo, 2009, pp. 59–69. See also `http://www.cas.uio.no/Publications/Seminar/Confluence_Martin.pdf`.[Smith-Moore] David A. Smith and Lawrence C. Moore, *Calculus: Modeling and Application*, 2nd ed., 2010, `http://calculus-course.maa.org/`.

[S-Focus] Keith D. Stroyan, The changing face of calculus: Engineering math at the University of Iowa, *MAA FOCUS*, February, 2006.

[S-Projects] _____ , *Projects for Calculus: The Language of Change*, `http://www.math.uiowa.edu/~stroyan/CTLC3rdEd/ProjectsCTLC/ctlcProjects.htm` (originally published by Academic Press, 1998).

[SN] Keith Stroyan and Mark Nawrot, *Visual Depth from Motion Parallax and Eye Pursuit*, submitted, 2010.

[SD] `http://demonstrations.wolfram.com/HerdImmunityForSmallpox/`.

[C:TLC] Keith Stroyan, *Calculus: The Language of Change*, `http://www.math.uiowa.edu/~stroyan/CTLC3rdEd/3rdCTLCText/ctlctoc.htm` (originally published by Academic Press, 1993 and 1998).

Mathematics Journals: What Is Valued and What May Change

Report on the Workshop Held at MSRI, Berkeley, California, February 14–16, 2011

Mathematics relies on its journal literature as the main conduit for peer review and dissemination of research, and it does so more heavily and differently than other scientific fields. The conflict between universal access and the traditional subscription model that funds the journals has been debated for the past decade, while hard data on financial sustainability and usage under the different models has been slow to appear. However, the last ten years have seen the move from print to the electronic version of journals becoming the version of record. The workshop "Mathematics Journals: What Is Valued and What May Change" took an evidence-based approach to discussing dissemination, access, and usage of mathematics journals.

The workshop goal was to discuss what is important and unique to the publishing of mathematical research articles and how we can best ensure that publishing practices support peer reviewed research in the long term. Much of the current discussion is taking place between funders and publishers, including scholarly societies, but not directly with mathematicians. A second goal was to see if we can find a consensus of opinion on what is important about journal publishing to mathematicians, that is, where the balance lies between the need for profits from publishing and the desire for broader dissemination of research.

The presentations ranged widely; written reports of the talks can be found at `http://www.msri.org/attachments/workshops/587/MSRIfinalreport.pdf`. During the first morning, John Vaughn, Sam Rankin, and Jim Crowley described the way the world works in Washington, leading us to think about the future of mathematics journals should new legislation be passed to mandate open access[1] of federally sponsored research in the USA. Interleaved with those talks was a presentation on the work of the IMU from John Ball and a talk from Jean-Pierre Bourguignon that placed journals in the broader context of the research they publish and the nature of mathematical work.

We heard talks on how mathematics journals work in practice and saw evidence of the growth of journals and the changing behavior of readers and authors. Information was provided on the balance between not-for-profit and commercial publishers, the governance of learned societies, who reads mathematics journals, and the value of the older material to current mathematics research from the citation records. An unscheduled talk by Kristine Fowler, a librarian from the University of Minnesota, gave some interesting results from a recent survey of mathematicians' views on open access. David Gabai's talk on the recent history of the *Annals of Mathematics* provided a fascinating insight into the effect of free open access on the journal's subscriptions, along with a description of the low cost of publishing the journal. Talks were presented by a variety of major mathematics publishers, ranging from the AMS and Elsevier to Project Euclid. Finally, new publishing models for changing access were presented from a variety of speakers: mathematicians, publishers, and a new university office of scholarly communication.

---

[1] *"Open access" refers to any research paper that is made freely available in published form at no cost to the reader; it does not distinguish between funded "gold" open access, where the author or research funder pays for publication, and unfunded "green" open access.*

Here is a summary of what we learned from the meeting.

Characteristics that Distinguish Mathematics Journals from Other Disciplines

- There are lots of journals in the mathematical sciences—774 listed "cover-to-cover" in the Mathematical Reviews database alone.
- They are fully international; one cannot distinguish how a journal operates according to which country it comes from. There are no boundaries to submission from overseas authors and no boundaries to the choice of country where an author may submit a paper.
- There are no speed pressures; refereeing is expected to be rigorous and detailed. The average time a paper spends between submission and acceptance is many months.
- Published articles form the building blocks of future mathematical research. A theorem, once proved, stands for all time and is cited for as long as the literature can be found. It is therefore important not to lose the building blocks.
- Evidence was shown for the longevity of mathematics papers in terms of both continued reading and citation of the oldest material.
- The community calls them referees rather than reviewers. Journals frequently rely on a single referee to provide a rigorous check of the work, plus opinions from others on the relative importance of the work.
- Data sets and other supplemental materials are rare in pure mathematics, and the paper stands on its own. This means there is no easy way to cheat in terms of the result presented, apart from direct plagiarism.
- Applied mathematics may include data and other supplemental material, but the data sets are commonly available, and it is not a part of the culture to refuse to give background data.
- Applied mathematics is distinct from applications of mathematics—both are valid, but the relevance of the work is judged on different criteria.

On the arXiv

Mathematicians recognize the value of having free access to prerefereed material, and the presence of a preprint on the arXiv (`http://arxiv.org/`) already fulfills most of the requirements laid out by the green open access lobby. In view of the long referee times, posting a paper on the arXiv first establishes primacy of the result in the few cases where this is important to mathematicians. Publishers have learned that they cannot put the genies back in the bottles and that much of "their" content is already freely available. Instead, they work to promote the final published version as the "version of record" and distinguish that from the arXiv version. Nowadays publishers encourage authors to post the early versions up to and including the final accepted version with an acknowledgement "to be published in the *Journal of X*". However, many authors fail to keep the record updated, and there are problems with referencing an arXiv preprint. This keeps the publishers happy that they still have something of value in hosting and selling the final published version in return for the costs of editing and dissemination.

For some sampled mathematics journals, as many as half the published papers have preprint versions posted on the arXiv, and the percentage is growing. This makes the arXiv by far the dominant preprint repository and the first place many mathematicians in certain areas of the discipline look for new research. It is supported by the many thousands who choose to post their preprints there; no university or publisher forces them to do so: As a result, there was no enthusiasm expressed during the workshop for alternative institutional repositories, which one speaker described as self-aggrandizing university projects. The prior assertion of copyright ownership made by some universities in order to deposit articles in their own repositories has the effect of removing the right of the author to decide where he wishes his work to be published. In contrast, the arXiv is widely and increasingly used; it is fully international, and the barriers to posting an initial preprint are very low.

A problem is that there is no long-term economic model for paying for the arXiv beyond the recent plea to major universities to support it through donations. We believe that there is an urgent need for the mathematics community to come up with a truly international solution during the next few years, and it is hoped that researchers from other subject areas, most notably theoretical physics, are also looking for a solution. The arXiv may need a fully capitalized perpetual fund to be set up; the IMU might consider what it can do to facilitate further discussion.

On the Archive

The switch to online versions as the primary source of mathematics journals has led to an interesting dilemma. Libraries would like to be the permanent repositories of the mathematical literature but have already begun to reduce their paper archives while not taking on the direct hosting of the journals they license. The publishers are now responsible for archiving and upgrading the online versions in line with demand for more functionality. The question is, what happens if the publisher folds? In the past the literature was scattered across many libraries. Nowadays publishers sign with archiving services like CLOCKSS, but this does not meet the desire for upgrades, and storing out-of-date formats has little value. This is particularly important in mathematics, where the rendering of mathematical symbols and formulas remains an issue. The recent development of MathJax is likely to help but may herald another change in format that will require publishers to charge for future developments. Libraries may need to review their long-term archiving policies.

Open Access, Green and Gold

There was general consensus at the workshop that the "gold" open access model discriminates against unfunded authors, including retired authors and those from developing countries, although research councils around the world are considering whether to fund mandated open access. The question was raised whether mathematicians should become involved in the judgment of "who pays" for those papers where the author has no funding. It would be one more burden on mathematicians to identify the deserving needy, but if they are not involved, the publishers will make their own choices. If the National Science Foundation (NSF) decides to fund a government-mandated open access policy, the money will go to those publishers who have set up charges for optional open access. For "gold" open access, there is no embargo period, and once the NSF has paid the fee, the article is immediately freely available online.

Evidence from the *Annals* experiment in green open access was stark; libraries cancelled 34 percent of the subscriptions between 2003 and 2008, when the journal was freely available online. The *Annals* is one of the best journals in mathematics and one of the cheapest, and so it came as a surprise to many at the workshop to hear that some of the best-funded libraries in the U.S. had decided to save on the subscription rather than support the experiment in widening access.

On Embargo Periods

We did not hear anyone at the workshop support the principle of green open access after a short embargo like the National Institute of Health (NIH) model—a twelve-month embargo period (i.e., a manuscript must be deposited by an author in a public access repository within twelve months of publication). Many mathematicians voluntarily post their preprints to the arXiv, and this could answer the demand, if there is any, for public access. The window between a preprint being freely available on the arXiv, then again being freely available in published form just twelve months later is generally held to be too small given the long life of articles and the slow pace of publication in mathematics. The fear is that libraries will do as they did with the *Annals* and cancel the journal subscriptions and have their readers look at the preprint version for an extra twelve months. With no subscription income and no gold open access fees, many journals will not survive.

However, there was appreciable support for mandating green open access after a period that is more appropriate to mathematics, say after five years. This was mirrored by proposals from French and German mathematicians for making the archives of all journals freely available after five years. Should mathematicians be forced to choose a model for publicly funded future research, we think it likely that they would see five years as the best alternative even if it were at the expense of the closure of the very few "reverse" moving wall experiments, such as those operated by the London Mathematical Society.

List of Invited Workshop Speakers

John Ball	Oxford and IMU
J. P. Bourguignon	IHES
David Clark	Elsevier
James Crowley	SIAM
David Gabai	Annals of Mathematics
Robert Guralnick	Transactions of the AMS
Susan Hezlet	LMS
Carol Hutchins	Courant Institute
Robion Kirby	MSP and Berkeley
Hans Koelsch	Springer
Matthias Kreck	MPI Bonn
Angus Macintyre	LMS
Paolo Mangiafico	Duke
Donald McClure	AMS
Samuel Rankin	AMS
Bernard Teissier	CNRS
John Vaughn	AAU
Mira Waller	Project Euclid
Tom Ward	University of East Anglia

Other Matters: Plagiarism, Impact Factors

There was strong criticism of the misuse of journal impact factors to evaluate individual papers, but concern was raised that it may not be possible for the IMU to provide any useful alternative index. Other concerns about the use of such metrics for quantifying journal quality have been well documented.

There was also a discussion on the apparent increase in plagiarism and in multiple submissions (where an author submits a paper to more than one journal simultaneously), along with the global rise in the number of mathematics papers being written. It was agreed that there is a need for societies/publishers to maintain standards. Tools such as CrossCheck have helped combat egregious cases, but these place an additional burden on staff and editorial boards. By comparison, the arXiv is used by some editors when checking complaints, and there was a discussion on whether its use could be extended to provide a more formal registration of papers.

Conclusions

The mathematics research community values its own standards of rigorous peer review, which it calls refereeing, and the longevity of its journals. Mathematicians want access to the old material and the certainty that it will be maintained and remain accessible regardless of the medium. They are wary of attempts to change scholarly publishing from the values of a nonscientific political world that does not understand the value and nature of the mathematical literature.

Some people would like to change the funding model for mathematics journals, arguing that they wish to provide public access to publicly funded knowledge. The arXiv already provides public access, but it suffers from having no long-term funding mechanism. We believe the most benefit to the community would come from addressing this problem and providing a permanent solution.

There is an argument for letting mathematicians decide what they want to support voluntarily rather than forcing new business models into the market. We should certainly encourage new experimental models, some of which have been very successful. Even those that are no longer free have helped apply pressure to keep the price of journals down. Through allowing mathematicians to decide which model they want to support voluntarily, one can discover sustainable long-term solutions. There may need to be some fail-safe mechanism to ensure that the past volumes of failed experimental journals are not lost to the literature.

The mathematics community has long argued against the high price of certain journals and would be happy to see a change in the funding model that reduces those profits that are not fed back into the research economy. As a result, the community is not closed to the idea of freeing up access, but it recognizes that any new model should not risk the long-term future of scholarly mathematics journals by imposing dangerously short mandated embargo periods. What the U.S. government decides to do will affect the worldwide mathematics community. It is hoped that the U.S. government does not force a model on its own researchers that may restrict the choice of where to submit a paper.

There should also be a clear division between funding research and being involved in evaluating the output of the research once funded. Paying for publication may influence the reader's judgment of the value of the research. In general, we see such schemes as unfair and a barrier to new research from unfunded mathematicians. If mandated open access were to be funded, there would be a case for no embargo period. Many publishers have already set up optional paid open access schemes to accommodate research funders who may impose a mandate. It is to be hoped that green open access that mandates open access twelve months after publication would not be imposed. Five years is considered a more appropriate period for mathematics.

Disclaimer

We have written the conclusions in the knowledge that there will never be a perfect list and certainly not all the workshop participants would support these views, which are our own. However, we believe that it is important to assert the unique value of peer review in mathematics journals and to describe what is necessary to support a healthy structure in which the very best of mathematical research can be distinguished while maintaining the breadth of mathematics journals. The many diverse journals in the mathematical sciences provide a platform for worthy research which has real value. We hope that this report may be used in future debates as fuel for the phrase "one size does not fit all".

—James Crowley, SIAM; Susan Hezlet, London Mathematical Society; Robion Kirby, University of California; Don McClure, American Mathematical Society

Mathematics People

Cahn Receives Kyoto Prize

John W. Cahn has received the 2011 Kyoto Prize from the Inamori Foundation. The prize carries a cash award of 50 million yen (approximately US$625,000). Cahn is a pioneer in materials science whose work has a significant mathematical component. He has made seminal contributions to the understanding of the thermodynamics and kinetics of phase transformation. Together with John Hilliard, Cahn developed a method to describe the process of phase separation, and the resulting Cahn-Hilliard equation has since played a key role in materials science and engineering. Cahn established a theory of three-dimensional spinodal decomposition by extending the one-dimensional theory formulated by Mats Hillert in 1961. Cahn is also well known for his discovery, along with Shechtman, Blech, and Gratias, of quasicrystals. Cahn's work has had an impact in mathematics, and he has collaborated with several mathematical scientists, notably Jean E. Taylor, with whom he investigated questions about minimal surfaces and crystals. Cahn is on the staff of the National Institute of Standards and Technology (NIST) and is an affiliate member in the physics department at the University of Washington.

—Allyn Jackson

Håstad Awarded Gödel Prize

Johan T. Håstad, Royal Institute of Technology, Stockholm, was awarded the 2011 Gödel Prize of the Association for Computing Machinery at the ACM Symposium on the Theory of Computing (STOC) held at the Federated Computing Research Conference (FCRC), June 7, 2011, in San Jose, California. The prize carries a cash award of US$5,000.

Håstad was honored for his paper "Some optimal inapproximability results", published in the *Journal of the ACM*, **48**, 798–859, 2001. The prize citation reads:

"This is a landmark paper in computational complexity, specifically, the study of approximation properties of NP-hard problems. It improves on the PCP Theorem (recognized in a previous prize in 2001) to give novel probabilistic verifiers that can check membership proofs for NP languages while reading very few bits in them—as little as 3 bits. The existence of such verifiers implies that existing approximation algorithms for several problems such as MAX-3SAT cannot be improved if P is different from NP. In other words, there is a 'threshold' approximation ratio which is possible to achieve in polynomial time, but improving upon which is NP-hard. Before this paper such 'optimal' inapproximability results seemed beyond reach. The Fourier analytic techniques introduced in this paper have been adapted in dozens of other works and are now taught in graduate courses in computational complexity. They also directly influenced subsequent work, such as the formulation of the unique games conjecture for proving further optimal inapproximability results, and lower bounds for geometric embeddings of metric spaces."

The 2011 Gödel Prize committee consists of Sanjeev Arora (Princeton University), Josep Diaz (Universitèt Politècnica de Catalunya), Cynthia Dwork (Microsoft Research), Mogens Nielsen (University of Aarhus), Mike Paterson (University of Warwick), and Eli Upfal (Brown University). The Gödel Prize for outstanding papers in the area of theoretical computer science is sponsored jointly by the European Association for Theoretical Computer Science (EATCS) and the Special Interest Group on Algorithms and Computation Theory of the Association for Computing Machinery (ACM-SIGACT). The award is presented annually, with the presentation taking place alternately at the International Colloquium on Automata, Languages, and Programming (ICALP) and the ACM Symposium on Theory of Computing (STOC). The prize is named in honor of Kurt Gödel in recognition of his major contributions to mathematical logic and of his interest, discovered in a letter he wrote to John von Neumann shortly before von Neumann's death, in what has become the famous "P versus NP" question.

—Elaine Kehoe

Shi Awarded ICTP Ramanujan Prize

YUGUANG SHI of the School of Mathematical Sciences, Peking University, has been awarded the 2010 Ramanujan Prize of the International Centre for Theoretical Physics (ICTP).

The prize recognizes Shi's "outstanding contributions to the geometry of complete (noncompact) Riemannian manifolds, specifically the positivity of quasi-local mass and rigidity of asymptotically hyperbolic manifolds." It also recognizes his substantial contributions to mathematics in China. Immediately following the award ceremony, Shi gave a presentation on "Some geometry problems related to general relativity", based on his current research interest in differential geometry and its relation to general relativity.

The Ramanujan Prize, established in 2005, is awarded annually to a young mathematician (under age forty-five) from a developing country. The prize is funded by the Norwegian Academy of Science and Letters through the Abel Fund, with the cooperation of the International Mathematical Union (IMU). The ICTP awards the prize through a selection committee in conjunction with the International Mathematical Union (IMU). The members of the committee were Ramadas Ramakrishnan (chair), Wilfrid Gangbo, Helge Holden, Gang Tian, and Marcelo Viana.

—From an Abel Prize announcement

McMullen and Wellner Receive Humboldt Research Awards

CURTIS T. MCMULLEN of Harvard University and JON A. WELLNER of the University of Washington have been awarded Humboldt Research Awards in recognition of lifetime achievements in research. The awardees are invited to carry out research projects of their own choice in cooperation with specialist colleagues in Germany.

—Elaine Kehoe

AWM Essay Contest Winners Announced

The Association for Women in Mathematics (AWM) has announced the winners of its 2011 essay contest, "Biographies of Contemporary Women in Mathematics".

The grand prize was awarded to STEPHANIE WENCLAWSKI of John F. Kennedy High School in Cedar Rapids, Iowa, for her essay "Mrs. Nan Mattai: More Than a Parking Spot". This essay won first place in the high school level category and will be published in the *AWM Newsletter*.

First place in the undergraduate level category went to JARAMI BOND of Heritage Christian Academy in Zebulon, North Carolina, for her essay "The Masterpiece". First place in the middle school level category was awarded to SOPHIA MARUSIC of Wydown Middle School in St. Louis, Missouri, for her essay "The Square Dancing Market Researcher".

—From an AWM announcement

Mathematical Sciences Awards at the 2011 ISEF

The 2011 Intel International Science and Engineering Fair (ISEF) was held May 8–13, 2011, in Los Angeles, California. More than fifteen hundred students in grades 9 through 12 from sixty-five countries, regions, and territories participated in the fair. The Society for Science and the Public, in partnership with the Intel Foundation, selects a Best in Category contestant, who receives a cash award of US$5,000. The student chosen this year was MATTHEW RUSSEL BAUERLE, a seventeen-year-old homeschooled student from Fenton, Michigan, for his project "Reformulating the Newton direction computation as a linear least squares problem for smoothed overdetermined $L1$ functionals". Bauerle also received a First Award, which carries a cash prize of US$3,000. In addition, a grant of US$1,000 was given to his school. Other award winners were the following.

First Award: ALLEN YUAN, seventeen, Detroit Country Day School, Beverly Hills, Michigan, for "Linearly many faults in (n,k)-star graphs". Second Award (US$1,500): AISHWARYA ANANDA VARDHANA, sixteen, Jesuit High School, Portland, Oregon, "A novel implementation of the elliptic curve method, stage 2: Using Weierstrass and Edwards elliptic curves for faster factorization"; MANOSIJ G. DASTIDAR, eighteen, South Point High School, Kolkata, India, "Integer partitions and sequences"; and SIMANTA GAUTAM, fifteen, Albemarle High School, Charlottesville, Virginia, "On the patterns existing among carousel primes in base n". Third Award (US$1,000): KATE A. GESCHWIND, sixteen, Mayo High School, Rochester, Minnesota, "Developing analytical approaches to forecast wind farm production, phase II"; WENYU CAO, eighteen, Phillips Academy, Andover, Massachusetts, "On the second eigenvalue and expansion of bipartite regular graphs"; AARON L. ZWEIG, fourteen, Randolph High School, Randolph, New Jersey, "Properties of Hawkins primes"; PRATHEEK NAGARAJ, seventeen, Marjory Stoneman Douglas High School, Parkland, Florida, "Method of optimizing the Monte Carlo statistical algorithm to increase computational efficiency in multidimensional integration"; ANIRUDH PRABHU, sixteen, West Lafayette Junior-Senior High School, West Lafayette, Indiana, "Lower bounds for odd perfect numbers".

—From an ISEF announcement

Royal Society of London Elections

The following mathematical scientists have been elected to the Royal Society of London: Béla Bollobás, Trinity College Cambridge and University of Memphis; Steffen Lauritzen, Oxford University; James McKernan, Massachusetts Institute of Technology; and Simon Tavaré, University of Cambridge. Elected as a foreign fellow was Mikhail Gromov, IHES.

—From a Royal Society announcement

AMS Menger Awards at the 2011 ISEF

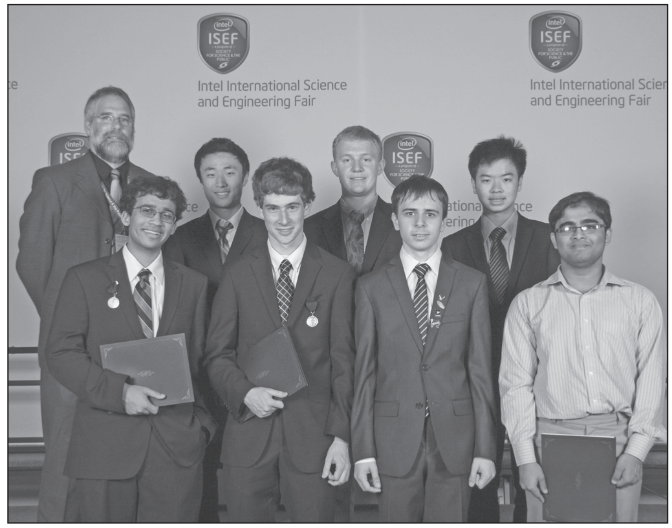
The 2011 Intel International Science and Engineering Fair (ISEF) was held May 8–13, 2011, at the Los Angeles Convention Center in Los Angeles, California. In this sixty-first year of the ISEF competition more than 1,500 students in grades nine through twelve from sixty-five countries participated in the world's largest precollege science research competition. Student finalists who compete at the ISEF go through a multi-step process to qualify and have won an all-expense-paid trip to the fair. They qualify by winning local, regional, and state fairs in the United States or national science fairs abroad. In addition to numerous grand awards presented by the ISEF, nearly seventy federal agencies and professional and educational organizations, including the American Mathematical Society (AMS), participated by giving special awards. Prizes given by the AMS included cash, certificates, AMS tote bags, and a booklet about Karl Menger given to each award winner.

For the AMS this was the twenty-third year of participation and it was the twenty-first year of the presentation of the Karl Menger Awards. The members of the 2010–2011 AMS Menger Prize Committee and AMS Special Awards Judges were Greg Fasshauer, Illinois Institute of Technology (chair); Ed Connors, University of Massachusetts; and Jonathan King, University of Florida. The panel of judges initially reviewed all sixty-one projects in mathematics as well as mathematically oriented projects in computer science, physics, and engineering. From these entries they selected a subset of students which were interviewed for further consideration for a Menger Prize. The AMS gave awards to one first-place winner, two second-place winners, four third-place winners, and honorable mentions to five others.

The Karl Menger Memorial Prize winners for 2011 are as follows:

First Place Award (US$1,000): Manosij G. Dastidar, South Point High School, Kolkata, India, "Integer Partitions and Sequences".

Second Place Awards (US$500): John Tilla Parish IV, home schooled, Colorado Springs, Colorado, "On the Verge of Where It Wasn't: A Multiple Model Approach to Estimation and Tracking Using Extended Kalman Filtering and Intelligent Selection of Integrated Models"; and



AMS Menger Awards. Back row, left to right: Greg Fasshauer (judge), Jonathan F. Li, John Tilla Parish IV, Tzu-Hsuan Su. Front (l-r): Anirudh Prabhu, Benjamin Jerome Kraft, Vasily Sergeevich Bolbachan, Manosij G. Dastidar.

Tzu-Hsuan Su, Taipei Municipal Jianguo High School, Taipei City, Chinese Taipei, "Perfect Tiling of a Rectangle into Rectangles".

Third Place Awards (US$250): Vasily Sergeevich Bolbachan, Advanced Science and Education Center—A. N. Kolmogorov School, Moscow, Moscow Region, Russia, "Rational Approximants for Euler-Gompertz Constant"; Benjamin Jerome Kraft, Liberty High School, Bethlehem, Pennsylvania, "Entries of Random Matrices"; Jonathan F. Li, St. Margaret's Episcopal School, San Juan Capistrano, California, "Effects of Cell Compressibility, Motility, and Contact Inhibition on the Growth of Tumor Cell Clusters"; Anirudh Prabhu, West Lafayette Junior-Senior High School, West Lafayette, Indiana, "Lower Bounds for Odd Perfect Numbers".

Honorable Mention Awards: Ryan Thomas Baker, Hillcrest High School, Midvale, Utah, "Modeling Wind Power Generation Using Polynomial Chaos Expansion"; Rebecca Chen, Park Tudor School, Indianapolis, Indiana, "Braid Group Representations and Braiding Quantum Gates"; Kate Alexandra Geschwind, Mayo High School, Rochester, Minnesota, "Developing Analytical Approaches to Forecast Wind Farm Production, Phase II"; Georgiy Vladimirovich Kolyshev, Stuyvesant High School, New York, New York, "Toward Solution of Soifer-Erdos Problems"; Aaron Lawrence Zweig, Randolph High School, Randolph, New Jersey, "Properties of Hawkins Primes".

Fifty-one individual students and ten two- or three-member teams from fourteen different countries competed in the mathematics category with fifty-one of the participants being male and twenty-one female. The panel of judges was impressed by the quality, breadth, and originality of the work, and the dedication and enthusiasm of the students. As indicated by the titles of the award-winning projects listed above, the student research covered a wide range of topics. Jonathan F. Li (Third Place) and Kate Alexandra Geschwind (Honorable Mention) were the only 2011 winners who also won in 2010. This year's youngest winner was Aaron Lawrence Zweig (14, Honorable Mention).

The Society for Science and the Public (`http://www.societyforscience.org/`), a nonprofit organization based in Washington, D.C., owns and has administered the ISEF since 1950. Intel became the title sponsor of ISEF in 1996. The Intel ISEF is the premiere science competition in the world and annually provides a forum for more than 1,500 high school students from sixty-five countries, regions and territories. The 2012 Intel ISEF finals will be held May 13–18 in Pittsburgh, Pennsylvania.

The AMS's participation in the Intel-ISEF is supported in part by income from the Karl Menger Fund, which was established by the family of the late Karl Menger. The income from the donation by the Menger family covers less than the amount of the awards. The balance, including the travel expenses of the judges, comes from the AMS's general fund. For more information about this program or to make contributions to this fund contact the AMS Development Office, 201 Charles Street, Providence, RI, 02904-2294 or send email to `development@ams.org`, or phone 401-455-4103.

—Greg Fasshauer,
Professor of Applied Mathematics,
Illinois Institute of Technology

Lincoln K. Durst (1924–2011)

Lincoln Kearney Durst, a former AMS executive staff member and *Notices* managing editor, died on June 2, 2011. He was eighty-six and had lived in Barrington, Rhode Island, since 1970. The cause of death was Alzheimer's disease, from which he had suffered for several years.

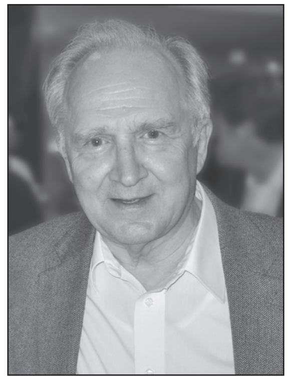
Born in Santa Monica, California, on August 5, 1924, Durst received his undergraduate degree in 1945 from the University of California at Los Angeles and his Ph.D. in mathematics in 1952 from the California Institute of Technology. His doctoral advisor was Morgan Ward, and the title of his dissertation was *Apparition and Periodicity Problems of Equianharmonic Divisibility Sequences.* Durst was on the faculty of Rice University from 1951 to 1967 and then at the Claremont Colleges from 1967 to 1970. From 1970 to 1985 he was deputy executive director of the AMS, where he was for many years the managing editor of the *Notice*s. The Society staff particularly appreciated his intelligence, kindness, and sense of humor.

The author of a calculus text, *The Grammar of Mathematics* (1969), Durst was also active in the Mathematical Association of America; in particular, in 1966 and 1967 he took leave from Rice to serve as associate director and then executive director of the MAA's Committee on the Undergraduate Program in Mathematics, which was then located in Berkeley. In addition, he participated in several summer writing sessions of the School Mathematics Study Group, the project that in the 1960s and 1970s led to the so-called "new math" educational reforms.

—Allyn Jackson

John Osborn (1936–2011)

We are very sorry to report that John Osborn, emeritus professor of mathematics at the University of Maryland, College Park, passed away on May 30, 2011, due to complications of surgery. He was an exemplary colleague, scholar, and friend.



John Osborn

John's research concerned finite element methods, with particular emphasis on eigenvalue problems. He was a leader in introducing computational methods into undergraduate mathematics courses. He also made considerable contributions to the University of Maryland in his leadership as mathematics department chair and college dean.

He leaves behind his wife Janice, three children, and eight grandchildren.

John's friends echo the sentiments in the eulogy given by Ron Lipsman: "All of you who knew John well will understand me when I say that when it came to compassion, empathy, courtesy, and grace, John was in a class by himself. All of us were truly blessed to have experienced his kindness, his loyalty, his understanding, and his love."

A memorial fund in John's name is being established in the University of Maryland Foundation.

—Ricardo H. Nochetto and Dianne O'Leary,
University of Maryland, College Park

(Photograph by Jim Yorke (`yorke@umd.edu`))

Mathematics Opportunities

American Mathematical Society Centennial Fellowships

Invitation for Applications for Awards for 2012–2013
Deadline December 1, 2011

Description: The AMS Centennial Research Fellowship Program makes awards annually to outstanding mathematicians to help further their careers in research. The number of fellowships to be awarded is small and depends on the amount of money contributed to the program. The Society supplements contributions as needed. One fellowship will be awarded for the 2012–2013 academic year. A list of previous fellowship winners can be found at `http://www.ams.org/profession/prizes-awards/ams-awards/centennial-fellow`.

Eligibility: The eligibility rules are as follows. The primary selection criterion for the Centennial Fellowship is the excellence of the candidate's research. Preference will be given to candidates who have not had extensive fellowship support in the past. Recipients may not hold the Centennial Fellowship concurrently with another research fellowship such as a Sloan or NSF Postdoctoral Fellowship. Under normal circumstances, the fellowship cannot be deferred. A recipient of the fellowship shall have held his or her doctoral degree for at least three years and not more than twelve years at the inception of the award (that is, received between September 1, 2000, and September 1, 2009). Applications will be accepted from those currently holding a tenured, tenure-track, postdoctoral, or comparable (at the discretion of the selection committee) position at an institution in North America. Applications should include a cogent plan indicating how the fellowship will be used. The plan should include travel to at least one other institution and should demonstrate that the fellowship will be used for more than reductions of teaching at the candidate's home institution. The selection committee will consider the plan in addition to the quality of the candidate's research and will try to award the fellowship to those for whom the award would make a real difference in the development of their research careers. Work in all areas of mathematics, including interdisciplinary work, is eligible.

Grant amount: The stipend for fellowships awarded for 2012–2013 is expected to be US$79,000, with an additional expense allowance of about US$7,900. Acceptance of the fellowship cannot be postponed.

Deadline: The deadline for receipt of applications is **December 1, 2011**. The award recipient will be announced in February 2012 or earlier if possible.

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

—AMS announcement

Call for Nominations for CRM-Fields-PIMS Prize

The Centre de Recherches Mathématiques (CRM), the Fields Institute, and the Pacific Institute for the Mathematical Sciences (PIMS) invite nominations for the joint CRM-Fields-PIMS prize, awarded in recognition of exceptional research achievement in the mathematical sciences. The prize recipient will be chosen on the basis of outstanding contributions to the advancement of the mathematical sciences, with excellence in research as the main selection criterion. The candidate's research should have been conducted primarily in Canada or in affiliation with a Canadian university. A monetary prize will be awarded, and the recipient will be asked to present a lecture at the CRM, the Fields Institute, and PIMS.

The deadline for nominations is **November 1, 2011**. Nominations should be submitted by at least two sponsors of recognized stature and must include the following: three supporting letters, curriculum vitae, list of publications, and up to four preprints. Nominations will remain active for two years. At most one prize will be awarded during any academic year. Submit nominations to `crm-fields-pims-prize@fields.utoronto.ca`. Only electronic submissions will be accepted.

The prize was established in 1994 as the CRM-Fields prize. Renamed in 2005, all subsequent prizes have been awarded jointly by all three institutes. The selection committee is appointed by the three institutes and will select the prizewinner.

—From a CRM-Fields-PIMS announcement

Call for Nominations for Clay Research Fellowships

The Clay Mathematics Institute (CMI) solicits nominations for its competition for the 2012 Clay Research Fellowships. Fellows are appointed for a period of one to five years. They may conduct their research at whatever institution or combination of institutions best suits their research. In addition to a generous salary, the Fellow receives support for travel, collaboration, and other research expenses.

The selection criteria are the quality of the candidate's research and promise to make contributions of the highest level. All those selected are recent Ph.D.s, and most are selected as they complete their thesis work. Selection decisions are made by CMI's Scientific Advisory Board.

To nominate a candidate, please send the following items by **October 30, 2011:** (1) letter of nomination, (2) names and contact information of two other references, (3) curriculum vitae for the nominee, and (4) publication list for the nominee. Nominations should be sent to the attention of Gigi Patel, Clay Mathematics Institute, One Bow Street, Cambridge, MA 02138. Electronic submissions are also accepted at `nominations@claymath.org`.

Information about the Clay Research Fellows is available on the CMI website at `http://www.claymath.org/research_fellows`. Additional information may be obtained by calling Gigi Patel at 617-995-2602.

Current and alumni Clay Research Fellows are Mohammed Abouzaid, Spyros Alexakis, Timothy Austin, Artur Avila, Roman Bezrukavnikov, Manjul Bhargava, Daniel Biss, Alexei Borodin, Maria Chudnovsky, Dennis Gaitsgory, Soren Galatius, Daniel Gottesman, Ben Green, Sergei Gukov, Adrian Ioana, Bo'az Klartag, Elon Lindenstrauss, Ciprian Manolescu, Davesh Maulik, Maryam Mirzakhani, Sophie Morel, Mircea Mustata, Sam Payne, Igor Rodnianski, Sucharit Sarkar, Peter Scholze, David Speyer, Terence Tao, Andras Vasy, Akshay Venkatesh, Teruyoshi Yoshida, and Xinyi Yuan.

—Clay Mathematics Institute announcement

AWM Travel Grants for Women

The National Science Foundation (NSF) and the Association for Women in Mathematics (AWM) sponsor travel grant programs for women mathematicians.

AWM Travel Grants enable women to attend research conferences in their fields, thereby providing scholars valuable opportunities to advance their research activities and their visibility in the research community. A Mathematics Travel Grant provides full or partial support for travel and subsistence for a meeting or conference in the grantee's field of specialization. The Mathematics Education Research Travel Grants provide full or partial support for travel and subsistence in math/math education research for mathematicians attending a math education research conference or for math education researchers attending a math conference.

AWM Mentoring Travel Grants are designed to help junior women develop long-term working and mentoring relationships with senior mathematicians. A mentoring travel grant funds travel, subsistence, and other expenses for an untenured woman mathematician to travel to an institute or a department to do research with a specified individual for one month.

The final deadline for the Travel Grants program for 2011 is **October 1, 2011**. The deadlines for 2012 are **February 1, 2012**; **May 1, 2012**; and **October 1, 2012**. For the Mentoring Travel Grants program the deadline is **February 1, 2012**. For further information and details on applying, see the AWM website, `http://www.awm-math.org/travelgrants.html#standard`; telephone: 703-934-0163; email: `awm@awm-math.org`; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

—From an AWM announcement

NRC-Ford Foundation Diversity Fellowships

The National Research Council (NRC) administers the Ford Foundation Diversity Fellowships program. The program seeks to promote the diversity of the nation's college and university faculties by increasing their ethnic and racial diversity, to maximize the educational benefits of diversity, and to increase the number of professors who can and will use diversity as a resource for enriching the education of all students. Predoctoral fellowships support study toward a Ph.D. or Sc.D.; dissertation fellowships offer support in the final year of writing the Ph.D. or Sc.D. thesis; postdoctoral fellowships offer one-year awards for Ph.D. recipients. Applicants must be U.S. citizens or nationals in research-based fields of study. Membership in one of the following groups will be considered a positive factor: Alaska Native (Eskimo, Aleut, or other indigenous peoples), Black/African American, Mexican American/Chicana/Chicano, Native American Indian, Native Pacific Islander (Hawaiian/Polynesian/Micronesian), or Puerto Rican.

Approximately forty predoctoral fellowships will be awarded for 2012. The awards provide three years of support and are made to individuals who, in the judgment of the review panels, have demonstrated superior academic achievement, are committed to a career in teaching and research at the college or university level, show promise of future achievement as scholars and teachers, and are well prepared to use diversity as a resource for enriching the education of all students. The annual stipend is US$20,000, with an institutional allowance of US$2,000. The deadline for applying online is **November 14, 2011.**

Approximately twenty dissertation fellowships will be awarded for 2012 and will provide one year of support for individuals working to complete a dissertation leading to a Ph.D. or D.Sc. degree. The stipend for one year is US$21,000. The deadline for applying online is **November 17, 2011.**

The postdoctoral fellowship program offers one year of postdoctoral support for individuals who have received their Ph.D.s no earlier than November 30, 2004, and no later than November 8, 2011. The stipend is US$40,000, with an employing institution allowance of US$1,500. Approximately eighteen postdoctoral fellowships will be awarded for 2012. The deadline for applying online is **November 17, 2011.**

More detailed information and applications are available at the website http://sites.nationalacademies.org/PGA/FordFellowships/index.htm. The postal address is: Fellowships Office, The National Academies, 500 Fifth Street, NW, Fifth Floor, Washington, DC 20001. The telephone number is 202-334-2872. The email address is infofell@nas.edu.

—From an NRC announcement

AIM Workshops

The American Institute of Mathematics (AIM) seeks proposals for workshops in all areas of the mathematical sciences. Proposals should include (1) a plan for the workshop, including a description of the workshop focus and goals; (2) a list of at least two and at most four organizers; (3) a list of potential participants; and (4) the mathematics subject classification and a list of references. Workshops generally last four or five days and can support up to twenty-eight participants.

Proposals for workshops may be submitted online at www.aimath.org; the deadline for submissions is **November 1, 2011.** The AIM workshop format is designed to encourage new collaborations to make plans or progress toward a research goal: there are two talks each morning of the workshop and structured group activities each afternoon, including research in small groups.

Further details and a list of upcoming workshops are available at www.aimath.org.

—AIM announcement

News from BIRS

The Banff International Research Station for Mathematical Innovation and Discovery (BIRS) is now accepting proposals for its 2013 program. The station provides an environment for creative interaction and the exchange of ideas, knowledge, and methods within the mathematical, statistical, and computing sciences and with related disciplines and industrial sectors.

Full information, guidelines, and online forms are available at the new BIRS website: http://www.birs.ca/.

BIRS is hosting a forty-eight-week scientific program in 2013. Each week the station will be running either a full workshop (forty-two people for five days) or two half-workshops (each with twenty-one people for five days). As usual, BIRS provides full accommodation, board, and research facilities at no cost to the invited participants in a setting conducive to research and collaboration.

The deadline for proposals for the five-day workshops and summer school proposals is **September 30, 2011.**

In addition, BIRS will operate its Research in Teams and Focused Research Groups programs, which allow smaller groups of researchers to get together for several weeks of uninterrupted work at the station. The preferred date to apply for these programs is **September 30, 2011.** However, proposals for projects involving Research in Teams or Focused Research Groups can be submitted at any time—subject to availability—and must be received at least four months before the requested start date.

Proposal submissions should be made using the online submission form. Please use https://www.birs.ca/proposals.

—BIRS announcement

News from the CIRM

The Centro Internazionale per la Ricerca Matematica (CIRM), in Trento, Italy, is seeking proposals for meetings and conferences, as well as applications for postdoctoral fellowships, visiting positions, and its Research in Pairs program.

Conferences: Proposals for conferences must contain (1) a scientific proposal, with names of tentative speakers; (2) a detailed financial budget of which up to 50 percent will be supported by the CIRM; (3) specification of the other available or planned financial resources. For a listing of 2011 conferences, see http://www.science.unitn.it/cirm/. The application deadline for the year 2012 is **September 15, 2011.** Application materials may be mailed to Fondazione Bruno Kessler (FBK), Centro Internazionale per la Ricerca Matematica, Via Sommarive n. 14–Povo, 38100 Trento, or sent by email to micheletti@fbk.eu.

Postdoctoral Fellowships: Two postdoctoral fellowships in mathematics (one annual and one triennial) are available for study at the CIRM in Trento, Italy. Each fellowship offers support in the amount of 23,500 euros (approximately US$33,600) per year. The deadline for applications is **September 20, 2011**. Applications should be mailed to Fondazione Bruno Kessler, Centro Internazionale per la Ricerca Matematica, Via Sommarive n. 14–Povo, 38100 Trento, Italy, or sent by email to micheletti@fbk.eu. The recipient of the triennial fellowship must submit a detailed research report at the end of each twelve-month period to be considered for renewal of the fellowship. Applications for the annual fellowship may be submitted before the official awarding of the Ph.D. or equivalent with a guarantee that the degree will be awarded before November 30th, 2011. It is expected that the results of the selection process will be announced by October 5, 2011. See the website http://cirm.fbk.eu/en/home for more details.

Visiting Positions: The CIRM is seeking applications for visiting professor and visiting scholar positions. Visiting scholars will perform mathematical research in cooperation with scientists and researchers at Trento University or the Trento area and will hold some research seminars. Visiting professors will conduct short Ph.D. courses, summer courses, or series of seminars. The visiting positions may be filled either through individual applications or by invitation. Applications must contain a specific indication of the proposed dates for the visit, usually between fifteen days and three months, and must include a plan for cooperation with researchers associated with the University of Trento. Applications should be mailed to FBK, Centro Internazionale per la Ricerca Matematica, Via

Sommarive n. 14–Povo, 38100 Trento, Italy, or sent by email to `micheletti@fbk.eu`. Applications and proposals may be sent at any time and are reviewed three times a year, so please allow sufficient time for review when submitting.

Research in Pairs: This program supports the work of two or three partners from universities in different locations who intend to work on a definite research project for a well-specified period of time ranging from one to six weeks. Applicants must submit details of a research program that will result in one or more scientific publications in journals of excellent mathematical level. Participants in the program will be free to pursue their scientific goals and will also give occasional research seminar talks at the CIRM or at the University of Trento. Applications may be mailed to FBK, Centro Internazionale per la Ricerca Matematica, Via Sommarive n. 14–Povo, 38100 Trento, Italy, or sent by email to `micheletti@fbk.eu`. Applications should include a brief description of the research proposal, a curriculum vitae for each partner, a list of publications, and possibly electronic copies of some recent articles. The dates of the intended visit must be specified. Applications should be submitted a few months before the planned stay, as decision making might require three months or more. More details about all of these programs are available at the website `http://cirm.fbk.eu/en/home`.

—Augusto Micheletti, Secretary
CIRM

Travel Grants for ICME-12, Seoul, Korea

Applications for travel grants are now available to attend the Twelfth International Congress on Mathematical Education (ICME-12), which will be held in Seoul, Korea, from July 8-15, 2012. (See `http://www.icme12.org/`). Contingent on the funding of a proposal pending at the National Science Foundation, grants will be available and awarded by the beginning of 2012. These grants will support expenses related to attending ICME-12 including hotel accommodations, meal costs, conference registration, and air transportation. The NSF grants are available only to U.S. citizens and permanent resident aliens and will support travel expenses to ICME-12 for pre-K–12 mathematics teachers, mathematicians, graduate students, and mathematics teacher educators from the United States.

The travel grant application and selection criteria are available on the NCTM website at `http://www.nctm.org/icme` or from Margaret Iding, 116 North Kedzie, Michigan State University, East Lansing, MI 48824; telephone (517) 355-1708, ext. 105; fax (517) 432-9868, email `idingm@msu.edu`. The application deadline is **September 30, 2011**. Notifications will be made by January 16, 2012. Questions can be directed to Gail Burrill, `burrill@msu.edu`.

—Gail Burrill, Michigan State University

Inside the AMS

Andrews Presents Testimony

On March 11, 2011, George Andrews of the Pennsylvania State University and past president of the American Mathematical Society testified before the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies regarding Fiscal Year 2012 appropriations for the National Science Foundation (NSF). Andrews noted the difficult budget challenges facing the Congress at this time but hailed the work of the NSF as the only federal agency that supports research and education across all fields of science, engineering, and mathematics. The text of Andrews's testimony follows.

Chairman Wolf, Ranking Member Fattah, and members of the committee, I am George Andrews, past president of the American Mathematical Society, an organization of over 30,000 professional mathematicians. I am here today to request an FY 2012 budget of $7.767 billion for the National Science Foundation (NSF). This investment will allow the NSF to continue to support innovative and transformational scientific research that fuels the American economy, upholds national security, maintains our global competitiveness, and improves health and quality of life for millions of Americans. This budget level is consistent with the Administration's FY 2012 Budget Request and with the FY 2012 budget authorized in the bipartisan America COMPETES Act (P.L. 111–358), signed into law on January 4 of this year.

I would like to thank the Committee for its past support of NSF. This support has been very important for maintaining our nation's scientific enterprise, which is critical for innovation and technological development.

I recognize that Congress faces the difficult and unenviable challenge of reducing the federal budget deficit. This task is made especially problematic in troubled economic times. I sympathize fully with how hard this is, and you have my admiration for your dedication to protecting our future. It is my hope that you will be able to wield the budget-cutting axe judiciously. The National Commission on Fiscal Responsibility and Reform made the point that, even when it is necessary to make budget cuts, "at the same time we must invest in education, infrastructure, and high value research and development to help our economy grow, keep us globally competitive, and make it easier for businesses to create jobs."

NSF is the perfect agency through which investments in education and high-value research can be made. It is the only federal agency that supports research and education across all fields of science, engineering, and mathematics and at all educational levels. Research and education programs supported by NSF are fundamental for increasing and developing the knowledge base needed for pushing the frontiers of science, mathematics, and engineering disciplines, developing new fields of inquiry, and supporting technological innovation.

Society has benefitted from the many products, procedures, and methods resulting from NSF-supported research—research performed over many years and not always predetermined toward specific applications. These benefits include well-known innovations such as Google, magnetic resonance imaging (MRI), and bar code technology. Today the NSF portfolio includes research that contributes to finding cures for certain types of cancer; aids the improvement and development of arterial stents and artificial heart valves; increases the possibility of fabricating 3-D computer memory chips; and promotes understanding of how atoms and molecules interact with surfaces, thereby aiding the development of nanoscale devices.

NSF is important to the mathematical sciences, as over 45 percent of federal funding for mathematical sciences research comes from NSF, with the remainder of support split among three other agencies. NSF accounts for 65 percent of federal support for academic research in the mathematical sciences, and it is the only agency that supports mathematics research broadly across all fields.

In FY 2010 over 70 percent of NSF's budget went to support research and education projects in colleges and universities in all fifty states. The Agency evaluated over 55,600 proposals through its merit review process, funding 13,000 of these proposals. This is a success rate of 23 percent and indicates how competitive it is to receive an NSF grant. If NSF had more funds, the Agency could support many more highly rated proposals. In fact, each year on average, over $1.7 billion is requested for declined proposals that receive ratings at least as high as the average rating for all awarded proposals. These declined proposals have the potential to produce substantial research and education results.

The U.S. must maintain its leadership in high-level research and education, and NSF is an agency that contributes substantially to this endeavor. Even under tight budget constraints, it is important to make adequate yearly investments in NSF. Dependable funding will enable the scientific community to plan, develop infrastructure, create a manageable pipeline of graduate and postdoctoral students, and have feasible expectations. A predictable pattern of funding facilitates a continuous stream of high-level research and researchers.

I ask that the Committee give strong consideration to providing an FY 2012 budget of $7.767 billion for NSF. Thank you for this opportunity to speak to you and for your support of NSF.

—AMS Washington Office

AMS Sponsors Exhibit at Capitol Hill Event

Keith Promislow of Michigan State University represented the AMS at the annual Coalition for National Science Funding (CNSF) Exhibition on Capitol Hill on May 11, 2011. Promislow presented his work on energy conversion to more than 280 attendees at this annual event showcasing research and education projects supported by the National Science Foundation.

Promislow's exhibit, titled "Efficient Energy Conversion: Mathematics of Nanoscale Network", provided information on the need to capture energy from the environment, convert it to concentrated forms, and store it for later use. He explained that a key ingredient of the devices that store this energy is the "membrane separator", which permits ions of one charge to cross, but not ions of the opposite charge. He explained that efficient energy conversion requires good membrane separators. Promislow's research has developed a model that has the possibility to revolutionize the design of membrane separators, with significant ramifications for the design of more efficient energy conversion and storage devices.

The 2011 CNSF Exhibition included thirty-five displays on a wide range of projects.

—AMS Washington Office

Homework Software Survey Report Available

The American Mathematical Society undertook an online survey of 1,230 U.S. mathematics and statistics departments in spring 2009 to assess the experiences of departments using homework software and to understand the concerns of departments that were considering such software. If you would like a copy of the Homework Survey Report, please send a request to `prof-serv@ams.org`.

—AMS Public Awareness Office

From the AMS Public Awareness Office

Feature Column

These monthly essays on mathematical topics are now searchable, and readers can browse by subject area. Recent columns, some of which use MathJax to display mathematics, include "What's normal?" by Bill Casselman, "How not to square the circle" by Tony Phillips, "Complexity" by Joe Malkevitch, and "Aligning sequence reads to assemble the genome puzzle" by David Austin. The authors aim to make the columns as self-contained as possible and hope the columns will be read by teachers, students, and the general public, as well as by mathematicians. See the most recent column and link to others at `http://www.ams.org/featurecolumn`.

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

Deaths of AMS Members

Nicolas Artemiadis, of Greece, died on October 10, 2010. Born on May 17, 1917, he was a member of the Society for 50 years.

Leon Ehrenpreis, of Brooklyn, New York, died on September 5, 2010. Born on May 22, 1930, he was a member of the Society for 60 years.

Isidore Fleischer, of New York, New York, died on March 24, 2011. Born on June 4, 1927, he was a member of the Society for 26 years.

Franklin H. Fowler, of State College, Pennsylvania, died on May 24, 2011. Born on March 8, 1917, he was a member of the Society for 71 years.

Adriano M. Garsia, professor, University of California San Diego, died on October 16, 2010. Born on August 20, 1928, he was a member of the Society for 55 years.

Stanley J. Greif, of Palm Coast, Florida, died on February 19, 2011. Born on May 5, 1926, he was a member of the Society for 55 years.

Bernard Harris, of Madison, Wisconsin, died on January 28, 2011. Born on June 20, 1926, he was a member of the Society for 47 years.

David R. Hayes, of Athol, Massachusetts, died on April 10, 2011. Born on July 14, 1937, he was a member of the Society for 50 years.

David M. Himmelblau, professor, University of Texas at Austin, died on April 27, 2011. Born on August 23, 1923, he was a member of the Society for 48 years.

Kiyoshi Iseki, of Osaka, Japan, died on March 14, 2011. Born on June 29, 1919, he was a member of the Society for 46 years.

G. Philip Johnson, of Rochester, Michigan, died on February 16, 2011. Born on November 13, 1926, he was a member of the Society for 54 years.

John B. Kelly, of Scottsdale, Arizona, died on December 27, 2010. Born on August 30, 1921, he was a member of the Society for 62 years.

Anatoly Aleksandrovich Kilbas, of Minsk, Belarus, died on June 28, 2010. Born on July 20, 1948, he was a member of the Society for 17 years.

Heinrich Kleisli, of Marly, Switzerland, died on April 5, 2011. Born on October 19, 1930, he was a member of the Society for 48 years.

John P. Line, professor, University of Michigan, died on January 5, 2011. Born on March 2, 1929, he was a member of the Society for 57 years.

William H. Marlow, of Arlington, Virginia, died on April 21, 2011. Born on November 26, 1924, he was a member of the Society for 62 years.

Edward O. Nelson, professor, University of Minnesota, died on October 26, 2010. Born on October 3, 1924, he was a member of the Society for 51 years.

Ronald J. Nunke, professor, University of Washington, died on April 3, 2011. Born on March 9, 1926, he was a member of the Society for 59 years.

John E. Osborn, professor, University of Maryland, died on May 30, 2011. Born on July 12, 1936, he was a member of the Society for 48 years.

Thomas D. Rogers, of Edmonton, Canada, died on May 16, 2011. Born on May 6, 1935, he was a member of the Society for 37 years.

Mildred L. Stancl, of New Boston, New Hampshire, died on April 16, 2011. Born on May 17, 1930, she was a member of the Society for 47 years.

Ralph G. Stanton, professor, University of Manitoba, died on April 21, 2010. Born on October 21, 1923, he was a member of the Society for 63 years.

Wilhelm F. Stoll, of Fort Wayne, Indiana, died on July 31, 2010. Born on December 22, 1923, he was a member of the Society for 52 years.

John Jerry Uhl, professor, University of Illinois, died on October 24, 2010. Born on June 27, 1940, he was a member of the Society for 45 years.

J. Ernest Wilkins, of Chicago, Illinois, died on May 1, 2011. Born on November 27, 1923, he was a member of the Society for 69 years.

Monica J. Wyzalek, of Chillicothe, Ohio, died on January 15, 2011. Born on May 3, 1934, she was a member of the Society for 53 years.

Reference and Book List

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

Contacting the *Notices*

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

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

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

Upcoming Deadlines

August 15, 2011: Nominations for Raymond J. Carroll Young Investigator Award. Nominations and supporting documents should be sent to Professor Jeff Hart, Chair, Raymond J. Carroll Young Investigator Award, Department of Statistics, Texas A&M University, 3143 TAMU, College Station, Texas 77843-3143; email: hart@stat.tamu.edu.

August 15, 2011: Nominations for SASTRA Ramanujan Prize. See http://www.math.ufl.edu/sastra-prize/nominations-2011.html.

August 19, 2011: Letters of intent for NSF Focused Research Groups. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5671.

August 24, 2011: Full proposals for REU sites. See http://www.nsf.gov/pubs/2009/nsf09598/nsf09598.htm.

August 31, 2011: Contributions to BSM study, "The Mathematical Sciences in 2025". See www.nas.edu/mathsci2025.

September 15, 2011: Nominations for Sloan Research Fellowships. See http://www.sloan.org/fellowships.

September 16, 2011: Full proposals for NSF Focused Research Groups. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5671.

September 30, 2011: Proposals for BIRS five-day workshops and summer school; preferred date for receipt of applications for BIRS Research in Teams and Focused Research Groups programs. See "Mathematics Opportunities" in this issue.

September 30, 2011: Nominations for 2011 Sacks Prize. See http://www.aslonline.org/Sacks_nominations.html.

October 1, 2011: Nominations for Emanuel and Carol Parzen Prize for Statistical Innovation. Contact Thomas Wehrly, Department of Statistics, 3143 TAMU, Texas A&M University, College Station, Texas 77843-3143.

October 1, 2011: Proposals for MSRI Hot Topic Workshops for 2012. See http://www.msri.org/msri-htw.

October 1, 2011: Proposals for MSRI Summer Graduate Schools for 2012. See http://www.msri.org/msri-sgw.

October 1, 2011: Applications for AWM Travel Grants. See "Mathematics Opportunities" in this issue.

October 15, 2011: Proposals for NSA Mathematical Sciences Grants. See http://www.nsa.gov/research/math_research/sabbaticals/index.shtml.

October 19, 2011: Proposals for NSF Postdoctoral Research Fellowships. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5301.

October 30, 2011: Nominations for Clay Research Fellowships. See "Mathematics Opportunities" in this issue.

October 30, 2011: Nominations for ICTP Ramanujan Prize. See http://prizes.ictp.it/Ramanujan/.

November 1, 2011: Nominations for CRM-Fields-PIMS Prize. See "Mathematics Opportunities" in this issue.

November 1, 2011: Proposals for AIM Workshops. See "Mathematics Opportunities" in this issue.

November 1, 2011: Applications for November review for National Academies Research Associateship Programs. See the National Academies website at http://sites.nationalacademies.org/PGA/RAP/PGA_050491 or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; email rap@nas.edu.

November 14, 2011: Applications for NRC-Ford Foundation Predoctoral Fellowships. See "Mathematics Opportunities" in this issue.

November 17, 2011: Applications for NRC-Ford Foundation Dissertation and Postdoctoral Fellowships. See "Mathematics Opportunities" in this issue.

December 1, 2011: Applications for AMS Centennial Fellowship Program. See "Mathematics Opportunities" in this issue.

December 1, 2011: Applications for PIMS postdoctoral fellowships. See http://www.pims.math.ca/scientific/postdoctoral or contact: assistant.director@pims.math.ca.

December 2, 2011: Entries for the 2012 Ferran Sunyer i Balaguer Prize. See the website http://ffsb.iec.cat.

December 21, 2011: Nominations for the Schauder Medal. Contact Lech Gorniewicz, tmna@mat.uni.torun.pl.

December 31, 2011: Nominations for Otto Neugebauer Prize for the History of Mathematics. See http://www.euro-math-soc.eu/node/995.

January 1, 2012: Proposals for MSRI Hot Topic Workshops for 2012. See http://www.msri.org/msri-htw.

January 1, 2012: Proposals for MSRI Summer Graduate Schools for 2012. See http://www.msri.org/msri-sgw.

February 1, 2012: Applications for AWM Travel Grants and Mentoring Travel Grants. See "Mathematics Opportunities" in this issue.

May 1, 2012: Applications for AWM Travel Grants. See "Mathematics Opportunities" in this issue.

October 1, 2012: Applications for AWM Travel Grants. See "Mathematics Opportunities" in this issue.

Where to Find It

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

Conference Board of the Mathematical Sciences

1529 Eighteenth Street, NW
Washington, DC 20036
202-293-1170
http://www.cbmsweb.org/

Ronald C. Rosier
Director
202-293-1170
410-730-1426 (Home)
Fax: 202-293-3412

Lisa R. Kolbe
Administrative Coordinator
202-293-1170
Fax: 202-293-3412

Member Societies:

American Mathematical Association of Two-Year Colleges (AMATYC)
American Mathematical Society (AMS)
American Statistical Association (ASA)
Association for Symbolic Logic (ASL)
Association for Women in Mathematics (AWM)
Association of Mathematics Teacher Educators (AMTE)
Association of State Supervisors of Mathematics (ASSM)

Benjamin Banneker Association (BBA)
Institute for Operations Research and the Management Sciences (INFORMS)
Institute of Mathematical Statistics (IMS)
Mathematical Association of America (MAA)
National Association of Mathematicians (NAM)
National Council of Supervisors of Mathematics (NCSM)
National Council of Teachers of Mathematics (NCTM)
Society for Industrial and Applied Mathematics (SIAM)
Society of Actuaries (SOA)
TODOS: Mathematics for ALL

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.

The Adventure of Reason: Interplay between Philosophy of Mathematics and Mathematical Logic, 1900-1940, by Paolo Mancosu. Oxford University Press, January 2011. ISBN-13: 978-01995-465-34.

Apocalypse When?: Calculating How Long the Human Race Will Survive, by Willard Wells. Springer Praxis, June 2009. ISBN-13: 978-03870-983-64.

At Home with André and Simone Weil, by Sylvie Weil. (Translation of *Chez les Weils,* translated by Benjamin Ivry.) Northwestern University Press, October 2010. ISBN-13: 978-08101-270-43. (Reviewed May 2011.)

**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. (Reviewed in this issue.)

The Autonomy of Mathematical Knowledge: Hilbert's Program Revisited, by Curtis Franks. Cambridge University Press, December 2010. ISBN-13: 978-05211-838-95.

The Best Writing on Mathematics: 2010, edited by Mircea Pitici. Princeton University Press, December 2010. ISBN-13: 978-06911-484-10.

The Big Questions: Mathematics, by Tony Crilly. Quercus, April 2011. ISBN-13: 978-18491-624-01.

The Black Swan: The Impact of the Highly Improbable, by Nassim Nicholas Taleb. Random House Trade Paperbacks, second edition, May 2010. ISBN-13: 978-08129-738-15. (First edition reviewed March 2011.)

The Calculus Diaries: How Math Can Help You Lose Weight, Win in Vegas, and Survive a Zombie Apocalypse, by Jennifer Ouellette. Penguin, reprint edition, August 2010. ISBN-13: 978-01431-173-77.

The Calculus of Selfishness, by Karl Sigmund. Princeton University Press, January 2010. ISBN-13: 978-06911-427-53.

Chasing Shadows: Mathematics, Astronomy, and the Early History of Eclipse Reckoning, by Clemency Montelle. Johns Hopkins University Press, April 2011. ISBN-13: 978-08018-969-10.

The Clockwork Universe: Isaac Newton, the Royal Society, and the Birth of the Modern World, by Edward Dolnick. Harper, February 2011. ISBN-13: 978-00617-195-16. (Reviewed April 2011.)

Complexity: A Guided Tour, by Melanie Mitchell. Oxford University Press, April 2009. ISBN-13: 978-01951-244-15. (Reviewed April 2011.)

Crafting by Concepts: Fiber Arts and Mathematics, by Sarah-Marie Belcastro and Carolyn Yackel. A K Peters/CRC Press, March 2011. ISBN-13: 978-15688-143-53.

Duel at Dawn: Heroes, Martyrs, and the Rise of Modern Mathematics, by Amir Alexander. Harvard University Press, April 2010. ISBN-13: 978-06740-466-10. (Reviewed November 2010.)

**An Early History of Recursive Functions and Computability from Gödel to Turing*, by Rod Adams. Docent Press, May 2011. ISBN-13: 978-09837-004-01.

Euler's Gem: The Polyhedron Formula and the Birth of Topology, by David S. Richeson. Princeton University Press, September 2008. ISBN-13: 978-06911-267-77. (Reviewed December 2010.)

The Evolution of Logic, by W. D. Hart. Cambridge University Press, August 2010. ISBN-13: 978-0-521-74772-1

**Flatland,* by Edwin A. Abbott, with notes and commentary by William F. Lindgren and Thomas F. Banchoff, Cambridge University Press, November 2009. ISBN-13: 978-05217-599-46.

The Grand Design, by Stephen Hawking and Leonard Mlodinow. Bantam, September 2010. ISBN-13: 978-05538-053-76.

Hidden Harmonies (The Lives and Times of the Pythagorean Theorem), by Robert and Ellen Kaplan. Bloomsbury Press, January 2011. ISBN-13: 978-15969-152-20.

**The History and Development of Nomography,* by H. A. Evesham. Docent Press, December 2010. ISBN-13: 978-14564-796-26.

Hot X: Algebra Exposed, by Danica McKellar. Hudson Street Press, August 2010. ISBN-13: 978-15946-307-05.

I Want to Be a Mathematician: A Conversation with Paul Halmos. A film by George Csicsery. Mathematical Association of America, March 2009. ISBN-13: 978-08838-590-94. (Reviewed June/July 2011.)

Le Operazioni del Calcolo Logico, by Ernst Schröder. Original German version of Operationskreis des Logikkalkuls and Italian translation with commentary and annotations by Davide Bondoni. LED Online, 2010. ISBN-13: 978-88-7916-474-0.

Logicomix: An Epic Search for Truth, by Apostolos Doxiadis and Christos Papadimitriou. Bloomsbury USA, September 2009. ISBN-13: 978-15969-145-20. (Reviewed December 2010.)

Loving + Hating Mathematics: Challenging the Myths of Mathematical Life, by Reuben Hersh and Vera John-Steiner. Princeton University Press, January 2011. ISBN-13: 978-06911-424-70.

The Math Book: From Pythagoras to the 57th Dimension, 250 Milestones in *the History of Mathematics,* by Clifford A. Pickover. Sterling, September 2009. ISBN-13: 978-14027-579-69.

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

Mathematicians Fleeing from Nazi Germany: Individual Fates and Global Impact, by Reinhard Siegmund-Schultze. Princeton University Press, July 2009. ISBN-13: 978-06911-4041-4. (Reviewed November 2010.)

Mathematics and Reality, by Mary Leng. Oxford University Press, June 2010. ISBN-13: 978-01992-807-97.

Mathematics Education for a New Era: Video Games as a Medium for Learning, by Keith Devlin. A K Peters/CRC Press, February 2011. ISBN-13: 978-1-56881-431-5.

A Motif of Mathematics: History and Application of the Mediant and the Farey Sequence, by Scott B. Guthery. Docent Press, September 2010. ISBN-13: 978-4538-105-76.

Mysteries of the Equilateral Triangle, by Brian J. McCartin. Hikari, August 2010. ISBN-13: 978-954-91999-5-6. Electronic copies available for free at `http://www.m-hikari.com/mccartin-2.pdf`.

**NIST Handbook of Mathematical Functions,* Cambridge University Press, Edited by Frank W. J. Olver, Daniel W. Lozier, Ronald F. Boisvert, and Charles W. Clark. Cambridge University Press, May 2010. ISBN-13: 978-05211-922-55 (hardback plus CD-ROM); ISBN-13: 978-05211-406-38 (paperback plus CD-ROM). (Reviewed in this issue.)

Nonsense on Stilts: How to Tell Science from Bunk, by Massimo Pigliucci. University of Chicago Press, May 2010. ISBN-13: 978-02266-678-67. (Reviewed April 2011.)

Number Freak: From 1 to 200—The Hidden Language of Numbers Revealed, by Derrick Niederman. Perigee Trade, August 2009. ISBN-10: 03995-345-98.

Numbers: A Very Short Introduction, by Peter M. Higgins. Oxford University Press, February 2011. ISBN-13: 978-0-19-958405-5.

Numbers Rule: The Vexing Mathematics of Democracy, from Plato to the Present, by George G. Szpiro. Princeton University Press, April 2010. ISBN-13: 978-06911-399-44. (Reviewed January 2011.)

Origami Inspirations, by Meenakshi Mukerji. A K Peters, September 2010. ISBN-13: 978-1568815848.

Perfect Rigor: A Genius and the Mathematical Breakthrough of the Century, by Masha Gessen. Houghton Mifflin Harcourt, November 2009. ISBN-13: 978-01510-140-64. (Reviewed January 2011.)

**The Perfect Swarm: The Science of Complexity in Everyday Life,* by Len Fisher. Basic Books, March 2011 (paperback). ISBN-13: 978-04650-202-49.

Plato's Ghost: The Modernist Transformation of Mathematics, by Jeremy Gray. Princeton University Press, September 2008. ISBN-13: 978-06911-361-03. (Reviewed February 2010.)

**The Pleasures of Statistics: The Autobiography of Frederick Mosteller.* Edited by Stephen E. Fienberg, David C. Hoaglin, and Judith M. Tanur. Springer, January 2010. ISBN-13: 978-03877-795-53.

Problem-Solving and Selected Topics in Number Theory in the Spirit of the Mathematical Olympiads, by Michael Th. Rassias. Springer, 2011. ISBN-13: 978-1-4419-0494-2.

Proofiness: The Dark Arts of Mathematical Deception, by Charles Seife. Viking, September 2010. ISBN-13: 978-06700-221-68.

Proofs from THE BOOK, by Martin Aigner and Günter Ziegler. Expanded fourth edition, Springer, October 2009. ISBN-13: 978-3-642-00855-9.

The Quants: How a New Breed of Math Whizzes Conquered Wall Street and Nearly Destroyed It, by Scott Patterson. Crown Business, January 2011. ISBN-13: 978-03074-533-89. (Reviewed May 2011.)

Recountings: Conversations with MIT Mathematicians, edited by Joel Segel. A K Peters, January 2009. ISBN-13: 978-15688-144-90.

Roads to Infinity: The Mathematics of Truth and Proof, by John C. Stillwell. A K Peters/CRC Press, July 2010. ISBN-13: 978-15688-146-67.

The Shape of Inner Space: String Theory and the Geometry of the Universe's Hidden Dimensions, by Shing-Tung Yau (with Steve Nadis). Basic Books, September 2010. ISBN-13: *978-04650-202-32.* (Reviewed February 2011.)

The Strangest Man, by Graham Farmelo. Basic Books, August 2009. ISBN-13: 978-04650-182-77.

Street-Fighting Mathematics: The Art of Educated Guessing and Opportunistic Problem Solving, by Sanjoy Mahajan. MIT Press, March 2010. ISBN-13: 978-0-262-51429-3. (Reviewed August 2011.)

Survival Guide for Outsiders: How to Protect Yourself from Politicians, Experts, and Other Insiders, by Sherman Stein. BookSurge Publishing, February 2010. ISBN-13: 978-14392-532-74.

Symmetry in Chaos: A Search for Pattern in Mathematics, Art, and Nature, by Michael Field and Martin Golubitsky. Society for Industrial and Applied Mathematics, second revised edition, May 2009. ISBN-13: 978-08987-167-26.

**The Theory That Would Not Die: How Bayes' Rule Cracked the Enigma Code, Hunted Down Russian Submarines, and Emerged Triumphant from Two Centuries of Controversy,* by Sharon Bertsch McGrayne. Yale University Press, April 2011. ISBN-13: 978-03001-696-90.

Train Your Brain: A Year's Worth of Puzzles, by George Grätzer. A K Peters/CRC Press, April 2011. ISBN-13: 978-15688-171-01.

**Visual Thinking in Mathematics,* by Marcus Giaquinto. Oxford University Press, July 2011. ISBN-13: 978-01995-755-34.

What's Luck Got to Do with It? The History, Mathematics and Psychology of the Gambler's Illusion, by Joseph Mazur. Princeton University Press, July 2010. ISBN-13: 978-069-113890-9.

Why Beliefs Matter: Reflections on the Nature of Science, by E. Brian Davies. Oxford University Press, June 2010. ISBN-13: 978-01995-862-02.

SPECIAL SECTION

2011 American Mathematical Society Election

CONTENTS

2011 AMS Elections

Special Section

List of Candidates–2011 Election

President
(one to be elected)

John M. Guckenheimer
David A. Vogan, Jr.

Vice President
(one to be elected)

Andrew Odlyzko
A. G. (Loek) Helminck

Trustee
(one to be elected)

Ruth Charney
Nassif Ghoussoub

Member at Large of the Council
(five to be elected)

Dan Abramovich
Rodrigo Bañuelos
Hélène Barcelo
Arthur Benjamin
James Carlson
Lloyd Douglas
Robert McCann
Vicki Powers
Bruce Sagan
Ileana Streinu

Nominating Committee
(three to be elected)

Steven Bell
Fred Cohen
Susan Friedlander
Fan Chung Graham
John C. Meakin
Steven Smith

Editorial Boards Committee
(two to be elected)

Ralph Greenberg
Jonathan Hall
David Hoff
Dana Randall

Ballots

AMS members will receive email with instructions for voting online by August 22, or a paper ballot by September 15. If you do not receive this information by that date, please contact the AMS (preferably before October 1) to request a ballot. Send email to `ballot@ams.org` or call the AMS at 800-321-4267 (within the U.S. or Canada) or 401-455-4000 (worldwide) and ask to speak with Member Services. The deadline for receipt of ballots is November 4, 2011.

Write-in Votes

It is suggested that names for write-in votes be given in exactly the form that the name occurs in the *Combined Membership List* (`www.ams.org/cml`). Otherwise the identity of the individual for whom the vote is cast may be in doubt and the vote may not be properly credited.

Replacement Ballots

For a paper ballot, the following replacement procedure has been devised: A member who has not received a ballot by September 15, 2011, or who has received a ballot but has accidentally spoiled it, may write to `ballot@ams.org` or Secretary of the AMS, 201 Charles Street, Providence, RI 02904-2294, USA, asking for a second ballot. The request should include the individual's member code and the address to which the replacement ballot should be sent. Immediately upon receipt of the request in the Providence office, a second ballot, which will be indistinguishable from the original, will be sent by first class or airmail. Although a second ballot will be supplied on request and will be sent by first class or airmail, the deadline for receipt of ballots cannot be extended to accommodate these special cases.

Biographies of Candidates

The next several pages contain biographical information about all candidates. All candidates were given the opportunity to provide a statement of not more than 200 words to appear at the end of their biographical information.

Description of Offices

The **president** of the Society serves one year as president elect, two years as president, and one year as immediate past president. The president strongly influences, either directly or indirectly, most of the scientific policies of the Society. A direct effect comes through the president's personal interactions with both members of the Society and with outside organizations. In addition, the president sits as member of all five policy committees (Education, Meetings and Conferences, Profession, Publications, and Science Policy), is the chair of the Council's Executive Committee, and serves ex officio as a trustee. Indirect influence occurs as the president appoints chairs and members of almost all committees of the Society, including the policy committees. The president works closely with all officers and administrators of the Society, especially the executive director and the secretary. Finally, the president nominates candidates for the Nominating Committee and the Editorial Boards Committee. Consequently, the president also has a long-term effect on Society affairs.

The **vice president** and the **members at large of the AMS Council** serve for three years on the Council. That body determines all scientific policy of the Society, creates and oversees numerous committees, appoints the treasurers and members of the Secretariat, makes nominations of candidates for future elections, and determines the chief editors of several key editorial boards. Typically, each of these new members of the Council also will serve on one of the Society's five policy committees.

The **Board of Trustees**, of whom you will be electing one member for a five-year term, has complete fiduciary responsibility for the Society. Among other activities, the trustees determine the annual budget of the Society, prices of journals, salaries of employees, dues (in cooperation with the Council), registration fees for meetings, and investment policy for the Society's reserves. The person you select will serve as chair of the Board of Trustees during the fourth year of the term.

The candidates for vice president, members at large, and trustee were suggested to the Council either by the Nominating Committee or by petition from members. While the Council has the final nominating responsibility, the groundwork is laid by the **Nominating Committee**. The candidates for election to the Nominating Committee were nominated by the current president, Eric M. Friedlander. The three elected will serve three-year terms. The main work of the Nominating Committee takes place during the annual meeting of the Society, during which it has four sessions of face-to-face meetings, each lasting about three hours. The Committee then reports its suggestions to the spring Council, which makes the final nominations.

The **Editorial Boards Committee** is responsible for the staffing of the editorial boards of the Society. Members are elected for three-year terms from a list of candidates named by the president. The Editorial Boards Committee makes recommendations for almost all editorial boards of the Society. Managing editors of *Journal of the AMS*, *Mathematics of Computation*, *Proceedings of the AMS*, and *Transactions of the AMS*; and Chairs of the *Collqouium*, *Mathematical Surveys and Monographs*, and *Mathematical Reviews* editorial committees are officially appointed by the Council upon recommendation by the Editorial Boards Committee. In virtually all other cases, the editors are appointed by the president, again upon recommendation by the Editorial Boards Committee.

Elections to the **Nominating Committee** and the **Editorial Boards Committee** are conducted by the method of approval voting. In the approval voting method, you can vote for as many or as few of the candidates as you wish. The candidates with the greatest number of the votes win the election.

A Note from AMS Secretary Robert J. Daverman

The choices you make in these elections directly affect the direction the Society takes. If the past election serves as a reliable measure, about 13 percent of you will vote in the coming election, which is comparable with voter participation in other professional organizations which allow an online voting option. This is not mentioned as encouragement for you to throw the ballot in the trash; instead, the other officers and Council members join me in urging you to take a few minutes to review the election material, fill out your ballot, and submit it. The Society belongs to its members. You can influence the policy and direction it takes by voting.

Also, let me urge you to consider other ways of participating in Society activities. The Nominating Committee, the Editorial Boards Committee, and the Committee on Committees are always interested in learning of members who are willing to serve the Society in various capacities. Names are always welcome, particularly when accompanied by a few words detailing the person's background and interests. Self-nominations are probably the most useful. Recommendations can be transmitted through an online form (`www.ams.org/committee-nominate`) or sent directly to the secretary (`secretary@ams.org`) or Office of the Secretary, American Mathematical Society, 237Ayres Hall, University of Tennessee, 1403 Circle Drive, Knoxville, TN 37996-1320.

PLEASE VOTE.

A Proposal for a Fellows Program of the AMS

The January 2011 Council directed that the following proposal be presented to the membership in 2011 for their vote to support or oppose an AMS Fellows Program. The Council further directed that the ballot be accompanied by this statement: "If more than 1/2 of the members voting on this issue are in favor, then the AMS will implement the program."

Information about the history of the AMS Fellows Proposals can be found at
`www.ams.org/about-us/governance/elections/fellows-info`

The Fellows program is created and updated by the Council of the AMS. The program below describes in general terms what a new Fellows program will look like. If approved, some details of the program may be changed by the AMS Council prior to implementation in order to address practical needs. Future Councils can make further changes, keeping in mind the intent of the membership in approving the initial program.

The goals of the Fellows Program are:

- To create an enlarged class of mathematicians recognized by their peers as distinguished for their contributions to the profession.

- To honor not only the extraordinary but also the excellent.
- To lift the morale of the profession by providing an honor more accessible than those currently available.
- To make mathematicians more competitive for awards, promotion, and honors when they are being compared with colleagues from other disciplines.
- To support the advancement of more mathematicians in leadership positions in their own institutions and in the broader society.

I. Program (steady-state)

A. The Fellows program of the American Mathematical Society recognizes members who have made outstanding contributions to the creation, exposition, advancement, communication, and utilization of mathematics.

B. The responsibilities of Fellows are:

- To take part in the election of new Fellows,
- To present a "public face" of excellence in mathematics, and
- To advise the President and/or the Council on *public matters* when requested.

C. The target number of Fellows will be determined by the AMS Council as a percentage of the number of members.[1] The target percentage will be revisited by the Council at least once every ten years and may be increased or decreased in light of the history of the nomination and selection process. The intended size of each year's class of new Fellows should be set with this target size in mind.

D. Following a selection process (see below), individuals are invited to become Fellows. They may decline and they may also resign as Fellows at any time.

E. Fellows receive a certificate and their names are listed on the AMS website. The names of new Fellows are also included in the *Notices* each year.

F. If they are not already Fellows, the AMS President and Secretary are made Fellows when they take office.

II. Initial Implementation

A. In the initial year of the program, all eligible AMS members during both the years 2010 and 2011 as of January 1, 2012 and who have done one or more of the following will be invited to become AMS Fellows.[2]

1. Given an invited AMS address (including at joint meetings).[3]
2. Been awarded an AMS research prize.[4]
3. Given an invited address at an International Congress of Mathematicians (ICM) or an International Congress of Industrial and Applied Mathematicians (ICIAM).[3]

B. An additional 50 members who are AMS members during both the years 2010 and 2011 as of January 1, 2012, will be selected to become AMS Fellows. These will be chosen by a committee appointed by the President with the advice of the Executive Committee of the Council. Attention will be paid to selecting AMS members recognized for their contributions beyond research.

III. Selection Process

A. New Fellows are selected each year after a nomination process. The nomination process is carried out under the direction of the Secretary with help from the AMS staff. The procedures for nominating AMS Fellows will be available on the AMS website.

B. The Selection Committee will consist of twelve members of the AMS who are also Fellows, each serving a three-year term, and with four new members appointed each year. The AMS president, in consultation with the Executive Committee of the Council, nominates the new members of the Selection Committee in November of each year. At the same time, the President nominates a continuing member of the Selection Committee to serve as Chair.

C. The Selection Committee accepts nominations for Fellows between February 1 and March 31 each year. Nominations are made by members of the AMS. A member can nominate no more than 2 nominees a year.

D. To be eligible for nomination to Fellowship, an individual must be an AMS member for the year in which he or she is nominated as well as for the prior year.

E. A nominator must supply a package with the following information on the nominee:

1. A Curriculum Vitae *of no more than five pages.*
2. A citation of fifty words or less explaining the person's accomplishments.
3. A statement of cause of 500 words or less explaining why the individual meets the criteria of Fellowship.
4. The signatures of the nominator and three additional AMS members who support the nomination, with at least two of these individuals current Fellows.

F. Any person who is nominated and is not selected a Fellow will remain an active nominee to be considered by the Selection Committee for possible selection for a further 2 years.

G. Each year the January Council provides a guideline for the number of Fellows to be selected.[5] The Selection Committee chooses Fellows from the nominations bearing in mind this guideline, diversity of every kind, and the quality and quantity of the external nominations. The Selection Committee has the discretion to make nominations to fulfill the general goals of the fellowship.

[1] *This proposal's recommendation to Council is 5% of members. At present there are about 30,000 members so the number of Fellows would be about 1,500.*

[2] *The seeding process described in II.A would produce offers of Fellows status to more than 800 current AMS members.*

[3] *An invited address is one given at the invitation of the program committee and delivered before January 1, 2012.*

[4] *These are the Birkhoff, Bôcher, Cole, Conant, Doob, Eisenbud, Fulkerson, Moore, Robbins, Satter, Steele, Veblen, Whiteman, and Weiner prizes. These prizes must have been awarded before January 1, 2012.*

[5] *It is anticipated that during a transition period of approximately 10 years about 75 new Fellows will be appointed each year. In the steady state of 1500, it is anticipated that about 40 new Fellows positions will occur annually due to attrition.*

H. Those members who are chosen by the Selection Committee are invited by the President to become new Fellows of the AMS.

Frequently Asked Questions about the AMS Fellows Proposal

Q. *How was the AMS Fellows program proposal developed?*

A. Over the past decade various committees and subcommittees of the AMS have discussed the possibility of instituting an AMS Fellows Program, partly influenced by the existence of such programs in a number of other scientific societies. In 2003 an ad hoc committee on Fellows gave a report to the Council in which arguments were presented for and against the concept. Because it is hard to judge a program in the abstract, a smaller committee was appointed with the charge to formulate a specific proposal. This committee included the Council members John Franks, Susan Friedlander (Chair) and Sheldon Katz. After months of analysis of earlier committee reports, discussions with many AMS members, comparative research into other Fellows programs, and deliberation of what kind of program might suit the AMS, the committee reported back to the Council in 2006 with a specific proposal.

The Council, after strenuous debate, voted to put the proposal on the 2006 AMS ballot. The members could vote for or against the proposal with the information that if two-thirds of the vote was in favor, the program would be implemented. The vote in 2006 was 63.2% in favor.

The proposal brought to the membership in 2008 was a modified version of the 2006 proposal. It took into account certain issues raised by members and also benefitted from feedback between the AMS proposal and a proposal for SIAM Fellows that has since been implemented.

In 2011, the AMS Council voted almost unanimously (with one negative vote) to place the latest proposal on the 2011 AMS ballot; the overwhelming sentiment of the Council was to support this proposal.

Q. *Is excellence in research the only criterion for being a Fellow?*

A. Research excellence is not the sole criterion envisioned for selection of AMS Fellows. The Fellows program could recognize excellence in educational activities and "diversity of every kind".

Q. *What are the goals of the Fellows program?*

A. The goals are:

- To create an enlarged class of mathematicians recognized by their peers as distinguished for their contributions to the profession.
- To honor not only the extraordinary but also the excellent.
- To lift the morale of the profession by providing an honor more accessible than those currently available.
- To make mathematicians more competitive for awards, promotion, and honors when they are being compared with colleagues from other disciplines.
- To support the advancement of more mathematicians in leadership positions in their own institutions and in the broader society.

Q. *What are arguments in favor of a Fellows program?*

A. Here are some of the arguments in favor:

1. The celebration of newly created Fellows of the AMS would bring positive publicity to mathematics and to excellent mathematicians.
2. The proposed initial procedure and the relatively large number of AMS Fellows envisaged for the program would enable a more diverse group of mathematicians to be recognized.
3. Mathematics has been somewhat reluctant to recognize excellence in its midst, other than truly exceptional achievement. The Fellows Programs will enable broader recognition of mathematicians.
4. AMS Fellows individually and departments associated with AMS Fellows would be given an external recognition which could bring additional resources to mathematics.
5. The AMS Fellows Program should raise the visibility of the AMS within the mathematics community and could increase the sense of connectivity of mathematicians with the AMS.
6. SIAM has instituted a fellows program very similar to that of the proposed AMS Fellows Progam with almost no negative reaction or response.

Q. *What are arguments against a Fellows program?*

A. Here are some of the arguments against:

1. An AMS Fellows Program could be viewed as not consistent with the tradition of egalitarianism.
2. Fellows are likely to be those people who already have been recognized in other ways.
3. Mathematicians named AMS Fellows and their departments are already sufficiently distinguished that the selection of AMS Fellows will lack importance.
4. Any selection process will necessarily be somewhat political and could be divisive.
5. Some not chosen to be Fellows may feel a weaker connection to the AMS.

Q. *Where can I find more detailed discussions?*

A. Pro and con articles concerning an AMS Fellows program appeared in the AMS *Notices* in advance of the 2006 vote (Vol 53, Aug 2006, pp. 754–756, also found at `http://www.ams.org/notices/200607/fea-fellows.pdf`.)

Q. *Do other societies in the mathematical sciences have Fellows programs?*

A. Yes. For example, the American Statistical Association, Association for Computing Machinery, INFORMS and the Society for Industrial and Applied Mathematics all have Fellows programs.

Q. How does the proposed AMS program compare to the size of the programs of other societies?

A. In its steady state the proposed AMS Fellowship would be approximately 5% of the total membership (i.e., about 1,500 Fellows out of about 30,000 members). In some other societies surveyed the Fellowship varies between about 5% and about 13%.

In its steady state it is expected that the number of new Fellows elected each year will be approximately 0.2% of the membership. Each year, the American Physical Society elects no more than 0.5 % of all members and the American Statistical Association elects no more than 0.33% of all members.

Q. How will the AMS Fellowship be started and how will new Fellows be elected?

A. This is spelled out in detail in the proposal itself.

Q. How many Fellows will there be in the "seed pool" and how will the steady state be achieved?

A. The seed process is expected to generate approximately 1,000 Fellows in January 2012. In future years, guidelines for the number of new Fellows would be set by the AMS Council with an expectation of 75 new Fellows appointed in each year of the first decade of the program. See the proposal for further detail.

Q. Why is there a start-up procedure?

A. There are several reasons for starting the program with a well defined set of criteria for selecting an initial set of Fellows.

- If the program is worth having then it should be up and running from the start with a substantial number of Fellows, so that it is a healthy program.
- A well specified algorithm is required to avoid an otherwise massive task of individual evaluation of the initial set of Fellows. The algorithm should be clear in advance to avoid questions after the fact regarding who was selected and why.

Q. How will the Fellows program be changed in the future?

A. The current proposal for the Fellows program was created by the Council, and it can be modified by the Council in the future. The details of administering the program may be changed in the future to address practical needs, even as the program is initially implemented.

Q. How can I find out more about the Fellows program?

A. Updated information will appear at

http://www.ams.org/secretary/fellows-info.

That site will also contain a form to ask questions about the program.

Nominations for President

Nomination of John Guckenheimer

Martin Golubitsky

When I was approached to write an article for the *Notices* in support of John Guckenheimer's candidacy for president of the American Mathematical Society, I had two initial reactions. First, I was reminded of John's extraordinary breadth in both research and policy making, and how he has so often managed to translate his ideas into actions. Second, I was slightly surprised since John had been president of SIAM and to my knowledge no one has ever been given the opportunity to serve as president of both AMS and SIAM. Since the AMS Nominating Committee knew of John's SIAM connection, I focused on why that committee had asked John to run for the AMS presidency. On reflection, I believe that the committee has made a really inspired choice.

Presidents of professional societies help steer their profession in a variety of ways that include:

- Research environment (books and journals, conferences, advocacy in Washington and elsewhere, and prizes)
- Pedagogy (texts, best practices)
- The society itself (chairing the Council, representing the Society, participating in decisions that can alter the directions of the society in future years).

I have known John for nearly forty years; he thinks deeply about problems facing the mathematics community and he follows trends in a large number of areas in mathematics. I have seen John perform admirably on a variety of assignments that demonstrate that he would be a superb AMS president, in ways that I will now discuss.

Research

John Guckenheimer's research is a broad, delightful, and rare blend of the theoretical, the computational, and the applied. He is a distinguished researcher who has made significant contributions in dynamical systems, bifurcation theory, computational methods and scientific software, neuroscience, and a variety of engineering application areas. Based on his research John was appointed Abram R. Bullis Professor in Mathematics at Cornell and elected a Fellow of the American Academy of Arts and Sciences.

Martin Golubitsky is professor of mathematics at Ohio State University. His email address is mgolubitsky@mbi.osu.edu.

Specifically, John has contributed to theoretical dynamical systems (for example, universality of periods in one-dimensional maps; chaotic properties of the Lorenz attractor, and canard dynamics in multi-time-scale systems; indeed he was the first to define a *geometric* Lorenz attractor). In a remarkable series of papers, John demonstrated the universality of periods of stable periodic orbits and the Holder-continuity of entropy for a wide class of unimodal smooth maps. This research helped explain chaotic properties of the Lorenz attractor. John has also worked on multiple time-scale systems, in particular the forced van der Pol equation. Cartwright, Littlewood, Levinson and Levi showed that this system had chaotic solutions, which inspired Smale's development of the horseshoe map that is now a central concept in the analysis of chaotic systems. With collaborators, Guckenheimer showed how horseshoes occur in the periodically forced van der Pol equation, thus providing a capstone to this line of research.

A 1988 paper by Guckenheimer and Holmes contains one of my personal favorite bifurcation theory results. The authors show that intermittency observed in a fluid dynamics experiment and in associated models is driven by heteroclinic cycles that are structurally stable because of symmetry. This seminal paper spawned a vast literature exploring heteroclinic cycles in equivariant dynamical systems.

In computational dynamical systems John and his collaborators created *DSTool*, a widely used "toolbox" for interactive investigation of dynamical systems. John is among the pioneers of computer-generated proofs, and he invented important algorithms for approximating periodic orbits and invariant manifolds.

In mathematical neuroscience John worked with a team of neurobiologists led by Harris-Warrick. Together they constructed detailed models of motor neural networks in the lobster nervous system and the mouse spinal cord. These models predicted parameters that provided experimentalists with a key insight into understanding how neurons generate rhythmic behavior.

John's forays into engineering applications include work on fluid mechanics (relationships between chaotic dynamics and complicated fluid motion) and robotics (specifically the derivation of models for legged motion). Recently, I spoke to one of John's engineering collaborators and was truly impressed by how much he valued John's contributions.

Pedagogy

In 1983 Guckenheimer and Holmes published *Nonlinear Oscillations, Dynamical Systems, and Bifurcation of Vector Fields*, a text that has become a classic and that has trained a generation of researchers in applied dynamical systems, as well as researchers in core mathematics, applied mathematics, and a number of applied disciplines.

In recent years John has worked both on core dynamical systems and on applications in the biological sciences. As is John's way, to do this he spent much effort understanding the important issues in a variety of areas in the biological sciences and how mathematics could contribute to these areas. These efforts led to an undergraduate text on *Dynamic Models in Biology* co-authored with Steve Ellner (a noted ecologist) in 2006.

Policy

John Guckenheimer has participated in important policy discussions about the mathematical sciences over the past 20 years in at least two distinct ways. First, in his association with SIAM, John helped create two of the largest SIAM activity groups—one in Computational Science and Engineering and the other in the Life Sciences. Indeed, John was the founding chair of the Life Sciences AG. In each case John was ahead of the curve in seeing the need to support emerging fields within the mathematical sciences and acting to help create that support. Not surprisingly, John has also served as chair of the Dynamical Systems Activity Group. These three AGs are now among the six largest of the 16 SIAM Activity Groups.

A second way that John has participated in policy issues is by serving on panels to explore new directions in the Mathematical Sciences. I point to two such efforts that were both timely and effective: Mathematics and Biology in 1992 and Foundations for Complex Systems Research in the Physical Sciences and Engineering in 2008.

Advocacy in Washington is an activity that the American mathematics profession cannot afford to ignore. Our community needs to explain the myriad of ways that the mathematical sciences contribute to societal goals. Indeed, AMS, SIAM, and MAA all have strong and cooperative (through JPBM) Washington presences. John has contributed to these efforts for many years and in many ways, from testifying before congressional committees, to visiting congressional staffers, to writing white papers on specific needs, to discussing funding directions at NSF.

Publications

One of the important challenges that will affect professional societies is how to continue publications in the electronic age. John has had broad experience in publication: from writing successful books to serving on multiple editorial boards.

In summary, John Guckenheimer has the talents, past experiences, and wisdom, along with a deep love of the mathematical sciences, to make an ideal AMS president. If elected, John would undoubtedly further the interests of mathematics, both in its core and in its applications, and he would promote excellence in research, teaching, and exposition.

Nomination of David A. Vogan Jr.

Jeffrey Adams

David Vogan is an eminent research mathematician with a broad view of mathematics, its future, and its role in

Jeffrey Adams is professor of mathematics at the University of Maryland. His email address is jda@math.umd.edu.

society. David has a powerful sense of commitment to mathematics, and has worked tirelessly over the years on behalf of his students, colleagues, and the mathematical community. He is an effective administrator with extensive experience at MIT, with the AMS, and elsewhere. He would be a superb president of the American Mathematical Society.

David has been at the forefront of representation theory of Lie groups since his revolutionary Ph.D. thesis. His energy, generosity, and outgoing nature have put him at the center of an ongoing research program at the highest level. Currently, David is spearheading an innovative project to use computers to study representation theory. He has had many collaborators, has directed 28 Ph.D. students, and has mentored many postdocs. David is a talented writer and speaker—he has written four books and numerous expository articles, and he continuously travels the world lecturing to audiences at all levels.

David Vogan is an outstanding candidate for president of the AMS because of his mathematical accomplishments, his service to the mathematical community, and his administrative experience. I will discuss his mathematics, followed by his service.

Mathematics

David studies representations of Lie groups, which are named after the nineteenth-century mathematician Sophus Lie, and are continuous symmetry groups. The concept of symmetry is woven deep in the fabric of mathematics, and Lie groups are ubiquitous. A great deal of mathematics begins with the measure-preserving action of a group G on a measure space X. Understanding this action is at the heart of some of the most important subjects in mathematics. A powerful technique is to linearize the action of G on X by replacing it with the action of G, by linear operators, on the Hilbert space $L^2(X)$ of square-integrable functions. Such an action is a representation of G, and translates questions about the action of G on X to questions in representation theory, which are often more tractable.

Furthermore, these representations inherit from $L^2(X)$ the property of being unitary: they preserve the positive definite Hermitian form $(f,g)=\int^X f\bar{g}dx$. The action of G on $L^2(X)$ can be decomposed into irreducible representations of G (those with no closed invariant subspaces). Therefore it is of great interest to understand the irreducible unitary representations of G. This is the problem of the unitary dual, one of the most important unsolved problems in representation theory, and indeed in all of mathematics.

Hermann Weyl's approach to quantum mechanics is an example of this, with a Lie group G acting on a phase space X. On the other hand, taking X to be the quotient of $SL(2, \mathbb{R})$ (two-by-two real matrices of determinant one) by a discrete subgroup gives the setting of the solution to Fermat's Last Theorem. Generalizations to other groups, such as $GL(n, \ )$ (all $n\times n$ invertible matrices), form the basis of much of number theory, including the Langlands program, which is currently a topic of intense study.

David has made numerous contributions to this broad field, many of which are motivated by the goal of understanding the unitary dual of an arbitrary Lie group. Work on the unitary dual has generated a great deal of mathematics of independent interest, in much the same way that Fermat's Last Theorem has led to deep results in algebraic geometry and number theory.

Prior to David's 1976 MIT thesis, representation theory of Lie groups had been primarily an analytical subject. David turned many analytic questions into algebraic ones, thus bringing powerful techniques from algebra to bear. This gives a new approach to the study of representation theory, providing very different information than that provided by analytical methods. David's 1981 book, *Real Reductive Lie Groups*, laid the foundation for this theory.

One potential disadvantage of the algebraic approach is that it is not, a priori, well suited to studying unitary representations. In the algebraic setting, a representation may have an invariant Hermitian form. To be unitary this form must be positive definite, leading to the problem of computing signatures of invariant Hermitian forms.

In David's groundbreaking 1984 paper, "Unitarizability of certain series of representations", he defined the signature character of a representation, which makes it possible to study signatures of invariant Hermitian forms, and hence unitarity, in the algebraic setting. This deep result gives substantial new information about the structure of the unitary dual.

Recently, David's work on the unitary dual has turned in an innovative new direction. In his 1984 paper, David formulated an algorithm for computing the unitary dual. However, this algorithm depends on computing some signs which were inaccessible at the time. In 2002, David was a founding member of the "Atlas of Lie Groups and Representations", dedicated to exploring the possibility of completing this algorithm. The first goal of the project is to implement representation theory of Lie groups on a computer, for use by researchers and as an educational tool. The second is to use the software to compute the unitary dual.

Carrying out this project has required carefully rethinking the entire subject from the ground up, with explicit algorithms in mind. This is a project for which David is uniquely qualified. One of his hallmarks is his precision and attention to detail (he *never* makes mistakes). As David foresaw, this process has led to a deeper understanding of the mathematics, and David recently had a fundamental new insight into the subject. He observed that using a modification of the invariant Hermitian form on a representation resolves the issues of signs, which had remained intractable since 1984, and makes it possible to complete the algorithm to compute the unitary dual. This observation also suggests deep connections between the unitary dual and the theory of mixed Hodge modules. The Atlas project is now on the verge of tackling the final step: computing signatures of Hermitian forms, and the unitary dual.

Essential to understanding the representation theory of a (semisimple) Lie group are its Kazhdan-Lusztig-Vogan (KLV) polynomials. The problem of computing these polynomials is a famously difficult one. A demanding test case of the computation is for the largest real exceptional Lie group, E_8. In 2006, after substantial mathematical and computational advances, the Atlas project achieved a notable milestone in the computation of the KLV polynomials for E_8. The project put out a press release on the computation, and the resulting media attention heightened awareness of research mathematics worldwide.

Service

David Vogan is a gifted expositor, not only for specialists, but also for students and the general public. David's charming 2007 *Notices* article on the E_8 calculation (see the end of the previous section), an accessible description of the calculation for the nonspecialist, was the winner of the 2011 AMS Levi Conant Prize for mathematical exposition. His 1987 book, *Unitary Representations of Reductive Lie Groups*, is an excellent overview of the subject, and is a valuable entry point for graduate students and anyone else interested in the field. David co-authored the book *Cohomological Induction and Unitary Representations* with Anthony Knapp, which is the standard reference for the subject. He has also co-authored one other research-level book and a number of expository articles.

David Vogan has given many distinguished lectures, including a plenary address at the International Congress of Mathematicians in Berkeley, the Hermann Weyl Memorial Lectures at Princeton, and the Ritt Lectures at Columbia. Every year David lectures at conferences and departments around the world, often in developing countries. David's dedication to mathematics worldwide is also reflected in his past membership on the Committee on the Human Rights of Mathematicians.

Everyone who knows David Vogan is aware of his quiet dedication to all facets of mathematics, and he brings the same energy and intellectual rigor to these aspects of mathematical life as he does to his research. David has served the AMS in many ways over the years, including as a member of both the AMS Council and the Science Policy Committee. David was a founder of the electronic AMS journal *Representation Theory*. Thanks in part to David's efforts, it has become one of the top journals in the subject. David has also served on the editorial boards of the *Bulletin of the AMS* and *International Mathematical Research Notices*, and was a corresponding editor for Princeton University Press.

I have often heard David speak passionately of his commitment to education and mentoring, and how rewarding he finds these aspects of his job. Except for a stint as a postdoc at the Institute for Advanced Study, David has been teaching and doing research at MIT continuously since he was a graduate student, where he has been a mentor to a continuous stream of postdocs and visiting researchers. Indeed many of the young (or not so young anymore) people working in the subject have either been David's students or have been mentored by him. For over thirty years, David has organized the MIT Lie groups seminar, an important forum for new developments in the subject. He has also helped to organize numerous conferences, including the graduate component of a summer Park City Mathematics Institute.

David is equally committed to undergraduate education, and has played a leading role in the undergraduate mathematics program at MIT. Over the years, he has served multiple terms as chair of both the graduate and undergraduate committees. From 1993–1998 David served on the AMS Task Force on Excellence in Mathematics Scholarship.

David was head of the Department of Mathematics at MIT from 1999–2004. He is highly regarded for his work in this demanding position, leading a large and prestigious department that includes both pure and applied mathematics. As head, David was a forceful advocate for women, as he has been his entire career—eight of his Ph.D. students are women, as well as two of his Master's students.

The president of the AMS should be a first-rate research mathematician with a perspective on all aspects of mathematics. He should be a spokesman for the subject, and skillful at explaining mathematics to all audiences. He should be committed to the mathematical community, and be an effective administrator. These are all qualities that David Vogan has embodied throughout his career, and that would make him an outstanding president.

Biographies of Candidates 2011

Biographical information about the candidates has been supplied and verified by the candidates.

Candidates have had the opportunity to make a statement of not more than 200 words (400 words for presidential candidates) on any subject matter without restriction and to list up to five of their research papers.

Candidates have had the opportunity to supply a photograph to accompany their biographical information.

Candidates with an asterisk (*) beside their names were nominated in response to a petition.

Abbreviations: American Association for the Advancement of Science (AAAS); American Mathematical Society (AMS); American Statistical Association (ASA); Association for Computing Machinery (ACM); Association for Symbolic Logic (ASL); Association for Women in Mathematics (AWM); Canadian Mathematical Society, Société Mathématique du Canada (CMS); Conference Board of the Mathematical Sciences (CBMS); Institute for Advanced Study (IAS), Institute of Mathematical Statistics (IMS); International Mathematical Union (IMU); London Mathematical Society (LMS); Mathematical Association of America (MAA); Mathematical Sciences Research Institute (MSRI); National Academy of Sciences (NAS); National Academy of Sciences/National Research Council (NAS/NRC); National Aeronautics and Space Administration (NASA); National Council of Teachers of Mathematics (NCTM); National Science Foundation (NSF); Society for Industrial and Applied Mathematics (SIAM).

President

John Guckenheimer

A. R. Bullis Professor of Mathematics, Cornell University, Ithaca, NY.

Born: September 26, 1945, Baton Rouge, LA, USA.

Ph.D.: University of California, Berkeley, 1970.

Selected Addresses: ICM Berkeley, Invited Address on behalf of Michael Jakobson, 1986; Past Presidential Address, SIAM, 1999; Charles Amick Lecturer, University of Chicago, 1999; Frontiers Lecturer, Texas A&M, 2000; New Zealand Society of Mathematics Lecturer, 2000.

Additional Information: SIAM Board of Trustees, 1994–1999, President, 1997–1998, Founding Chair, Activity Group on Life Sciences, 1999–2001, Chair, Activity Group on Dynamical Systems, 2003–2005, Mathematics Awareness Month Advisory Committee, 2011; Boards of Directors/Trustees of Mathematics Institutes: MSRI, 1982–1985, Fields Institute, 2004–2008, MBI 2008–; Advisory Boards: European Science Foundation Network on Nonlinear Science, 1988–1991, Mathematical Sciences Institute, Cornell University, 1989–1991, The Geometry Center, 1992–1996; Panel member, International Review of Mathematics in United Kingdom, 2003; Fellow, American Association for Advancement of Science, 2002, American Academy of Arts and Sciences, 2008, SIAM, 2009; Editorial Boards: *Physica D*, 1986–1992, *SIAM Review*, 1989–1986, *Journal of Experimental Mathematics*, 1995–2007, *Moscow Mathematical Journal*, 2001–, *SIAM Journal of Applied Dynamical Systems*, 2002–; Guggenheim Fellow, 1984; Fellow, American Association for Advancement of Science, 2002, American Academy of Arts and Sciences, 2008, SIAM 2009.

Selected Publications: 1. with P. Holmes, *Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields*, Springer-Verlag, 1983. MR**0709768 (85f:58002)**; 2. with S. Johnson, Distortion of *S*-unimodal maps, *Ann. of Math. (2)*, **132** (1990), No. 1, 71–130. MR**1059936 (91g:58157)**; 3. with S. Gueron and R. Harris-Warrick, The dynamics of a conditionally bursting neuron, *Phil. Trans.*, **341** (1993), 345–359; 4. with M. Wechselberger and L.–S. Young, Chaotic attractors of relaxation oscillators, *Nonlinearity* **19** (2006), No. 3, 701–720. MR**2209295 (2006k:37085)**; 5. with C. Kuehn, Computing slow manifolds of saddle type, *SIAM J. Appl. Dyn. Syst.* **8** (2009), No. 3, 854–879. MR2**533627 (2010g:37156)**.

Statement: As president of the AMS, I will enthusiastically pursue its goals, which include promoting mathematical research and communicating its results, supporting mathematical education at all levels, advancing the status of the profession and fostering connections with other disciplines.

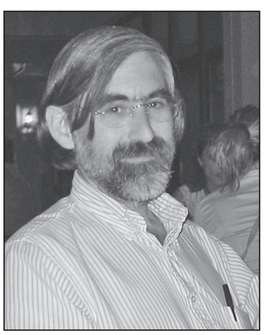
Recent financial crises have constricted professional opportunities for young mathematicians and threaten the resources we need for our work. In response, the AMS needs to advocate even more strongly the importance of mathematics. Indeed, the current era demands that we do more. Society expects us to participate in research that enhances human welfare and ameliorates the increasing environmental impacts of mankind. It behooves us to accept this responsibility and enlarge the scope of our activities. Fundamental mathematics research has much to gain from this engagement. The infusion of problems and insights from other disciplines has long stimulated far reaching mathematical discoveries, for example in the work of Gauss. I am well prepared to lead the AMS in addressing these issues.

Throughout my career, I have pursued mathematics research on dynamical systems together with interdisciplinary collaborations. I have been fortunate to participate in mathematical discoveries that give striking insight into universal phenomena occurring in seemingly unrelated settings. The diversity of my research is reflected by publications in mathematics, physics, chemistry, biology and engineering journals and by two books that make mathematics accessible to broader scientific audiences. My collaborations have posed fascinating questions that became part of my mathematics research and contributed to my skills in representing mathematics to larger communities.

My experience includes a term as president of the Society for Industrial and Applied Mathematics, a department chairmanship and membership on boards of three mathematics institutes. I have continuously championed the importance of fundamental mathematics research in all these endeavors, because effective solutions of many applied problems require new mathematical theory. I will seek to deepen connections with other disciplines, thereby stimulating research in core mathematics and enhancing the status of our profession. I will be especially pleased to lead the AMS during the 2013 Emphasis Year on Mathematics of Planet Earth, a global initiative of mathematics societies and institutes.

The AMS and our profession will thrive by embracing a broad view of mathematics that engages our curiosity about the world around us as well as the world inside us. I will be honored to serve as AMS president while it extends its boundaries.

David Vogan



Professor of Mathematics, Massachusetts Institute of Technology, Boston, MA.

Born: September 8, 1954, Mercer, PA, USA.

Ph.D.: Massachusetts Institute of Technology, 1976.

AMS Offices: Member at Large of the Council, 1985–1987.

AMS Committees: Review Committee for JPBM, 1987; Committee on Science Policy, 1989–1991; Committee to Select the Gibbs Lecturer, 1990–1991; Task Force on Excellence in Mathematics Scholarship, 1993–1998; Committee on the Human Rights of Mathematicians, 1999–2001.

Selected Addresses: AMS Invited Address, Eugene, OR, 1984; Hermann Weyl Memorial Lectures, Institute for Advanced Study, 1986; Invited Address, International Congress of Mathematicians, Berkeley, 1986; Graduate Summer School of the Park City Mathematics Institute, 1998; Ritt Lectures, Columbia University, 2007.

Additional Information: Editorial positions: *Bulletin of the AMS*: Associate Editor for Research-Expository Articles, 1987–1992, Associate Editor for Research Reports, 1995–2001, Associate Editor for *Bulletin* articles, 2001–2002; *Journal of Representation Theory*: Managing Editor, 1996–2003, Editorial Board, 2003–; Member, Board of Directors, The Giving Back Fund, (`http://www.givingback.org`) 2000–; Member, American Academy of Arts and Sciences, 1996–; Levi Conant Prize for Mathematical Exposition, 2011.

Selected Publications: 1. The unitary dual of $GL(n)$ over an Archimedean field, *Invent. Math.*, 83 (1986), No. 3, 449–505. MR**0827363 (87i:22042)**; 2. *Unitary Representations of Reductive Lie Groups*, Annals of Mathematics Studies, Princeton University Press, 1987. MR**0908078 (89g:22024)**; 3. with J. Adams and D. Barbasch, *The Langlands Classification and Irreducible Characters for Real Reductive Groups*, Progress in Mathematics, 104, Birkhäuser Boston, Inc., 1992. MR**1162533 (93j:22001)**; 4. with A. Knapp, *Cohomological Induction and Unitary Representations*, Princeton Mathematical Series, 45, Princeton University Press, 1995. MR**1330919 (96c:22023)**; 5. The character table for E_8, *Notices Amer. Math. Soc.*, **54** (2007), No. 9, 1122–1134. MR**2349532 (2008g:22020)**.

Statement: Most of the wonderful mathematics that I have experienced has been a gift from someone else: from teachers, from fellow students, from colleagues and, perhaps most of all, from my own students. We are stewards of a powerful and beautiful collection of tools. Our responsibility, our privilege, and our joy is to pass along those tools, in a form even more powerful and beautiful than we received them. The members of the AMS do this work every day. It is the task of the Society to support that work, particularly in directions that we can't do as individuals. The publications of the Society, from MathSciNet to the journals to the book series, are perhaps the most visible presence of the Society in our daily lives. The meetings of the Society, the large lectures there, and the special sessions are an important part of how we give mathematics to each other. All of these things have been in existence for longer than I can remember (a phrase which grows more impressive every day), and all of them have changed, mostly for the better, in fundamental ways. I've learned in mathematics that new ideas are usually wrong, and often a step backward. But occasionally—and these are the occasions we are always working for—new ideas can open up our understanding with breathtaking power. I hope to work for the AMS by thinking about change and by listening to suggestions for change, with an attitude informed by that mathematical experience. Not surprisingly, some of the areas where we mathematicians have made the greatest efforts are those where the greatest efforts are still required: making mathematics open to everyone; making and keeping the literature accessible (in every sense) to all mathematicians; thinking about how we teach at every level; and smoothing the process of finding and holding a job in mathematics. These problems are clearly unsolvable, and therefore worthy of our best efforts.

Vice President

Aloysius G. Helminck

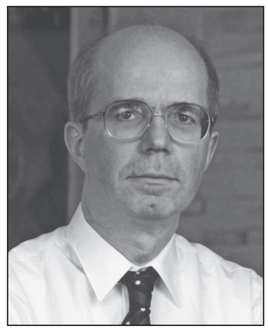
Professor of Mathematics, North Carolina State University.
Born: January 10, 1954, Rotterdam, The Netherlands.
Ph.D.: University of Utrecht, The Netherlands, 1985.
AMS Committees: Committee on Meetings and Conferences, 2007–2010 (Chair, 2010).
Selected Addresses: Invited Speaker, Representations of reductive p-adic groups, Montreal, Canada, 1999; Plenary Speaker, Twente conference on Lie Groups, The Netherlands, 2005; Plenary Speaker, Symmetric Varieties and Involutions of Algebraic Groups, Germany, 2008; Plenary Speaker, Quantum groups and Lie theory, Shanghai, China, 2008; Plenary Speaker, Quantized algebra and Physics, Chern Institute of Mathematics, China, 2009; Plenary Speaker, Analysis, Geometry and Group Representations for Homogeneous Spaces, Leiden, The Netherlands, 2010.
Additional information: Head, Department of Mathematics at NC State University, 2005–; Founder and Director, Institute for Mathematics at NC State; Founder and Director of "Alliance for Building Faculty Diversity in the Mathematical Sciences"; Co-Director of "National Alliance for Doctoral Studies in the Mathematical Sciences"; Committees of other societies: SIAM Diversity Committee, 2007–2013, AWM Committee on Committees, 2010–2013.
Selected Publications: 1. with S. P. Wang, On rationality properties of involutions of reductive groups, *Adv. in Math.*, **99** (1993), No. 1, 26–97. MR**1215304 (94d:20051)**; 2. with G. F. Helminck, The structure of Hilbert flag varieties, *Publ. Res. Inst. Math. Sci.*, **30** (1994), No. 3, 401–442. MR**1299523 (96a:58016)**; 3. On the classification of k-involutions, *Adv. in Math.*, **153** (2000), No. 1, 1–117. MR**1771689 (2001f:20094)**; 4. with G. Schwarz, Orbits and invariants associated with a pair of commuting involutions, *Duke Math. J.*, **106** (2001), No. 2, 237–280. MR**1813432 (2002j:20086)**; 5. with G. Schwarz, On generalized Cartan subspaces, *Transformation Groups* (2011), to appear.
Statement: The AMS is the preeminent mathematics organization in the world, and has done much to advance our discipline. I am honored to be nominated for Vice President and hope to help keep AMS vital to all of us through maintaining its strong traditions while mounting new initiatives to fit with the changing landscape of mathematics and the world.

The AMS serves mathematicians by promoting and disseminating mathematics; providing structures for meetings and conferences; and supporting the careers of mathematicians at all stages. As Chair of the AMS committee on Meetings and Conferences I proposed the formation of AMS activity groups (AMSAGs). These are groups of mathematicians with a common (research) interest that provide a focused network for exploring a targeted area of mathematics. AMSAGs organize conferences, special sessions, newsletters, electronic communications, Web sites, etc.

As Head of the Department of Mathematics at NC State I have initiated numerous programs that have enriched and strengthened our department. Our accomplishments were recognized by the AMS, which awarded us the 2010 AMS award for "Exemplary Program" and the 2011 AMS award for "programs that make a difference".

As vice president of the AMS I would work to serve all mathematicians and potential mathematicians, by maintaining the strong conference and journals of the AMS and instituting new programs that help us continue to produce first class scholars and scholarship.

Andrew M. Odlyzko



Professor, School of Mathematics, University of Minnesota, Minneapolis, Minnesota.
Born: July 23, 1949, Tarnow, Poland.
Ph.D.: Massachusetts Institute of Technology, 1975.
AMS Offices: Member at Large of the Council, 1996–1998; Executive Committee of the Council, 1996–1999.
AMS Committees: AMS–IMS Committee on Translations, 1981–1984; Committee on the Publication Program, 1985–1993; Committee on Electronic Exchange of Information, 1988–1989, Copyright Subcommittee of the AMS Committee on the Publication Program, Chair, 1993–1994; Committee on Publication Policy, 1994–1996; Abstracts Revision Task Force, 1995; Committee to select the Gibbs Lecturers for 1995–1996; Committee on Committees, 1997–1998; Fulkerson Prize Selection Committee, 2002–2004; Committee on Publications, 2009–2012; Editorial Committees: *Proceedings of the American Mathematical Society*, 1984–1989, Associate Editor, *Mathematics of Computation*, 1985–1988, *Mathematics of Computation*, 1989–1998, *Journal of the American Mathematical Society*, 1991–1998, Associate Editor, 2004–2010.
Selected Addresses: Invited Address, AMS Annual Meeting, Pittsburgh, 1981; Invited Address, International Congress of Mathematicians, Berkeley, 1986; Invited Address, MAA meeting, Toronto, 1998; International Association for Cryptologic Research Distinguished Lecture, Innsbruck, 2001; Infocom keynote, Rio de Janeiro, 2009.
Additional Information: Department Head, AT&T Bell Labs, 1983–1995, and AT&T Labs-Research, 1996–2001; Board of Trustees, MSRI, 1996–2001; Honorary doctorate, Univ. Marne la Vallee, 2000; Assistant Vice President for Research, University of Minnesota, 2001–2006; Director, Digital Technology Center, University of Minnesota, 2001–2008; Interim Director, Minnesota Supercomputing Institute, University of Minnesota, 2006–2008.

Selected Publications: 1. Some analytic estimates of class numbers and discriminants, *Invent. Math.*, **29** (1975), No. 3, 275–286. MR**0376613(51#12788)**; 2. with J. C. Lagarias, Solving low-density subset sum problems, *J. Assoc. Comput. Mach.*, **32** (1985), No. 1, 229–246. MR**0832341 (87i:11186)**; 3. with P. Flajolet, Singularity analysis of generating functions, *SIAM J. Discrete Math.*, 3 (1990), No. 2, 216–240. MR**1039294 (90m:05012)**; 4. Tragic loss or good riddance? The impending demise of traditional scholarly journals, *Notices Amer. Math. Soc.*, **42** (1995), 49–53; 5. The 10^{22}-nd zero of the Riemann zeta function, in *Dynamical, Spectral, and Arithmetic Zeta Functions*, Contemp. Math., 290, Amer. Math. Soc. (2001), 139–144. MR**1868473 (2003h:11109)**.

Statement: The AMS has played a key role in mathematics research, education, and outreach. It would be an honor for me to serve the AMS by helping it to preserve and strengthen its core mission while pursuing new opportunities in collaborative research and in novel methods of communications among mathematicians and with other disciplines and society at large.

Trustee

Ruth Charney

Professor, Brandeis University, Waltham, MA.

Born: December 30, 1950, New York, NY, USA.

Ph.D.: Princeton University, 1977.

AMS Offices: Member at Large of the Council, 1993–1995; Vice President, 2006–2009; Executive Committee, 2007–2011.

AMS Committees: Committee on the Profession, 1993–1995; Centennial Fellowship Committee, 1995–1997; Nominating Committee, 2000–2003; Central Section Program Committee, 2002–2004; Committee on the Profession, 2004–2005; Math Research Communities, Steering Committee, 2006–2010.

Selected Addresses: AMS Invited Address, Anaheim, CA, 1984; AMS Invited Address, Nashville, TN, 2004; MAA Distinguished Lecture, Washington, DC, 2008; Conference on Configuration Spaces, Pisa, Italy, 2010; Conference on Geometric Group Theory, Luminy, France, 2010.

Additional Information: NSF Postdoctoral Fellowship, 1979–1980; Yale Junior Faculty Fellowship, 1982–1983; AWM Executive Committee, 1990–1993; U.S. National Committee for Mathematics, 2005–2008; Trustee of Mathematical Sciences Research Institute, 1993–1995, 2007–.

Selected Publications: 1. Homology stability for GL_n of a Dedekind domain, *Invent Math.*, **56** (1980), No. 1, 1–17. MR**557579 (81h:18010)**; 2. with R. Lee, Moduli space of stable curves from a homotopy viewpoint, *J. Differential Geom.*, **20** (1984), No. 1, 185–235. MR**772131 (87f:14014)**; 3. with M. Davis, The $K(\pi,1)$-problem for hyperplane complements associated to infinite reflection groups, *J. Amer. Math. Soc.*, **8** (1995), No. 3, 597–627. MR**1303028 (95i:52011)**; 4. with A. Lytchak, Metric characterizations of spherical and Euclidean buildings, *Geom. Topol.*, **5** (2001), 521–550. MR**1833752 (2002h:51008)**; 5. with K. Vogtmann, Finiteness properties of automorphism groups of right-angled Artin groups, *Bull. London Math. Soc.*, **41** (2009), 94–102. MR**2481994 (2010a:20084)**.

Statement: The Board of Trustees is responsible for the financial stewardship of the AMS. As a Vice President and member of the Executive Committee of the AMS from 2006–2011, I have become well acquainted with the workings of the organization, including financial aspects of the operation. My experience over the past 5 years as a Trustee of the Mathematical Sciences Research Institute will also serve me well in this role. More generally, the AMS Board of Trustees, together with the Executive Committee, helps to set priorities for the organization. I have twice served on the Committee on the Profession where we grappled with key issues facing the profession. I believe that the AMS should be pro-active in addressing these issues. I look forward to the opportunity to continue to serve the AMS and the mathematical community in the role of trustee.

Nassif Ghoussoub

Professor of Mathematics and Distinguished University Scholar, Department of Mathematics, University of British Columbia.

Born: November, 9, 1953, Segou, Mali.

Ph.D.: Université Pierre et Marie Curie, 1979.

Selected Addresses: Plenary address, AMS Western Section Meeting, Claremont, California, 1993; Plenary speaker, A-HYKE2: Around HYperbolic and Kinetic Equations 2, École Normale Supérieure, Paris, 2004; Jeffrey-Williams Prize Lecture, CMS-MITACS meeting, Winnipeg, Canada, 2007; Plenary speaker, First Congress of PRIMA, Sydney, Australia, 2009; Plenary speaker, Analysis, Stochastics, and Applications, Vienna, Austria, 2010.

Additional Information: Coxeter-James Prize, Canadian Mathematical Society, 1990; Killam Senior Research Fellowship, University of British Columbia, 1992; Fellow of the Royal Society of Canada, 1994; Founding Director, Pacific Institute for the Mathematical Sciences, 1996–2003; Distinguished University Scholar, University of British Columbia, 2003; Doctorat Honoris Causa, Université Paris-Dauphine, 2004; Jeffrey-Williams Prize, Canadian Mathematical Society, 2006; Faculty of Science Achievement Award for outstanding service and leadership, University of British Columbia, 2007; Founder and Scientific Director of the Banff International Research Station 2004–2013; Co-Founder and Board of Directors of the MITACS network, 2008–2015; University of British Columbia, Board of Governors 2008–2013; The David Borwein Distinguished Career Award, 2010.

Selected Publications: 1. *Duality and Perturbation Methods in Critical Point Theory*, Cambridge Tracts, **107**, Cambridge University Press, 1993. MR**1251958 (95a:58021)**; 2. with C. Gui, On the De Giorgi's conjecture in dimensions 4 and 5, *Ann. of Math.* (2), **157** (2003), No. 1, 313–334. MR**1954269 (2004a:35070)**; 3. with F. Robert, Concentration estimates for Emden-Fowler equations with boundary singularities and critical growth, *IMRP Int. Math. Res. Pap.* 2006, 21867, 1–85. MR**2210661 (2006k:35094)**; 4. *Selfdual Partial Differential Systems and Their Variational Principles*, Springer Monographs in Mathematics, Springer-Verlag, NY, 2009. MR**2458698 (2010c:35001)**; 5. with P. Esposito and Y. J. Guo, Mathematical Analysis of Partial Differential Equations Modeling Electrostatic MEMS, Courant Lecture Notes in Mathematics, 20. Courant Institute of Mathematical Sciences, New York; American Mathematical Society, Providence, RI (2010). MR**2604963 (2011c:35005)**.

Statement: The AMS plays a major role in supporting and promoting the mathematical sciences worldwide. I will be happy to serve on its Board of Trustees, aided by my experiences on various Boards of mathematical professional societies and institutes (CMS, PIMS, MITACS, BIRS), but also on the Board of Governors of the University of British Columbia.

Member at Large

Dan Abramovich

Professor, Department of Mathematics, Brown University.

Born: March 12, 1963, Haifa, Israel.

Ph.D.: Harvard University, 1991.

AMS Committees: Committee on Committees, 2003, 2004.

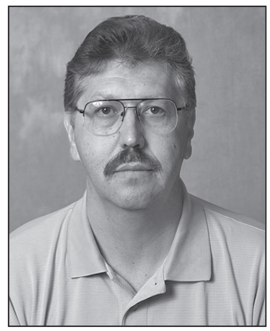
Selected Addresses: Poincaré Lecture Series, The Fields Institute for Research in Mathematical Sciences, Toronto, ON, Canada, 1997; Lecture series, Working Week on Resolution of Singularities, Obergurgl, Tirol, Austria, 1997; Lecture series, Summer School on Intersection Theory and Moduli, International Center for Theoretical Physics, Trieste, Italy, 2002; Lecture series, Clay summer school in Arithmetic Geometry, Gottingen, Germany, 2006; Algebraic Geometry and Arithmetic, Essen, Germany, 2010.

Additional Information: Director of Graduate Studies, Boston University, 1997–1998, Brown University, 2007–; *Transactions/Memoirs* Editorial Board, 2003–; Co-organizer, AMS Summer Institute in Algebraic Geometry, Seattle, WA, 2005; Co-organizer, AMS MRC program "Birational Geometry and Moduli", Snowbird, UT, 2010; Visiting professor, IHES, 1999, Landau Center, Jerusalem, 2002, MSRI, 2009; Member, AAAS, 1997–.

Selected Publications: 1. with J. F. Voloch, Toward a proof of the Mordell-Lang conjecture in characteristic p, *Internat. Math. Res. Notices* (1992), No. 5, 103–115. MR**1162230 (94f:11051)**; 2. with A. J. de Jong, Smoothness, semistability, and toroidal geometry, *J. Algebraic Geom.*, **6** (1997), No. 4, 789–801. MR**1487237 (99b:14016)**; 3. with K. Karu, Weak semistable reduction in characteristic 0, *Invent. Math.*, **139** (2000), No. 2, 241–273. MR**1738451 (2001f:14021)**; 4. with K. Karu, K. Matsuki, and J. Włodarczyk, Torification and factorization of birational maps, *J. Amer. Math. Soc.*, **15** (2002), No. 3, 531–572. MR**1896232 (2003c:14016)**; 5. with T. Graber and A. Vistoli, Gromov-Witten theory of Deligne-Mumford stacks, *Amer. J. Math.*, **130** (2008), No. 5, 1337–1398. MR**2450211 (2009k:14108)**.

Statement: It will be an honor to contribute to the missions of the AMS as a Member at Large of the Council. While I do not come with a specific agenda, my passion and much of my experience revolves around the promotion of early-career mathematicians. I am also interested in the AMS work to bring mathematics to the attention of government, other scientists, and the public, and in disseminating mathematics within the profession, where I bring experience in editorial work.

Rodrigo Bañuelos



Professor of Mathematics, Purdue University, West Lafayette, IN.

Born: June 5, 1954.

Ph.D.: University of California, Los Angeles, 1984.

AMS Committees: Central Section Program Committee, 1991–1993 (Chair, 1992–1993); Task Force on Participation of Underrepresented Minorities, 1995; *Transactions* and *Memoirs* Editorial Committee, 1996–2000; Doob Book Prize Committee, 2003–2004; Selection Committee for Invited Hour Speakers, Joint Meeting with Mexican Math. Society, 2004; Committee on Committees, 2004; Steele Prizes Committee, 2005–2008.

Selected Addresses: Seminar on Stochastic Processes, Annual Meeting, Seattle, 1992; Joint IMS 57th Annual Meeting and Third World Congress of the Bernoulli Society, Chapel Hill, 1994; AMS Invited Address, DePaul University, 1995; VI Latin American Congress in Probability Statistics, Valparaiso, 1995; Introductory Lectures, Workshop on Euclidean Stochastic Analysis, MSRI, 1998; "Topical Speaker", SIAM, Boston, 2006; Lars Ahlfors Centennial Celebration conference, 2007; Harmonic Analysis, Geometric Measure Theory and Quasiconformal Mappings, CRM, Barcelona, 2009; Eighth Virginia Chatelain Memorial Lecture, Kansas State University, 2009; The Marjorie Lee Browne Lecture, University of Michigan, 2010; From Carthage to the World, International Conference on isoperimetric inequalities, Tunis, 2010.

Additional Information: Bantrell Research Fellow, Caltech, 1984–1986; NSF Presidential Young Investigator, 1989–1994; Associate Editor, *Annals of Probability*, 1991–1997; Editorial Board, *Revista Matematica Iberoamericana*, 2007–; NSF Postdoctoral Fellow, University of Illinois, 1996–1997; United States National Committee on Mathematics, 1997–2000; MSRI Scientific Advisory Council, 1998–2002; Fellow, Institute of Mathematical Statistics, 2003; Blackwell-Tapia Prize recipient, 2004; IPAM Board of Trustees, 2005–2008; Head of Mathematics, Purdue University, 2007–2011; Simons Foundation Review Advisory Panel, 2010–.

Selected Publications: 1. Intrinsic ultracontractivity and eigenfunction estimates for Schrödinger operators, *J. Funct. Anal.*, **100** (1991), No. 1, 181–206. MR**1124298 (92k:35066)**; 2. with G. Wang, Sharp inequalities for martingales with applications to the Beurling-Ahlfors and Riesz transforms, *Duke Math. J.*, **80** (1995), No. 3, 575–600. MR**1370109 (96k:60108)**; 3. with T. Kulczycki, Spectral gap for the Cauchy process on convex, symmetric domains, *Comm. Partial Differential Equations*, **31** (2006), No. 10–12, 1841–1878. MR**2273977 (2008d:60065)**; 4. with P. Janakiraman, L^p-bounds for the Beurling-Ahlfors transform, *Trans. Amer. Math. Soc.*, **360** (2008), No. 7, 3603–3612. MR**2386238 (2009d:42032)**; 5. with P. J. Méndez-Hernéndez, Symmetrization of Lévy processes and applications, *J. Funct. Anal.*, **258** (2010), No. 12, 4026–4051. MR**2609537**.

Statement: The AMS is the premier mathematical society in the U.S., yet a good number of people feel that the society is not doing enough to promote the health of the profession, particularly in exerting an influence on research funding and bringing attention to job opportunities (or lack thereof) in the mathematical sciences. Such a perception is inimical to the work of the AMS and stunts the growth and health of the profession. Also, despite progress made in the last two decades to increase the participation of women and minorities in the mathematical sciences, we are still not attracting enough young people from these groups to see real changes in university faculties across the country. If elected, I will work within the AMS to raise greater awareness of these and other issues of interest to the mathematical community.

Hélène Barcelo

Deputy Director, Mathematical Sciences Research Institute; Professor, Arizona State University, Tempe, AZ.

Born: Montreal, Quebec, Canada.

Ph.D.: University of California, San Diego, 1988.

Selected Addresses: International Conference on Formal Power Series and Algebraic Combinatorics, Australia, 2002; International Conference on Combinatorics of Polytopes and Complexes, Israel, 2007; Applications of Algebraic Geometry, Vancouver, 2008; International Conference on Combinatorics, Iran, 2009; MAA Northern California, Nevada, and Hawaii Section Annual Meeting, 2009.

Additional Information: Editor-in-Chief for the *Journal of Combinatorial Theory*, Series A, (JCT A) 2001–2008, Editor on the Advisory Board for JCT A, 2009–; Long-term visiting scholar: Mittag-Leffler, 1992, 2005, University of New South Wales, 2005, Institute for Advanced Studies, Jerusalem, 2007, IMA, 2007, MSRI, 1996–1997, 2004, 2008; Member of the Permanent Committee for the International Conference on Formal Power Series and Algebraic Combinatorics, 2001–; Member, Canadian Mathematical Society, AWM.

Selected Publications: 1. with A. Ram, *Combinatorial Representation Theory, New Perspectives in Algebraic Combinatorics* (Berkeley, CA, 1996–97), Math. Sci. Res. Inst. Publ., 38, Cambridge University Press, 1999, 23–90. MR**1731814 (2000j:05125)**; 2. with E. Babson, M. de Longueville, and R. Laubenbacher, Homotopy theory of graphs, *J. Algebraic Combin.*, **24** (2006), No. 1, 31–44. MR**2245779 (2007d:05156)**; 3. with B. Sagan and S. Sundaram, Counting permutations by congruence class of major index, *Adv. in Appl. Math.*, **39** (2007) No. 2, 269–281. MR**2333652 (2008c:05010)**; 4. with V. Reiner and D. Stanton, Bimahonian distributions, *J. London Math. Soc.*, **77** (2008) No. 3, 627–646. MR**2418296 (2010c:05143)**; 5. with C. Severs and J. White, *k*-parabolic subspace arrangements, to appear in *Trans. Amer. Math. Soc.*

Statement: As a Member at Large I will first listen to the other Council members, AMS leadership, and especially AMS members to determine which issues are of foremost importance to the mathematical community—and I will work hard with the Council to address these issues. The AMS has many strengths, and it is important to recognize and build upon them. I believe that one critical issue is convincing the government and the public of the importance of mathematics and mathematicians to science, the economy, and everyone's daily lives. We must also endeavor to support all mathematicians at all stages of their careers; in the current economy, this is particularly challenging, and will require some creative thinking.

Arthur T. Benjamin

Professor of Mathematics, Harvey Mudd College.

Born: March 19, 1961, Cleveland, OH, United States.

Ph.D.: Johns Hopkins University, 1989.

AMS Committees: Arnold Ross Lecture Series Committee, 2001–2004; Committee on Education, 2004–2006.

Selected Addresses: MSRI Workshop on Combinatorial Games, 2006; Keynote Address, USAMO, Washington, DC, 2009; Keynote address, International Conference on Fibonacci Numbers and their Applications, Morelia, Mexico, 2010; Goldman Lecture, Johns Hopkins University, 2010; Z = 60 Festschrift for Doron Zeilberger, Rutgers, 2010.

Additional Information: Fellow of the Institute for Combinatorics and its Applications; Editor, *Math Horizons*, 2004–2008; Editor, *Spectrum Book Series*, 1996–2000; MAA Haimo Prize, 2000; Beckenbach Book Prize, 2006; First mathematician to appear on The Colbert Report, 2010.

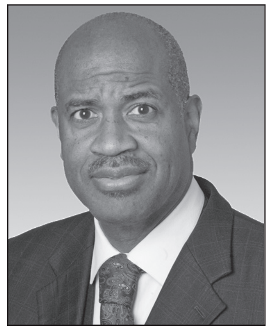
Selected Publications: 1. with J. Quinn, J. Quinn, and A. Wójs, Composite fermions and integer partitions, *J. Combin. Theory Ser. A*, **95** (2001), 390–397. MR**1845152 (2002g:81213)**; 2. with J. Quinn, *Proofs That Really Count: The Art of Combinatorial Proof*, Mathematical Association of America, Washington, DC, 2003. MR**1997773 (2004f:05001)**; 3. with M. Shermer, *Secrets of Mental Math*, Random House, 2006; 4. with S. Plott and J. Sellers, Tiling proofs of recent sum identities involving Pell numbers, *Ann. Comb.*, **12** (2008), No. 3, 271–278. MR**2447257 (2009g:05017)**; 5. Discrete Mathematics (DVD course produced by The Teaching Company), 2009.

Statement: The AMS does a great job of disseminating research through its publications, conferences, and services. I have much experience with directing undergraduate research, and would like to find ways to make the organization more appealing to faculty doing research at four-year colleges and groups that are underrepresented in the organization. As a member of the Council, I would draw on my experiences as an author, editor, and public speaker to find ways that AMS can reach more people.

James Carlson

President, Clay Mathematics Institute.
Born: November 14, 1946, Lewiston, Idaho, USA.
Ph.D.: Princeton University, 1971.
Selected Publications: 1. with D. Toledo, Harmonic mappings of Kähler manifolds to locally symmetric spaces, *Inst. Hautes Études Sci. Publ. Math.* (1989), No. 69, 173–201. MR**1019964 (91c:58032)**; 2. with D. Allcock and D. Toledo, The complex hyperbolic geometry of the moduli space of cubic surfaces, *J. Algebraic Geom.*, **11** (2002), No. 4, 659–724. MR**1910264 (2003m:32011)**; 3. with C. Peters and S. Mueller-Stach, *Period Mappings and Period Domains*, Cambridge Studies in Advanced Mathematics, 85, Cambridge University Press, Cambridge, 2003. MR**2012297 (2005a:32014)**; 4. with D. Allcock and D. Toledo, Hyperbolic geometry and moduli of real cubic surfaces, *Ann. Sci. Éc. Norm. Supér. (4)*, **43** (2010), No. 1, 69–115. MR**2583265 (2011c:14088)**; 5. with D. Allcock and D. Toledo, The moduli space of cubic threefolds as a ball quotient, *Memoirs Amer. Math. Soc.*, 985, 2011.
Statement: I would like to work on increased public understanding of mathematics. Success in this area should pay dividends in other important areas, such as support for graduate and postdoctoral fellowships, and support for mathematical research. The average educated layman shares with the mathematical community a very small vocabulary, set of common metaphors, and "stories" about mathematics. The average educated layman views mathematics largely as a dead subject in which the major problems were solved long ago. Even more surprisingly, there is little awareness of the key role that mathematics plays in modern technology. It is our responsibility as a community to increase the shared vocabulary and get a larger message out. Much has been done, but much more can and should be done.

Lloyd E. Douglas



Associate Director, Office of Sponsored Programs, University of North Carolina at Greensboro, NC.
Born: October 5, 1951, New York, NY, USA.

Selected Addresses: Special Session, AMS Central Sectional Meeting, Milwaukee, WI, 1997; Plenary Talk, AMS Conference on Summer Undergraduate Mathematics Research Programs, Arlington, VA, 1999; Plenary Speaker, Nebraska Conference for Undergraduate Women in Mathematics, Lincoln, NE, 2001; University of Nevada, Reno, Math Departmental Colloquium, Reno, NV, 2007; Keynote Speaker, AGMUS Undergraduate Research Symposium, San Juan, PR, 2010.
Additional Information: NSF, 1984–2008; NSF reviewer; External evaluator for a Research Experiences for Undergraduates project; NSF Special Achievement Award, 1989, 1990, 1992; NSF Director's Award for Equal Opportunity, 1995, 2002; NSF Commendable Service Award, 2000; NSF Director's Award for Collaborative Integration, 2001, 2006, 2007; Coordinator, International Math Olympiad, 2001; Vice President, Federal Executive Institute Alumni Association Foundation, 2003–2008; President, Federal Executive Institute Alumni Association, 2004–2006; President, NSF Employees Association, 2005; Member: AAAS, AWM, MAA; SIAM, NSF Director's Award for Superior Accomplishment, 2006; NSF Director's Award for Meritorious Service, 2007.
Selected Publication: 1. with J. Singer, M. Mayhew, E. Rom and R. Kuczkowski, The Research Experiences for Undergraduates (REU) Sites Program: Overview and Suggestions for Faculty Members, *Council on Undergraduate Research Quarterly*, 158–161 (2003).
Statement: The AMS has recently taken steps to address the issue of the cultivation of student members, an activity that I believe to be vital to our profession. Attracting and retaining members is something that provides a challenge, especially in these economic times. I believe that the sooner in their careers they can see the value that comes with being a member of the AMS, the more successful we will be at keeping them as lifelong members and engaged in the profession. We still have so much work to do in getting people outside of the mathematical sciences to recognize that our discipline is as important as we all know it to be. Success in this area can provide even more funding opportunities for our profession.

During my career at NSF, among my emphases were undergraduates, postdoctoral fellows, early career faculty, experienced faculty looking to expand their research and educational activities into other areas, providing outreach to the mathematical sciences community and I was able to see what types of ventures can be successful. I would thoroughly enjoy the opportunity to be able to continue to provide a service to our profession in these activities.

Robert J. McCann

Professor of Mathematics, University of Toronto, Toronto, ON, Canada.
Born: July 7, 1968, Windsor, ON, Canada.

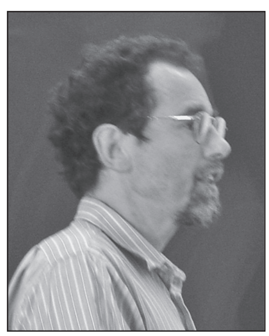
Ph.D.: Princeton University, 1994.

Selected Addresses: Plenary Lecture, AMS Southeastern Sectional Meeting, Bowling Green, KY, 2005; Plenary Lecture, CMS Summer Meeting, Waterloo, ON, 2005; Sylvester Institute for Mathematics, Computation and Applications lecture series, Baltimore, MD, 2009; Carnegie Mellon Center for Nonlinear Analysis minicourse, Pittsburgh, PA, 2010; Plenary Lecture, LMS Summer Meeting, London, UK, 2011.
Additional Information: NSERC Postdoctoral Fellowship (Brown and IHES), 1994–1996; AMS Centennial Fellowship, 1996–1998; Monroe Martin Prize in Applied Mathematics, 2001; Coxeter-James Prize of the Canadian Mathematical Society, 2005; Canadian Mathematical Society Board of Directors, 2005–2009; Editor-in-Chief, *Canadian Journal of Mathematics*, 2007–; Associate Editor, *SIAM Journal of Mathematical Analysis* and other journals, 2007–.
Selected Publications: 1. with W. Gangbo, The geometry of optimal transportation, *Acta Math.* **177** (1996), No. 2, 113–161. MR**1440931 (98e:49102)**; 2. with D. Cordero-Erausquin and M. Schmuckenschlaege, A Riemannian interpolation inequality à la Borell, Brascamp and Lieb., *Invent. Math.*, **146** (2001), No. 2, 219–257. MR**1865396 (2002k:58038)**; 3. with L. Caffarelli and M. Feldman, Constructing optimal maps in Monge's transport problem as a limit of strictly convex costs, *J. Amer. Math. Soc.*, **15** (2002), No. 1, 1–26. MR**1862796 (2003b:49042)**; 4. with L. Caffarelli, Free boundaries in optimal transport and Monge-Ampère obstacle problems, *Ann. of Math. (2)*, **171** (2010), No. 2, 673–730. MR**2630054 (2011b:49116)**; 5. with A. Figalli and Y. H. Kim, When is multidimensional screening a convex program?, *J. Econom. Theory*, **146** (2011), No. 2, 454–478.
Statement: I would be happy to bring the experience and perspectives I have gained as an academic mathematician employed in Canada and the United States to the AMS board of directors as a member-at-large.

Victoria Powers

Professor, Emory University, Atlanta, GA.
Born: July 28, 1958, Atlanta, Georgia, USA.
Ph.D.: Cornell University, 1985.
AMS Committees: Arnold Ross Lecture Committee, 2003–2006 (Chair, 2005–2006); Southeast Section Program Committee, 2008–2010 (Chair, 2009–2010).
Selected Addresses: Pólya's Theorem with Zeros, Real Algebraic Geometry, Oberwolfach, Germany, 2007; The Moment Problem and Real Algebraic Geometry, Colloquium, University of Illinois at Urbana-Champaign, 2007; A Quantitative Pólya's Theorem with Zeros, MEGA, Strobl, Austria, 2007; Representations of Positive Polynomials, NSF workshop on the future of Symbolic Computation, University of Rhode Island, 2009; Positivity and Sums of Squares, plenary talk, Real Algebraic Geometry 2011, Rennes, France, 2011.
Selected Publications: 1. with E. Becker, Sums of powers in rings and the real holomorphy ring, *J. Reine Angew. Math.*, **480** (1996), 71–103; 2. with B. Reznick, Polynomials that are positive on an interval, *Trans. Amer. Math. Soc.*, **352** (2000), No. 10, 4677–4692. MR**1707203 (2001b:12002)**; 3. with C. Scheiderer, The moment problem for non-compact semialgebraic sets, *Adv. Geom.*, **1** (2001), 71–88. MR**1823953 (2002c:14086)**; 4. with B. Reznick, C. Scheiderer, and F. Sottile, A new approach to Hilbert's theorem on ternary quartics, *C. R. Math. Acad. Sci. Paris*, **339** (2004), No. 9, 617–620. MR**2103198 (2005i:11051)**; 5. with M. Castle and B. Reznick, A quantitative Pólya's theorem with corner zeros, *J. Symbolic Comp.*, **44** (2009), No. 9, 1285–1290. MR**2532172 (2010d:13029)**.
Statement: The AMS serves the mathematical community well through its many activities which support and advance mathematical research and education. In addition, in the present economic climate, it is vitally important that the AMS redouble its efforts to advocate for the mathematical community both with the federal government and the public, and promote the value and importance of basic research in mathematics. It would be an honor to serve the mathematical community as a member of the Council if elected.

Bruce Sagan



Professor of Mathematics, Michigan State University, East Lansing, MI.
Born: March 29, 1954, Chicago, IL, USA.
Ph.D.: Massachusetts Institute of Technology, 1979. AMS **Committees:** AMS-IMS-SIAM Committee on Summer Research Conferences in the Mathematical Sciences, 2005–2006.
Selected Addresses: Featured Speaker, Bay Area Discrete Mathematics Days, Hayward, CA, 2001; Featured Speaker, Conference on Formal Power Series and Algebraic Combinatorics, San Diego, CA, 2006; Colloquium, Dartmouth, Hanover, NH, 2006; Lecture Series, Summer School on Algebraic Combinatorics, Lisbon, Portugal, 2007; Featured Speaker, British Combinatorial Conference, Exeter, United Kingdom, 2011.
Selected Publications: 1. with A. Blass, Mobius functions of lattices, *Adv. Math.*, **127** (1997), No. 1, 94–123. MR**1445364 (98c:06001)**; 2. Why the characteristic polynomial factors, *Bull. Amer. Math. Soc. (N.S.)*, **36** (1999), No. 2, 113–133. MR**1659875 (2000a:06021)**; 3. with A. Molev, A Littlewood-Richardson rule for factorial Schur

functions, *Trans. Amer. Math. Soc.*, **351** (1999), No. 11, 4429–4443. MR**1621694 (2000a:05212)**; 4. with M. Rosas, Symmetric functions in noncommuting variables, *Trans. Amer. Math. Soc.*, **358** (2006), No. 1, 183–214. MR**2171230 (2006f:05184)**; 5. with W. Martin, A new notion of transitivity for groups and sets of permutations, *J. London Math. Soc. (2)*, **73** (2006), No. 1, 1–13. MR**2197367 (2007a:05144)**.
Statement: I very much enjoyed my time as a member of the AMS-IMS-SIAM Committee on Summer Research Conferences in the Mathematical Sciences, working together with my colleagues to find the best scientific and educational proposals for such conferences. I am looking forward to possibly helping in similar ways as a Member at Large of the Council. I hope that my past experiences on the committee, as well as having been a program officer at NSF and serving as an Editor in Chief for the Electronic Journal of Combinatorics, will stand me in good stead for this position.

Ileana Streinu

Charles N. Clark Professor of Computer Science and Mathematics, Smith College, Northampton, MA.
Born: Bucharest, Romania.
Ph.D.s: Rutgers University, New Jersey, 1994, and University of Bucharest, Romania, 1994.
Selected Addresses: Automated Deduction in Geometry (ADG), Gainesville, FL, 2004; MAA, Northeastern Meeting, Worcester, MA, 2004; Discrete and Computational Geometry: 20 years after, Snowbird, UT, 2006; Geometric and Topological Combinatorics, Alcala de Henares, Spain, 2006; Formal Power Series and Applied Combinatorics, San Francisco, CA, 2010.

Additional Information: Grigore Moisil Award of the Romanian Academy, 2004; AMS David P. Robbins Prize, 2010; Editorial Board, *Discrete and Computational Geometry*; (co)-organizer of 15 conferences in Discrete and Computational Geometry and applications; Visiting positions: Technische Universitaet Berlin, École Normale Supérieure, Paris, Kyoto University, Stanford University, University Politecnica de Catalunia, Barcelona.

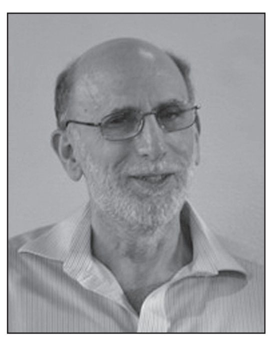
Selected Publications: 1. with G. Rote and F. Santos, Expansive motions and the polytope of pointed pseudo-triangulations, *Discrete and Computational Geometry*, Algorithms Combin. 25, Springer, Berlin (2003), 699–736. MR**2038499 (2005j:52019)**; 2. Pseudo-triangulations, rigidity and motion planning, *Discrete Comput. Geom.*, **34** (2005), No. 4, 587–635. MR**2173930 (2006g:68255)**; 3. with A. Lee, Pebble game algorithms and sparse graphs, *Discrete Math.*, **308** (2008), No. 8, 1425–1437. MR**2392060 (2009a:05179)**; 4. with C. Borcea, Periodic frameworks and flexibility, *Proc. R. Soc. Lond. Ser. A Math. Phys. Eng. Sci.*, **466** (2010), No. 2121, 2633–2649. MR**2671687**; 5. with C. Borcea, How far can you reach?, *Proc. ACM-SIAM Symp. on Discrete Algorithms*, (2010) 928–937.
Statement: It would be an honor to serve the mathematical community from the AMS Council. To further the Society's mission, nationally and internationally, I would advocate for (a) the recognition of mathematics' enhanced role and contributions to the larger scientific endeavors of our times, both foundational and applied; (b) broad promotion of its current achievements and challenges, and (c) mechanisms to attract and retain within its professional ranks the next generation of contributors: a diverse and creative group, committed to the tradition of high standards of our field.

Nominating Committee

Steven R. Bell

Professor of Mathematics and Associate Head for Graduate Studies, Department of Mathematics, Purdue University, West Lafayette, IN.
Born: March 24, 1954, Ypsilanti, Michigan, USA.
Ph.D.: Massachusetts Institute of Technology, 1980.
Selected Addresses: AMS Invited Address, Indianapolis, 1986.
Additional Information: NSF Postdoctoral Fellow, 1980; Sloan Fellow, 1984; AMS Centennial Research Fellowship, 1988; Stefan Bergman Prize, 1990; Associate Editor, *Proceedings of the AMS*, 1997–2000.
Selected Publications: 1. Biholomorphic mappings and the $\bar{\partial}$ problem, *Ann. of Math. (2)*, **114** (1981), 103–113. MR**625347 (82j:32039)**; 2. *The Cauchy Transform, Potential Theory, and Conformal Mapping*, Studies in Advanced Math, CRC Press, Boca Raton, 1992. MR**1228442 (94k:30013)**; 3. Unique continuation theorems for the $\bar{\partial}$ operator and applications, *J. Geom. Anal.*, **3** (1993), No. 3, 195–224. MR**1225295 (94d:32020)**; 4. with P. Ebenfelt, D. Khavinson, and H. Shapiro, On the classical Dirichlet problem in the plane with rational data, *J. Anal. Math.*, **100** (2006), 157–190. MR**2303308 (2008g:35021)**.
No statement provided

Frederick R. Cohen



Professor of Mathematics, University of Rochester.
Born: August 23, 1945, Chicago, Illinois, U.S.A.
Ph.D.: University of Chicago, 1972.
Selected Addresses: Invited speaker, International Congress for Mathematicians, 1983; Nankai University, Institute of Mathematics, 4 lectures, 1991; Invited hour lecture, Cornell Topology Festival, 2003; Invited hour lecture, "Geometry, Algebra and applications in honour of Boris Delone", Steklov

Institute, Moscow, 2010; Invited lecture series (4 lectures), "Configuration spaces: Geometry, Combinatorics and Topology", Centro di Ricerca Matematica Ennio De Giorgi, 2010.
Additional Information: A. P. Sloan Fellowship, 1971–1981; Member, Institute for Advanced Study, 1975–1977, 2006, 2011; Editorial Boards: *Proceedings of the AMS*, 1988–1991, *Forum Mathematicum*, 1989–, *Algebraic and Geometric Topology*, 2000–; Goergen Teaching Award, University of Rochester, 2008; Organizing committees: "Geometry, Algebra and applications in honour of Boris Delone", Steklov Institute, Moscow, 2010, "Topological methods in toric geometry, and combinatorics", Banff International Research Station, 2010, "Configuration spaces: Geometry, Combinatorics and Topology", Centro di Ricerca Matematica Ennio De Giorgi, 2010.

Selected Publications: 1. with T. Lada and J. P. May, *The Homology of Iterated Loop Spaces*, Lecture Notes in Mathematics, Vol. 533, Springer-Verlag, Berlin-New York, 1976. MR**0436146 (55 #9096)**; 2. with J. C. Moore and J. A. Neisendorfer, Torsion in homotopy groups, *Ann. of Math. (2)*, **109** (1979), No. 1, 121–168. MR**0519355 (80e:55024)**; 3. with R. L. Cohen, B. M. Mann, and R. J. Milgram, The topology of rational functions and divisors of surfaces, *Acta Math.*, **166** (1991), No. 3–4, 163–221. MR**1097023 (92k:55011)**; 4. with A. J. Berrick, Y. L. Wong, and J. Wu, Configurations, braids, and homotopy groups, *J. Amer. Math. Soc.*, **19** (2006), No. 2, 265–326. MR**2188127 (2007e:20073)**; 5. with A. Bahri, M. Bendersky, and S. Gitler, Decompositions of the polyhedral product functor with applications to moment-angle complexes and related spaces, *Proc. Natl. Acad. Sci. USA*, **106** (2009), No. 30, 12241–12244. MR**2539227 (2010j:57036)**.
Statement: It is an honor to be asked to run for the Nominating Committee. If elected, I will work hard to help the AMS.

Susan Friedlander

Professor of Mathematics and Director of the Center for Applied Mathematical Sciences, University of Southern California.
Born: January 26, 1946, London, England.
Ph.D.: Princeton University, 1972.
AMS Offices: Member at Large of the Council, 1983–1985; Associate Secretary, 1996–2010.
AMS Committees: *Notices* Editorial Board, 1993–2013; *Program Committees*: AMS-Benelux Meeting, 1995–1996, AMS–South Africa Meeting, 1996–1997, AMS-Australia Meeting, 1998–1999, AMS-Spain Meeting, 2001–2003, AMS-India Meeting, 2001–2003, AMS-German-Austrian Meeting, 2002–2005, AMS-Poland Meeting, 2005–2007, Joint Mathematics Meetings, New Orleans, 2006–2007, AMS-Shanghai Meeting, 2006–2008, AMS-Mexican Meeting, 2009–2010; Committee to select hour speakers (Midwest section), 1996–2010; Chair, Colloquium Publication Series, 1996–2005; Co-organizer, Special Session on Jean Leray, AMS Austin Meeting, 1999; Joint committee on Women 2003–2005; Committee to prepare a proposal for an AMS Fellowship, 2006–2012; AMS representative to the Steering Committee for the 2013 Mathematical Congress of the Americas, 2011–2013.
Selected Addresses: Invited Speaker, Conference in honor of Mary Cartwright, Cambridge, 1991; Invited hour address, AMS Meeting, Dekalb, 1993; Invited plenary address, SIAM Annual Meeting, Atlanta, 1999; Invited Speaker, Conference in honor of Roger Temam, Paris, 2000; Invited Speaker, Conference for the 85th Birthday of Cathleen Morawetz, Toronto, 2008.
Additional Information: NSF Professorship for Women Award, 1993; Elected Honorary Member of the Moscow Mathematical Society, 1995; Medal of the Institut Henri Poincaré, 1998; Member, Institute for Advanced Study, 1999, 2005; Scientific Advisory Committee for M.S.R.I, 2001–2006; Editor in Chief, AMS *Bulletin*, 2005–2014; Board of Mathematical Sciences and their Applications of the National Academies, 2008–2011.

Selected Publications: 1. with W. Strauss and M. M. Vishik, Nonlinear instability in an ideal fluid, *Ann. Inst. H. Poincaré Anal. Non Linéaire*, **14** (1997), No. 2, 187–209. MR**1441392 (99a:76057)**; 2. Lectures on stability and instability of an ideal fluid, *Hyperbolic Equations and Frequency Interactions (Park City, UT, 1995)*, 227–304, IAS/Park City Math. Ser., 5, Amer. Math. Soc., Providence, RI, 1999. MR**1662831 (2000a:76001)**; 3. with N. Pavlovic, Blow up in a three dimensional vector model for the Euler equation, *Comm. Pure App. Math.*, **57** (2004), No. 6, 705–725. MR**2038114 (2005c:35241)**; 4. with A. Cheskidov, P. Constantin, and R. Shvydkoy, Energy conservation and Onsager's conjecture for the Euler equations, *Nonlinearity*, **21** (2008), No. 6, 1233–1252. MR**2422377 (2009g:76008)**; 5. with V. Vicol, Global well-posedness for an advection-diffusion equation arising in magneto-geostrophic dynamics, *Ann. Inst. H. Poincaré Anal. Non Linéaire*, **28** (2011), 283–301.
Statement: If elected to serve on the Nominating Committee, I will do my best to use the contacts and experience that I have acquired in the mathematical community to ensure that diverse slates of excellent candidates are presented to the AMS members for their consideration. Many challenges now face our profession. It is particularly important that we involve talented, energetic and dedicated people in leadership positions in the AMS.

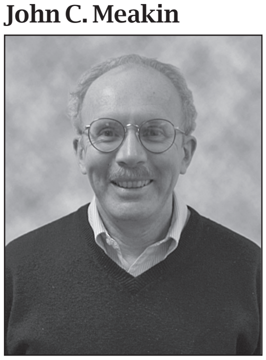
Fan Chung Graham

Professor of Mathematics, University of California, San Diego.
Born: October 9, 1949, Taiwan, R. O. C.
Ph.D.: University of Pennsylvania, 1974.
AMS Offices: Member at Large of the Council, 1989–1991.
AMS Committees: AMS-SIAM-IMS Joint Summer Research Conference Committee, 1991–1993; Editorial Board Committee, 1993–1996 (Chair, 1994); Committee on Committees,

1995–1996; National Award and Public Representation, 2000–2002, Fan Fund Committee, 2000–2003; Morgan Prize Committee, 2001–2004.
Selected Addresses: AMS/MAA Invited Address, Orono, Maine, 1991; AMS Invited Address, Washington, D. C., 1993; ICM Invited Address, Zürich, 1994; CBMS Lectures on Spectral Graph Theory, Fresno, CA, 1994; CBMS Lectures on the Combinatorics of Large Sparse Graphs, San Marcos, CA, 2004; AMS/MAA/SIAM Invited Address, San Diego, 2008; AWM Noether Lecture, Washington, D.C., 2009.
Additional Information: Conference Board on Mathematics Sciences, 1989–1992, 2001–2002; Allendoerfer Award, 1990; Board of Mathematical Sciences, National Research Council, 1995–1999; Member, American Academy of Arts and Sciences, 1998; Co-Editor-in-Chief: *Electronic Journal of Combinatorics*, 2000–2003, *Advances in Applied Mathematics*, 2000–2004, *Internet Mathematics*, 2003–, *Journal of Combinatorics*, 2010–; Editorial boards of 12 other journals.

Selected Publications: 1. Diameters and eigenvalues, *J. Amer. Math. Soc.* **2** (1989), No. 2, 187–196. MR**965008 (89k:05070)**; 2. with L. Lu and V. Vu, The spectra of random graphs with given expected degrees, *Internet Math.*, 1 (2004), No. 3, 257–275. MR2111009 (2005i:05175); 3. with L. Lu, *Complex Graphs and Networks*, CBMS Lecture Series, **107**, American Mathematical Society, 2006. MR**2248695 (2007i:05169)**; 4. with R. L. Graham and D. E. Knuth, A symmetric Eulerian identity, *J. Comb.* **1** (2010), 29–38. MR**2675920 (2011f:11025)**; 5. Graph theory in the information age, *Notices Amer. Math. Soc.*, **57** (2010), No. 6, 726–732. MR**2674816**.
No statement provided

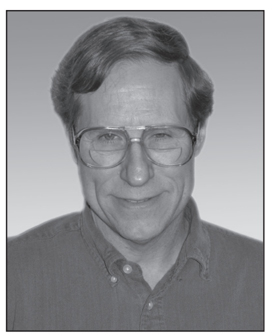
John C. Meakin



Milton Mohr Professor of Mathematics, University of Nebraska-Lincoln.
Born: March 13, 1946, Brisbane, Australia.
Ph.D.: Monash University, Australia, 1969.
AMS Committees: Committee on Professional Ethics (Chair, 2001–2004); Committee on Meetings and Conferences, 2006–2009.
Selected Addresses: Annual meeting of the Australian Mathematical Society, Townsville, Australia, 1990; International conference on words, languages and automata, Kyoto, Japan, 2000; Novikov conference, Moscow State University, Russia, 2001; Groups St. Andrews, Scotland, 2005 (four lectures); XXI Escola de Algebra, Brasilia, Brazil, 2010 (5 lectures).
Additional Information: Visiting positions (one month or more): University of Kerala, India, 1977–1978, Rijksuniversiteit te Gent, Belgium, 1983–1984, MSRI, Berkeley, 1989, Universite de Paris VI, 1989, Politecnico di Milano, 1994, Universite de Paris VII, 1999, CRM Barcelona, 2005; Managing Editor, *International Journal of Algebra and Computation*, 1990–2010; Chair, Department of Mathematics, University of Nebraska-Lincoln, 2003–2011; Organizing committee for international conferences on groups and semigroups at Monash University, Australia, 1990, University of Nebraska-Lincoln, 1998, 2000, 2009, AMS sectional meeting in Lincoln, Nebraska, 2005, special sessions of AMS meetings in Lincoln, Nebraska, 1987, 2005, College Station, Texas, 1993, Pisa, Italy, 2002.
Selected Publications: 1. with S. Margolis, Inverse monoids, trees and context free languages, *Trans. Amer. Math. Soc.*, **335** (1993), No. 1, 259–276. MR**1073775 (93h:20062)**; 2. with J.-C. Birget, S. Margolis, and P. Weil, PSPACE-complete problems for subgroups of free groups and inverse finite automata, *Theoret. Comput. Sci.*, **242** (2000), No. 1–2, 247–281. MR**1769781 (2001i:68058)**; 3. *Groups and Semigroups: Connections and Contrasts*, Groups St. Andrews 2005, Vol. 2, 357–400, London Math. Soc. Lecture Note Ser., 340, Cambridge Univ. Press, Cambridge, 2007. MR**2331597 (2008f:20145)**; 4. with T. Deis and G. Senizergues, Equations in free inverse monoids, *Internat. J. of Algebra Comput.*, **17** (2007), No. 4, 761–795. MR**2340815 (2008h:20088)**; 5. with M. Brittenham and S. Margolis, Subgroups of free idempotent generated semigroups need not be free, *J. Algebra*, **321** (2009), No. 10, 3026–3042. MR**2512640 (2010c:20070)**.

Statement: The American Mathematical Society is internationally recognized for its leadership in the promotion of research in the mathematical sciences, for the development and support of mathematical scientists, and for dissemination of mathematics and mathematical ideas. If elected, I will focus on identifying a diverse pool of people who have the talent, insight, energy and commitment to serve in various capacities in support of all aspects of the society's work.

Stephen D. Smith



Professor, Emeritus, University of Illinois at Chicago.
Born: June 11, 1948.
Selected Addresses: AMS Invited Address, South Bend, Indiana, 1991.
Additional Information: Rhodes Scholar, 1970–1973; Bateman Research Instructor, California Institute of Technology, 1973–1975; Member, London Mathematical Society; *Proceedings of the American Mathematical Society* Editorial Committee, 1999–2003.
Selected Publications: 1. Irreducible modules and parabolic subgroups, *J. Algebra*, **75** (1982), No. 1, 286–289. MR**0650422 (83g:20043)**; 2. with M. Aschbacher, On Quillen's conjecture for the *p*-groups complex, A*nn. of Math. (2)*, **137** (1993), No. 3, 473–529. MR**1217346 (94g:20073)**; 3. with M. Aschbacher, *The Classification of Quasithin Groups. II. Main Theorems: The Classification of Simple QTKE-groups.* Mathematical Surveys and Monographs, 112, American Mathematical Society, Providence, RI, 2004. MR**2097624 (2005m:20038b)**; 4. with D. Benson, *Classifying Spaces of Sporadic Groups*, Mathematical Surveys and Monographs, 147, American Mathematical Society,

Providence, RI, 2008. MR**2378355 (2009f:55017)**; 5. with M. Aschbacher, R. Lyons, and R. Solomon, *The Classification of Finite Groups: Groups of Characteristic 2 Type*, Mathematical Surveys and Monographs, 172, American Mathematical Society, Providence, RI, 2011.
Statement: If elected, I will serve.

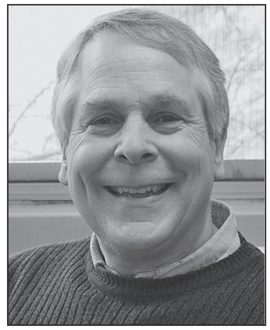
Editorial Boards Committee

Ralph Greenberg

Professor of Mathematics, University of Washington.
Born: September 2, 1944, Chester, Pennsylvania, USA.
Ph.D.: Princeton University, 1971.
Selected Addresses: Invited Address, AMS Summer Meeting, Eugene, Oregon, 1984; Invited Address, AMS Conference on Motives, Seattle, Washington, 1991; Seventh Kuwait Foundation Lecture, Cambridge, England, 2000; Plenary Lecture, Canadian Number Theory Association VIII Meeting, Toronto, Canada, 2004; Invited 45-Minute Lecture, ICM 2010, Hyderabad, India, 2010.
Additional Information: Organizer of Pacific Northwest Number Theory Conferences, Seattle, Washington, 1999, 2003 and 2007; Member, scientific organizing committee for conferences on Iwasawa theory, Besançon, France, 2004, Limoges, France, 2006, Kloster Irsee, Germany, 2008, Toronto, Canada, 2010.
Selected Publications: 1. On the Iwasawa invariants of totally real number fields, *Amer. J. Math.*, **98** (1976), No. 1, 263–284. MR**0401702 (53 #5529)**; 2. On the Birch and Swinnerton-Dyer conjecture, *Invent. Math.*, **72** (1983), No. 2, 241–265. MR**0700770 (85c:11052)**; 3. Iwasawa theory for p-adic representations, *Algebraic Number Theory*, 97–137, Adv. Stud. Pure Math., 17, Academic Press, Boston, MA, 1989. MR**1097613 (92c:11116)**; 4. Galois theory for the Selmer group of an abelian variety, *Compositio Math.*, 136 (2003), No. 3, 255–297. MR**1977007 (2004c:11097)**; 5. Iwasawa theory, projective modules, and modular representations, *Mem. Amer. Math. Soc.*, **992**, May, 2011.
Statement: The AMS journals perform a crucial function for the mathematical community. The choice of editors is an important one for maintaining the standards of the journals and for treating authors in a fair and responsible way. This is a time of change in the way our journals operate. If elected, I will do my best in the decision making tasks that will face the Editorial Boards Committee.

Jonathan I. Hall

Professor, Michigan State University, East Lansing, Michigan.
Born: October 20, 1949, Columbus, Ohio, USA.
D.Phil.: University of Oxford, 1974.
AMS Offices: Member of the Council, 2006–2010.
AMS Committees: Archives Committee, 2011–2014.
Selected Addresses: Invited Address, AMS Regional Meeting, Dayton, 1992; Williams College, Class of 1960



Lecturer, 2001; Invited Lecturer, Sociedad Matemática Mexicana, XXXIV Congreso Nacional, Toluca, 2001; Main Speaker, Loops '07, Prague, 2007; Main Speaker, Finite Groups and Algebraic Combinatorics, RIMS, Kyoto, 2007.
Additional Information: Editor, *Journal of Combinatorial Theory* (Series A), 1991–; Chairman, Department of Mathematics, Michigan State University, 1994–1997; J. S. Frame Teaching Award, Michigan State University, 2000; *Mathematical Reviews* Editorial Committee, 2001–2010 (Chair, 2006–2010); *AMS Proceedings* Editorial Committee, 2003–2011; Member, Institute of Electrical and Electronics Engineers, London Mathematical Society.

Selected Publications: 1. Classifying copolar spaces and graphs, *Quart. J. Math. Oxford Ser (2)*, **33** (1982), No. 132, 421–449. MR**0679813 (84b:51021)**; 2. with P. J. Cameron, Some groups generated by transvection subgroups, *J. Algebra*, **140** (1991), No. 1, 184–209. MR**1114913 (92g:20078)**; 3. with H. Cuypers, The 3-transposition groups with trivial center, *J. Algebra*, **178** (1995), No. 1, 149–193. MR**1358261 (96k:20056)**; 4. with S. M. Gagola III, Lagrange's theorem for Moufang loops, *Acta Sci. Math. (Szeged)*, **71** (2005), No. 1-2, 45–64. MR**2160355 (2006f:20079)**; 5. Periodic simple groups of finitary linear transformations, *Annals of Math.*, **163** (2006), No. 2, 445–498. MR**2199223 (2006k:20080)**.
Statement: The main contact the Society has with present and future mathematicians is through its publications. It is vital that publication quality and value remain high, and good editorial committees are essential for this. If elected, I will look for editors who are responsible, ethical, knowledgeable, and energetic. My goal would be broad, inclusive, and highly capable editorial committees that are committed to the quality and success of each publication.

David Hoff

Professor, Mathematics, Indiana University.
Born: October 23, 1948, Detroit, Michigan, USA.
Ph.D.: University of Michigan, 1977.
Selected Addresses: Plenary Lecture, RIMS Symposium on Mathematical Analysis in Fluid and Gas Dynamics, Kyoto, Japan, 2005; Plenary Lecture, FRG Workshop on Multidimensional Conservation Laws, Houston, 2006; Plenary Lecture, Conference on General Relativity and Shock Waves, Stanford University, 2006; Plenary Lecture, Conference on Hyperbolic Systems and Related Problems, Banff, 2006; Plenary Lecture, IMA Workshop on Compressible Flow, Minneapolis, 2009.
Additional Information: Chair, Department of Mathematics, Indiana University, 2003–2006.

Selected Publications: 1. Uniqueness of weak solutions of the Navier-Stokes equations of multidimensional compressible flow, *SIAM J. Math. Anal.*, **37** (2006), No. 6, 1742–1760. MR**2213392 (2006m:35280)**; 2. with M. Santos, Lagrangean structure and propagation of singularities in multidimensional compressible flow, *Arch. Ration. Mech. Anal.*, **188** (2008), No. 3, 509–543. MR**2393439 (2009c:35364)**; 3. with E. Tsyganov, Time analyticity and backward uniqueness of weak solutions of the Navier-Stokes equations of multidimensional, compressible flow, *J. Differential Equations*, **245** (2008), No. 10, 3068–3094. MR**2454813 (2009g:35235)**; 4. with M. Perepelitsa, Instantaneous boundary tangency and cusp formation in two-dimensional flow, *SIAM J. Math. Anal.*, **41** (2009), No. 2, 753–780. MR**2515784 (2010e:35215)**; 5. Asymptotic behavior of solutions to a model for the flow of a reacting fluid, *Arch. Ration. Mech. Anal.*, **196** (2010), No. 3, 951–979. MR**2644445**.

Statement: It is unquestioned that journals play an absolutely essential role in the dissemination of mathematical ideas. The AMS, being the main research-oriented professional society, should therefore play a major role in managing and publishing high-quality journals. Its editors and editorial board members must be accomplished research mathematicians whose interests reflect both the breadth and the depth of the subject, who exhibit organizational competence, and who meet the highest standards of professional integrity.

Dana Randall

Professor of Computer Science, Adjunct Professor of Mathematics, Georgia Institute of Technology.

Born: November 28, 1966, New York City, New York, USA.

Ph.D.: University of California at Berkeley, 1994.

AMS Committees: AMS-MAA Joint Program Committee, 2009; Program Committee for National Meetings, 2008–2010 (Chair, 2010).

Selected Addresses: AMS Invited Address, Joint Mathematics Meetings, Baltimore, MD, 2003; Invited Address, 28th Annual SIAM Southeast Atlantic Sectional Meeting, Johnson City, TN, 2004; Keynote Address, 4th Annual Conference on Nanoscience (FNANO), Snowbird, UT, 2007; AMS Arnold Ross Lecture, Augusta National Science Center, Augusta, GA, 2009; Invited Address, 12th Scandinavian Symposium and Workshops on Algorithm Theory (SWAT), Bergen, Norway, 2010.

Additional Information: NSF CAREER Award, 1997–2001; Alfred P. Sloan Research Fellow, 2001–2003; IBM Faculty Partnership Award, 2003; Co-Chair of the Planning Committee, Japanese-American Frontiers of Science Symposium (NAS and JSPS), Irvine, CA, 2006; Co-Chair of the Organizing Committee, DIMACS Special Focus on Discrete Random Models, 2006–2008; National Associate of the National Academies, 2008; Board of Governors, IMA, 2010–2012; Chair of the Program Committee, 22nd ACM/SIAM Symposium on Discrete Algorithms (SODA), San Francisco, CA, 2011; Editorial Boards: Associate Editor, *Annals of Applied Probability*, 2002–2005; Editor, *Theory of Computing*, 2004–; Associate Editor, SIAM *Journal on Discrete Mathematics*, 2007–.

Selected Publications: 1. with A. J. Sinclair, Self-testing algorithms for self-avoiding walks, *J. Math. Phys.*, **41** (2000), No. 3, 1570–1584. MR**1757970 (2001c:82033)**; 2. with M. Luby and A. J. Sinclair, Markov chain algorithms for planar lattice structures, *SIAM J. Comput.*, **31** (2001), No. 1, 167–192. MR**1857394 (2002h:82046)**; 3. with N. Madras, Markov chain decomposition for convergence rate analysis, *Ann. Appl. Probab.*, **12** (2002), No. 2, 581–606. MR**1910641 (2003d:60135)**; 4. with R. Martin, Disjoint decomposition of Markov chains and sampling circuits in Cayley graphs, *Combin. Probab. Comput.*, **15** (2006), No. 3, 411–448. MR**2216477 (2007f:60056)**; 5. with M. Cryan and M. Dyer, Approximately counting integral flows and cell-bounded contingency tables, *SIAM J. Comput.*, **39** (2010), No. 7, 2683–2703. MR**2645886**.

Statement: The AMS is widely recognized for the excellence of its journals and books. It is critical to the vitality of these publications that we appoint editorial boards who maintain these high standards while also representing the diversity and breadth of the mathematical community. I would aim to identify capable board members with a shared commitment to these values.

CALL FOR Suggestions

Your suggestions are wanted by:

The Nominating Committee, for the following contested seats in the 2012 AMS elections:
vice president, trustee,
and five members at large of the Council

Deadline for suggestions: November 5, 2011

The President, for the following contested seats in the 2012 AMS elections:
three members of the Nominating Committee
two members of the Editorial Boards Committee

Deadline for suggestions: February 25, 2012

The Editorial Boards Committee, for appointments to various editorial boards of AMS publications

Deadline for suggestions: Can be submitted any time
Send your suggestions for any of the above to:

Robert J. Daverman, Secretary
American Mathematical Society
Department of Mathematics
237 Ayers Hall
University of Tennessee
1403 Circle Drive
Knoxville, TN 37996-1320 USA
email: secretary@ams.org

AMS
AMERICAN MATHEMATICAL SOCIETY
www.ams.org

2012 AMS Election

Nominations by Petition

Vice President or Member at Large

One position of vice president and member of the Council *ex officio* for a term of three years is to be filled in the election of 2012. The Council intends to nominate at least two candidates, among whom may be candidates nominated by petition as described in the rules and procedures.

Five positions of member at large of the Council for a term of three years are to be filled in the same election. The Council intends to nominate at least ten candidates, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

Petitions are presented to the Council, which, according to Section 2 of Article VII of the bylaws, makes the nominations. The Council of 23 January 1979 stated the intent of the Council of nominating all persons on whose behalf there were valid petitions.

Prior to presentation to the Council, petitions in support of a candidate for the position of vice president or of member at large of the Council must have at least fifty valid signatures and must conform to several rules and procedures, which are described below.

Editorial Boards Committee

Two places on the Editorial Boards Committee will be filled by election. There will be four continuing members of the Editorial Boards Committee.

The President will name at least four candidates for these two places, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

The candidate's assent and petitions bearing at least 100 valid signatures are required for a name to be placed on the ballot. In addition, several other rules and procedures, described below, should be followed.

Nominating Committee

Three places on the Nominating Committee will be filled by election. There will be six continuing members of the Nominating Committee.

The President will name at least six candidates for these three places, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

The candidate's assent and petitions bearing at least 100 valid signatures are required for a name to be placed on the ballot. In addition, several other rules and procedures, described below, should be followed.

Rules and Procedures

Use separate copies of the form for each candidate for vice president, member at large, member of the Nominating or Editorial Boards Committees.

1. To be considered, petitions must be addressed to Robert J. Daverman, Secretary, American Mathematical Society, 237 Ayres Hall, University of Tennessee, Knoxville, TN 37996-1320 USA, and must arrive by 25 February 2012.
2. The name of the candidate must be given as it appears in the *Combined Membership List* (`www.ams.org/cml`). If the name does not appear in the list, as in the case of a new member or by error, it must be as it appears in the mailing lists, for example on the mailing label of the *Notices*. If the name does not identify the candidate uniquely, append the member code, which may be obtained from the candidate's mailing label or by the candidate contacting the AMS headquarters in Providence (amsmem@ams.org).
3. The petition for a single candidate may consist of several sheets each bearing the statement of the petition, including the name of the position, and signatures. The name of the candidate must be exactly the same on all sheets.
4. On the next page is a sample form for petitions. Petitioners may make and use photocopies or reasonable facsimiles.
5. A signature is valid when it is clearly that of the member whose name and address is given in the left-hand column.
6. The signature may be in the style chosen by the signer. However, the printed name and address will be checked against the *Combined Membership List* and the mailing lists. No attempt will be made to match variants of names with the form of name in the *CML*. A name neither in the *CML* nor on the mailing lists is not that of a member. (Example: The name Robert J. Daverman is that of a member. The name R. Daverman appears not to be.)
7. When a petition meeting these various requirements appears, the secretary will ask the candidate to indicate willingness to be included on the ballot. Petitioners can facilitate the procedure by accompanying the petitions with a signed statement from the candidate giving consent.

Nomination Petition
for 2012 Election

The undersigned members of the American Mathematical Society propose the name of

____

as a candidate for the position of (check one):

- ☐ **Vice President**
- ☐ **Member at Large of the Council**
- ☐ **Member of the Nominating Committee**
- ☐ **Member of the Editorial Boards Committee**

of the American Mathematical Society for a term beginning 1 February, 2013

Return petitions by 25 February 2012 to:
Secretary, AMS, 237 Ayres Hall, University of Tennessee, Knoxville, TN 37996-1320 USA

Name and address (printed or typed)	
	Signature
	Signature
	Signature
	Signature
	Signature
	Signature

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/.

September 2011

1–3 **Algebraic Representation Theory Conference**, Uppsala University, Uppsala, Sweden. (Mar. 2011, p. 496)
Invited speakers: Henning Haahr Andersen (Århus); Igor Burban (Bonn); Maud De Visscher (London); Berhnard Keller (Paris); Paul Martin (Leeds); Vanessa Miemietz (UEA); Sergey Mozgovoy (Oxford); Steffen Oppermann (Trondheim).
Organizer: Volodymyr Mazorchuk (Uppsala)
Information: http://www.math.uu.se/Conference/.

1–3 **Elementary Geometry from an Advanced Point of View**, University of Aveiro, Aveiro, Portugal. (Jun/Jul. 2011, p. 856)
Description: The general aim of the conference is to present several contemporary perspectives on Geometry including, among others, talks on visualization, applications and surveys, both at elementary and more advanced levels. The goal is to contribute to the current international reflection on the ICMI/IMU Klein Project concerning central topics on Geometry, its contents, interdisciplinary connections and approaches for the teaching of this mathematics discipline at senior secondary school and first years at University level. The conference includes the Workshop "EnsGeo I" to be held on September 3 (last day of the conference), focused on dissertation works in Geometry carried out on Graduate courses in Mathematics for Teaching.
Information: http://c3.glocos.org/egapv2011/.

1–3 **26th British Topology Meeting**, ICMS, South College Street, Edinburgh, England. (Aug. 2011, p. 1010)
Description: The 26th annual British Topology Meeting will take place at ICMS in Edinburgh September 1-3, 2011.
Invited speakers: Javier Aramayona (Galway), Stefan Friedl (Cologne), Jacob Rasmussen (Cambridge), Saul Schleimer (Warwick), Catharina Stroppel (Bonn), Ulrike Tillmann (Oxford) and Karen Vogtmann (Cornell).
Registration: Participants are required to register by August 1, 2011. See http://www.maths.gla.ac.uk/~ajb/btop/btop-meetings.html| for a list of previous British Topology Meetings.
Organizer: Jim Howie (Heriot-Watt) and Andrew Ranicki (Edinburgh).
Information: http://www.icms.org.uk/workshops/btm.

2–6 **Polynomial Identities in Algebras. II.**, Memorial University of Newfoundland, St. John's, NL, Canada. (Aug. 2011, p. 1010)
Description: The workshop is organized by Atlantic Algebra Centre and financially supported by Atlantic Association for Research in the Mathematical Sciences and Memorial University of Newfoundland. The first workshop under the same title was held at Memorial University of Newfoundland in August – September 2002. Since then the theory of polynomial identities in algebra has experienced a strong development. A number of problems have been solved. New methods have been introduced, in particular, the methods developed in the theory of group gradings of associative, Lie and Jordan algebras. In addition to traditional combinatorial methods, people working on polynomial identities make more frequent use of the representation theory, the theory of Hopf algebras, and techniques involving computers. The aim of this workshop is to survey the main achievements in the area for the last 9 years, discuss the current progress and to determine future directions and outstanding problems.
Information: http://www.mun.ca/aac/Workshops/NextWork/.

3–9 **10th International Conference on Geometry and Applications**, Geometrical Society "Boyan Petkanchin", Sofia, Bulgaria. (Apr. 2011, p. 628)
Description: 10th International Conference on Geometry and Applications is organized from Geometrical Society "Boyan Petkanchin" in Bulgaria. The following fields are included: differential geometry,

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/.

finite geometries, computer methods in geometry, algebra and analysis, education in the school and university by computers, didactic of mathematics.
Information: Please contact: Prof. Dr. Grozio Stanilov; `stanilov@fmi.uni-sofia.bg` and Chavdar Lozanov; `lozanov@fmi.uni-sofia.bg`.

* 4–8 **International Symposium of Geometric Function Theory and Applications**, Babes-Bolyai University, Cluj-Napoca, Romania.
Description: The aim of the conference is to bring together leading experts as well as young researchers working on topics mainly related to Univalent Functions and Geometric Function Theory with applications in various areas of mathematics and to present their recent work to the mathematical community. The conference is mainly dedicated to the 80th birthday of Professor Petru T. Mocanu.
Topics: Univalent and multivalent functions, special functions and series, differential subordinations, conformal and quasiconformal mappings, geometric function theory in several complex variables, potential analysis and applications, other areas related to GFTA.
Information: `http://www.uab.ro/conference/gfta/`.

5–9 **AGMP&MP2 Summer School: Mathematical Topics in Quantum Mechanics and Quantum Information**, Tjärnö, Sweden. (May 2011, p. 743)
Description: The aim of the Summer School is to introduce Ph.D. students and junior researchers of mathematical and physical specialities to mathematical methods of quantum mechanics and quantum information.
Information: `http://www.agmp.eu/3q11/`.

5–9 **5th International Conference on Stochastic Analysis and Applications**, Bonn, Germany. (Jun/Jul. 2011, p. 856)
Description: The main topics of the conference will be (but not limited to) A. Dirichlet forms and stochastic analysis B. Jump processes C. Stochastic partial differential equations D. Stochastic analysis and geometry E. Optimal transport and allocation problems F. Functional analysis G. Random media, percolation clusters and fractals H. Stochastic models in physics and biology. These areas are strongly related to each other and have been very active in recent years. They occupy a central place in modern probability theory and analysis. The primary goal of the conference is to bring researchers in areas listed above, from all over the world, to survey the fields, exchange ideas and to foster future collaborations. Another important goal is to expose young researchers and Ph.D. students to the most recent developments in active areas of probability theory. Deadline for submitting a talk: May 1st. Conference fee of 90(euro) for non-students and 60 for students to be paid on arrival.
Information: `http://icsaa.iam.uni-bonn.de/`.

* 5–9 **European Women in Mathematics (EWM)**, Centre de Recerca Matemàtica, Bellaterra, Barcelona.
Description: This meeting is the 15th general meeting of European Women in Mathematics (EWM), and is being held with the support of the Foundation Compositio Mathematica. European Women in Mathematics is an international association of women working in the field of mathematics. Its aims are: a) to encourage women to study mathematics, b) to support women in their careers, c) to provide a meeting place for like-minded people, d) to promote scientific communication, e) to cooperate with groups and organizations with similar goals, f) to gather and provide information on women in mathematics.
Information: `http://www.crm.cat/ewm`.

5–9 **Nonlinear Dynamics Conference in Memory of Alexei Pokrovskii**, University College Cork, Cork, Ireland. (Jun/Jul. 2011, p. 857)
Description: The aim of this meeting is to honour the memory and work of Alexei Pokrovskii, an eclectic mathematician and a pioneer in the mathematical theory of systems with hysteresis, who unexpectedly died on September 1, 2010, aged 62. For the last nine years Alexei was Professor and Head of Department of Applied Mathematics at University College Cork. Topics of this conference will reflect the diversity of Alexei's contribution to science and will include nonlinear dynamical systems, systems with hysteresis, chaos and complexity, stochastic systems, control theory, nonlinear functional analysis, singularly perturbed systems and mathematical modeling for applications in engineering, physics, biology and economics. Sponsors: KE Consulting Group (Cork), Tyndall National Institute (Cork).
Information: `http://www.ucc.ie/en/euclid/NonlinearDynamicsConferenceinMemoryofAlexeiPokrovskii/`.

5–9 **RSME2011 Congress of Young Researchers**, Campus Duques de Soria Universidad de Valladolid soria, Spain. (Jun/Jul. 2011, p. 857)
Description: Congress devoted to young researchers in mathematics in ocasion of the Spanish Royal Mathematical Society centenary.
Information: `http://www.jirsme.uva.es/`.

5–10 **Toric Topology and Automorphic Functions**, Pacific National University, Khabarovsk, Russia. (May 2011, p. 743)
Program Committee: Victor Buchstaber (Steklov Mathematical Institute, Moscow, chairman); Mikhail Guzev (Institute of Applied Mathematics, Vladivostok, vice-chairman); Frederic Cohen (Rochester University, USA); Mikiya Masuda (Osaka City University, Japan); Taras Panov (Moscow State University); Iskander Taimanov (Sobolev Institute of Mathematics); Alexander Podgaev (Pacific National University).
Important dates: Deadline for registration: April 30, 2011. Deadline for submission of abstracts: May 30, 2011. Recommended arrival day: September 4, 2011. September 5–10, 2011: Conference.
Information: See `http://iam.khv.ru/ttaf-2011/the1st_announcement.htm`.

6–9 **VI International Meeting on Lorentzian Geometry. Granada 2011**, Science Faculty, University of Granada, Granada, Spain. (Aug. 2011, p. 1010)
Description: Lorentzian Geometry was born as a mathematical theory useful for General Relativity. Nowadays, it constitutes a branch of Differential Geometry where many mathematical techniques are involved (Lie groups and algebras, Partial Differential Equations, Geometric Analysis, Functional Analysis,...). This meeting is the sixth edition of a biennial series which started in 2001.
Topics: On pure and applied Lorentzian Geometry such as geodesics, submanifolds, causality, black holes, Einstein equations, geometry of spacetimes or AdS-CFT correspondence, will be covered. The meeting will include two minicourses imparted by professors Vladimir Chernov (Dartmouth College, USA) and Paolo Piccione (University of Sao Paulo, Brazil).
Information: `http://gigda.ugr.es/gelogra/`.

7–9 **Fourth International Workshop on Analysis and Numerical Approximation of Singular Problems (IWANASP 2011)**, University of Chester, Chester, United Kingdom. (Jun/Jul. 2011, p. 857)
Description: The mathematical modelling of physical problems often leads to differential or integral equations whose coefficients have singularities. The numerical treatment of such models requires: a) the correct formulation of problems and the analysis of qualitative behavior of solutions; b) the use of efficient numerical algorithms which take into account the singularities of the problems. The main objective of the present workshop is to bring together mathematicians who deal with problems of this kind in different fields. The workshop will focus on the asymptotic properties of the solutions of equations and discretization methods. The themes that will be discussed include: mathematical modelling of physical phenomena involving singularities; numerical solution of singular boundary value problems for ordinary differential equations; numerical integration of functions with singularities; computational methods for integral equations with singular kernels.

Information: http://www.stochasticdelay.org.uk/IWANASP.

7–9 **ICERM Semester Program - Kinetic Theory: Analysis and Computation**, ICERM, Providence, Rhode Island. (Jun/Jul. 2011, p. 857)
Description: This semester-long program in kinetic theory and computation will provide the participants with an introduction to a broad range of analytical and computational aspects of kinetic theory. The program will be centered around three broad topics, for each of which an international workshop will be held.
Information: http://icerm.brown.edu/sp-f11/.

7–9 **IMA Hot Topics Workshop: Instantaneous Frequencies and Trends for Nonstationary Nonlinear Data**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota. (Oct. 2010, p. 1166)
Description: In this workshop, we will explore the issues involved in trend determination and instantaneous frequency. This workshop will bring together experts from these areas to exchange ideas and identify new research opportunities for this emerging research area. One of the main objectives of the workshop is to promote research that leads to the discovery and understanding of the underlying processes in order to provide a base for building predictive models. An extension of the trend study is the problem of regression, which is also of great interest to a broad research community, including the econometrics/finance community.
Information: See http://www.ima.umn.edu/2011-2012/SW9.7-9.11/.

8–9 **New York Workshop on the Symmetric Group and Related Topics**, CUNY Graduate Center, Manhattan, New York. (Jun/Jul. 2011, p. 857)
Description: This workshop will focus on current research and new developments in the study of the symmetric groups. Topics will include: ordinary and modular theory of the symmetric groups and related groups, graded and hecke algebras, connections with geometry, and combinatorics, number theory and partitions.
Information: http://symmetricgroup.commons.gc.cuny.edu/2010/10/03/ny-workshop-on-the-symmetric-group-and-related-topics/.

9–10 **IV International Conference named by academician Ivan I. Lyashko—Computational and Applied Mathematics**, Deparment of Cybernetics of the Kiev National Taras Shevchenko University, Kiev, Ukraine. (Jun/Jul. 2011, p. 857)
Description: Main areas of the conference: computational mathematics optimal control and theory of extremal problems mathematical modelling filtration theory.
Information: http://om.univ.kiev.ua/conf/.

10–11 **AMS Eastern Section Meeting**, Cornell University, Ithaca, New York. (Sept. 2010, p. 1036)
Information: http://www.ams.org/meetings/sectional/sectional.html.

10–17 **International Conference "Harmonic Analysis and Approximations, V"**, Tsaghkadzor, Armenia. (Mar. 2011, p. 496)
Description: The conference will be held at Yerevan State University's guesthouse, Tsaghkadzor (Armenia). The conference is dedicated to the 75th anniversary of academician of NAS of Armenia Norair Arakelian.
Talks: The following mathematicians have agreed to give a plenary lecture at the conference: David Drasin (USA), Sergey Konyagin (Russia), Michael Lacey (USA), Svitlana Mayboroda (USA), Jurgen Muller (Germany), Konstantin Oskolkov (Russia), Wieslaw Plesniak (Poland), Alexei Shadrin (UK), Winfried Sickel (Germany), Mikhail Sodin (Israel), Vilmos Totik (Hungary and USA), Przemyslaw Wojtaszczyk (Poland)
Information: http://math.sci.am/conference/sept2011/conf.html.

11–15 **Israeli-Polish Mathematical Meeting**, University of Łódz´, Poland. (May 2011, p. 743)
Description: Israeli-Polish Mathematical Meeting is a joint initiative of the Polish Mathematical Society (PTM) and Israel Mathematical Union (IMU). The main purpose of the conference is to stimulate the exchange of new ideas in all aspects of mathematics. Mathematicians from other countries are also cordially invited to participate. The meeting program will cover many topics pertaining to mathematical research conducted in Israel and Poland. The meeting will consist of plenary lectures, thematic sections and other informal scientific discussions and social activities as well. All the talks will be in English. The meeting will be hosted by the University of Łódz´, Faculty of Mathematics and Computer Science, Łódz´, Poland. The conference will start in the morning of Monday, September 12, 2011 and end in the afternoon of Thursday, September 15, 2011.
Information: http://imuptm.math.uni.lodz.pl.

11–17 **14th International Conference on Functional Equations and Inequalities**, Mathematical Research and Conference Center, Bedlewo (near Poznan), Poland. (Apr. 2011, p. 628)
Description: The International Conference on Functional Equations and Inequalities - ICFEI has been organized by the Institute of Mathematics of the Pedagogical University of Cracow since 1984. The conference is devoted to functional equations and inequalities, their applications in various branches of mathematics and other scientific disciplines, as well as related topics. The 14th ICFEI is included in the programme of the Stefan Banach International Mathematical Center of the Polish Academy of Sciences.
Information: http://mat.up.krakow.pl/icfei/14ICFEI/.

11–17 (NEW DATE) **Turning Dreams into Reality: Transformations and Paradigm Shifts in Mathematics Education**, Rhodes University, Grahamstown, South Africa. (Feb. 2010, p. 307)
Description: International Conference of The Mathematics Education into the 21^{st} Century Project.
Preliminary Announcement and Call for Papers: The Mathematics Education into the 21^{st} Century Project has just completed its tenth successful international conference in Dresden, Germany, following conferences in Egypt, Jordan, Poland, Australia, Sicily, Czech Republic, Malaysia and the USA. Our project was founded in 1986 and is dedicated to the planning, writing and disseminating of innovative ideas and materials in Mathematics, Statistics, Science and Computer Education.
Organizing Committee: The chairman is Professor Marc Schafer of Rhodes University.
Information:
Deadline: For proposals has been extended to February 1, 2011. Even though the official deadline was February 1, 2011 we will continue to accept them, but please send them as soon as possible. There is now a "new" conference bank account for registration fees. For further conference details please email Alan Rogerson, Chairman of the International Programme Committee: alan@rogerson.pol.pl; http://math.unipa.it/~grim/21project.htm.

12–14 **Workshop on Fluid Dynamics in Porous Media**, Department of Mathematics of University of Coimbra, Coimbra, Portugal. (Jun/Jul. 2011, p. 857)
Description: The workshop on Fluid Dynamics in Porous Media is an initiative of the UT Austin–Portugal programme for Mathematics, in partnership with CMUC (Centre for Mathematics of University of Coimbra). The event focuses on mathematical models and numerical simulation in fluid dynamics in porous media bringing together mathematicians, engineers, geoscientists, and computing experts in a cooperative environment.
Invited speakers: Faruk Civan, University of Oklahoma, USA; Vivette Girault, Université Pierre et Marie Curie, France; Majid Hassanizaded, Utrecht University, Netherlands; Andro Mikelic, Université Claude Bernard Lyon 1, France; Roland Muggli, Galp E&P, Portugal; Paula de

Oliveira, University of Coimbra, Portugal; Daniel Tartakovsky, University of California, USA.
Information: http://www.mat.uc.pt/~wfdpm.

* 12–15 **Geometry, Groups, and Topology**, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.
Description: The conference will highlight recent advances in geometry, topology, and geometric group theory and aims at fostering communication between experts and young researchers as well as identifying potential new directions of further research in these fields.
Organizers: Anand Dessai (Fribourg), Enrico Leuzinger (Karlsruhe) and Wilderich Tuschmann (Karlsruhe).
Information: http://www.math.kit.edu/iag5/seite/ggtconference.

12–16 **8th International Conference on Combinatorics on Words, WORDS 2011**, Czech Technical University in Prague, Prague, Czech Republic. (Dec. 2010, p. 1498)
Description: The central topic of WORDS conferences is the mathematical theory of words (i.e., finite or infinite sequences of symbols taken from a finite alphabet) from all points of view: combinatorial, algebraic, algorithmic, as well as its applications to physics, biology, linguistics and others.
Information: http://words2011.fjfi.cvut.cz/.

12–16 **25th IFIP TC 7 Conference on System Modeling and Optimization**, University of Technology, Berlin, Germany. (Nov. 2010, p. 1349)
Description: The International Federation for Information Processing (IFIP) Technical Committee 7 - System Modeling and Optimization - arranges in a cycle of two years highly regarded conferences in Applied Optimization, with topics such as Optimal Control of Ordinary and Partial Differential Equations, Modeling and Simulation, Nonlinear, Discrete, and Stochastic Optimization and Industrial Applications.
Information: http://www.ifip2011.de.

12–16 **AIM Workshop: L^2 invariants and their relatives for finitely generated groups**, American Institute of Mathematics, Palo Alto, California. (Aug. 2010, p. 905)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the study of the asymptotic behavior of some natural invariants of finitely generated groups.
Information: http://aimath.org/ARCC/workshops/l2invfggroups.html.

12–16 **ISAM-TopMath Summer School 2011: Variational Methods**, Technische Universitaet, Muenchen, Germany. (Aug. 2011, p. 1010)
Description: This is a joint summer school of ISAM (International School of Applied Mathematics) and TopMath on `Variational Methods' open to graduate students and postdocs. A line-up of speakers who are both outstanding researchers and excellent presenters will give state-of-the-art insight into – variational evolution problems (Mielke/Berlin) – optimal transport (Sturm/Bonn) – optimal control of PDE (Casas/Santander) and – applications in materials science (Ortiz/CalTech). A limited amount of funding is available.
Information: http://www.ma.tum.de/Mathematik/IsamSummerSchoolEn.

12–December 16 **Mathematical and Computational Approaches in High-Throughput Genomics**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Sept. 2010, p. 1036)
Description: The goal of this long program is to bring together mathematical and computational scientists, sequencing technology developers in both industry and academia, and the biologists who use the instruments for particular research applications. This presents a unique opportunity to foster interactions between these three communities over an extended period of time and advance the mathematical foundations of this exciting field. We urge you to apply as early as possible. Applications will be accepted through May 12, 2011, but decisions will be made starting in December.
Information: http://www.ipam.ucla.edu/programs/gen2011/.

12–16 **Satellite Meeting Unravelling and Controlling Discrete Dynamical Systems**, Vienna, Austria. (May 2011, p. 743)
Description: The Satellite Meeting Unravelling and Controlling Discrete Dynamical Systems is organized during the 8th European Conference on Complex Systems (ECCS).
Goals: Are fourfold: foster the interest in discrete dynamical systems; communicate the most recent advances on the means to quantitatively grasp and control discrete dynamical systems; perpetuate the dynamical systems point of view on the intriguing dynamics of cellular automata; gain insight into the dynamics of models based upon discrete modelling paradigms.
Deadline: For abstract submission: May 10, 2011.
Information: http://www.disdysys.ugent.be/.

12–16 **Summer School on Partial Differential Equations**, Märkisches Gildehaus, Caputh, Germany. (Aug. 2011, p. 1010)
Description: The aim of the Summer School is to offer young scholars the possibility to get an introduction to recent developments in partial differential equations and their applications by distinguished international experts. Lecture series are given by G. Huisken (MPI Golm), R. Klein (FU Berlin), H. Kozono (Tohoku), F. Otto (MPI Leipzig). The school addresses students working towards a Master's degree or a Ph.D. Young postdocs are also welcome. Scholarships are available which cover travel expenses and accommodation. For application details, please visit the website.
Information: http://www.math-conf.uni-hannover.de/pde11.

17–18 **40 Years and Counting: AWM's Celebration of Women in Mathematics**, Brown University, Providence, Rhode Island. (Jun/Jul. 2011, p. 858)
Description: 40 Years and Counting: 2011 is the 40th anniversary of the Association for Women in Mathematics (AWM). With this conference, AWM continues to celebrate the progress of women in mathematical professions and to recognize individual achievements. Join us this fall on the Brown University campus in historic Providence, RI.
Organizing Committee: Georgia Benkart (University of Wisconsin-Madison), Kristin Lauter (Microsoft Research), Jill Pipher (Brown University/ICERM).
Plenary Speakers: Andrea Bertozzi (UCLA), Laura DeMarco (University of Illinois at Chicago), Barbara Keyfitz (The Ohio State University), Hee Oh (Brown University).
Information: http://icerm.brown.edu/events/awm-anniversary-2011/.

* 18–20 **International Workshop on Next Generation Intelligent Medical Decision Support Systems**, Petru Maior University, Targu Mures, Mures, Romania.
Description: The purpose of the workshop is to bring together researchers working in the main areas of Applications in the Medical Domain and the Healthcare Domain. The workshop proposes themes like: Applied mathematics, Medical decision support systems, Medical informatics, Efficient archiving of visual medical information, Archiving of biomedical signals, Management of large medical databases, Complex systems, Biostatistics, Artificial Intelligence applied in medicine, Intelligent medical systems. The guests are invited to present their recently achieved results, exchange ideas and cooperate in a friendly framework.
Information: http://ncscs.upm.ro.

18–21 **2011 Federated Conference on Computer Science and Information Systems (FedCSIS)**, Szczecin, Poland. (Aug. 2011, p. 1010)
Call for Papers: Papers should be submitted by June 19th, 2011, using the FedCSIS EasyChair submission system: http://www.easychair.org/account/signin.cgi?conf=fedcsis2011.

Accepted and presented papers will be published in the IEEE Xplore Digital Library proceedings entitled: "2011 Federated Conference on Computer Science and Information Systems (FedCSIS)." The IEEE proceedings will be published under nonexclusive copyright. The events' organizers arrange quality journals, edited volumes, etc. and will invite extended and revised papers for post-conference publications (information can be found at the web-sites of individual events).
Information: http://www.fedcsis.org.

18–22 **Getting started with PDE**, Technion- I.I.T., Haifa, Israel. (Jun/Jul. 2011, p. 858)
Description: The workshop's aim is to introduce graduate and advanced undergraduate students to a variety of subjects of current research in Partial Differential Equations and Applied Mathematics. The required prerequisites are familiarity with the basic material taught in undergraduate courses in mathematics.
Information: http://www.math.technion.ac.il/cms/decade_2011-2020/year_2010-2011/summer-workshop/.

18–24 **8th International Conference on Function Spaces, Differential Operators, Nonlinear Analysis (FSDONA-2011)**, Tabarz/Thuringia, Germany. (Apr. 2011, p. 628)
Description: This meeting will continue the series of previous successful FSDONA-conferences held in Finland, Czech Republic, and Germany: Sodankylä-88, Friedrichroda-92, Paseky-95, Syöte-99, Teistungen-01, Milovy-04, Helsinki-08. It is our intention to stimulate international collaboration, and to promote the interaction of function spaces, PDE and computational mathematics in unifying efforts. This time the focus will lie on the theory of function spaces and its applications to various fields of mathematics like: PDE's (existence of solutions and regularity theory), spectral theory of differential and integral operators, approximation and computational mathematics, nonlinear analysis, inverse problems.
Information: http://fsdona2011.uni-jena.de/.

* 19–21 **Quantum groups, categorification and braids**, IRMA, CNRS & Université de Strasbourg, 7 rue René Descartes, 67084 Strasbourg, Cedex, France.
Description: This conference is to be held on the occasion of Christian Kassel's 60th birthday.
Speakers: E. Aljadeff, D. Bar-Natan, J. Bichon, C. Blanchet, P. Dehornoy, D. Hernandez, B. Keller, M. Kontsevich, B. Leclerc, H.-J. Schneider, C. Soulé, C. Stroppel, V. Turaev, E. Vasserot, P. Vogel.
Information: http://www-irma.u-strasbg.fr/annexes/conferences/K60/index.html.

19–23 **Probabilistic Reasoning in Quantitative Geometry**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1010)
Description: "Probabilistic Reasoning in Quantitative Geometry" refers to the use of probabilistic techniques to prove geometric theorems that do not have any a priori probabilistic content. A classical instance of this approach is the probabilistic method to prove existence of geometric objects. Other examples are the use of probabilistic geometric invariants in the local theory of Banach spaces, the more recent use of such invariants in metric geometry, probabilistic tools in group theory, the use of probabilistic methods to prove geometric inequalities, the use of probabilistic reasoning to prove metric embedding results such as Bourgain's embedding theorem, probabilistic interpretations of curvature and their applications, and the use of probabilistic arguments in the context of isoperimetric problems.
Information: http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm574.

19–23 **The Sixteenth Asian Technology Conference in Mathematics (ATCM 2011)**, Abant izzet Baysal University, Bolu, Turkey. (Dec. 2010, p. 1498)
Description: The ATCM 2011 is an international conference to be held in Turkey that will continue addressing technology-based issues in all Mathematical Sciences. Thanks to advanced technological tools such as computer algebra systems (CAS), interactive and dynamic geometry, and hand-held devices, the effectiveness of our teaching and learning, and the horizon of our research in mathematics and its applications continue to grow rapidly. 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.
Information: http://atcm2011.org.

19–23 **Workshop: Vlasov Models in Kinetic Theory**, ICERM, Providence, Rhode Island. (Jun/Jul. 2011, p. 858)
Description: Vlasov-type models deal with continua of particles where the electric charges dominate the collisions, so that the collisions are ignored. They occur in physical plasmas, including astrophysical plasmas and fusion reactors. There are many examples of astrophysical plasmas of this type, such as the solar wind. When a fusion reactor is very hot, the relevant times scales are so short that collisions can be ignored. Vlasov theory also models systems where the dominant force is gravity, such as clusters of stars or galaxies.
Information: http://icerm.brown.edu/sp-f11/workshop-1.php.

19–25 **ICNAAM2011 Symposium: Semigroups of Linear Operators and Applications**, G-Hotels, Halkidiki, Greece. (Feb. 2011, p. 336)
Information:
Description: The 2nd Symposium on "Semigroups of Linear Operators and Applications" brings together researchers from all over the world to present new results in the theory of linear operators and its applications. Besides scheduling talks from established mathematicians, we will give opportunity to junior researchers to present their works.
Topics: Groups and semigroups of linear operators, one-parameter semigroups and linear evolution equations, Markov semigroups and applications to diffusion processes, Schrödinger and Feynman-Kac semigroups, operator sine and cosine functions, C-semigroups, integrated semigroups,diffusion processes,diffusion processes and Stochastic analysis on manifolds, selfadjoint operator theory in quantum theory, dynamic lattice systems.
Information: http://www.fih.upt.ro/personal/dan.lemle/Lemle_Simpozion_2011.htm.

19–26 **Conference on Geometric Structures in Mathematical Physics**, Albena, Bulgaria. (Apr. 2011, p. 628)
Description: The purpose of the conference is to bring together physicists and mathematicians working in related areas of geometry, geometric analysis and theoretical physics. The main focus will be on special geometric structures and their applications in differential and algebraic geometry, theoretical physics and string theory.
Information: http://www.fmi.uni-sofia.bg/ivanovsp/MathPhys2011.html.

22–25 **16th annual cum 2nd International Conference of Gwalior Academy of Mathematical Sciences (GAMS) & 2nd International conference of bioinformatics**, S. S. Dempo College of Commerce and Economics, Altinho Panaji Goa, India. (Jun/Jul. 2011, p. 858)
Description: (GAMS) is a forum for activities on Mathematical Modeling of real life problems, launched in 1994 at School of Mathematics and Allied Sciences, Jiwaji University, Gwalior, India. Besides publishing "GAMS Journal of Mathematical Biosciences", it holds annual conferences every year, international conference every 4 years, organizes workshops and similar research level programs. Now GAMS is going to organize the Second International Conference besides the 16th Annual Conference. Original research papers are invited for presentation at the conference. Intended participants are invited to submit abstracts not exceeding 250 words on A-4 size paper in double spacing by April 30, 2011. Acceptance of the papers will be

sent by June 6 2011. The abstracts may also be sent by email to: bioinfo2011@gmail.com.
Organizers: The event is jointly organized by GAMS and S. S. Dempo College of Commerce and Economics, Altinho, Panaji Goa.
Information: http://www.gamsinfo.com.

22–25 **The 19th conference on applied and industrial mathematics CAIM 2011**, "Ion Ionescu de la Brad" University, Mihail Sadoveanu Lane, 3, 700490, Iasi, Romania. (Jun/Jul. 2011, p. 858)
Description: The Romanian Society of Applied and Industrial Mathematics (ROMAI), "Ion Ionescu de la Brad" University of Agricultural Sciences and Veterinary Medicine of Iasi (UASVM), The Academy of Romanian Scientists (ARS), the Faculty of Mathematics of the "Al. I. Cuza" University of Ias (UAIC), "Gh. Asachi" Technical University of Iasi (TUI) and the Romanian Mathematical Society, Iasi branch announce the organization of the 19th Conference on Applied and Industrial Mathematics – CAIM 2011.
Information: http://www.uaiasi.ro/caim2011/.

24–25 **AMS Western Section Meeting**, Wake Forest University, Winston Salem, North Carolina. (Sept. 2010, p. 1036)
Information: http://www.ams.org/meetings/sectional/sectional.html.

25–October 2 **II International Conference "Optimization and Applications" (OPTIMA-2011)**, Petrovac, Montenegro. (Jun/Jul. 2011, p. 858)
Call for participation: September 25–October 2, 2011, Montenegrian Academy of Sciences and Arts, University of Montenegro and Dorodnicyn Computing Center Russian Academy of Sciences will organize Second International conference "Optimization and Applications" (OPTIMA-2011). Abstracts of the talks are invited.
Conference themes: Mathematical programming, Global optimization, Nondifferential Optimization, Integer Programming and Combinatirial Optimization, Multicriteria Optimization, Equilibrium programming, Game Theory, Optimal Control, Applications in natural sciences, engineering, economics, biology, medicine, etc.
Information: http://www.ccas.ru/optima2011/.

26–30 **Function Spaces, Weights, and Variable Exponent Analysis**, Centre de Recerca Matemàtica (CRM), Bellaterra, Barcelona, Spain. (Aug. 2011, p. 1011)
Description: The conference is aimed to discuss the current state of the theory of function spaces. In particular, the conference will cover the following topics: Function Spaces of Real Variables (Lebesgue, Lorentz, Orlicz, Sobolev, Nikol'skii-Besov, Lizorkin-Triebel, Morrey, Campanato), Embedding/Duality/Extension theorems, Weights, Weighted inequalities, generalized Lebesgue-Sobolev spaces of variable order. The main topics planned include: 1. Mapping properties of the main operators of harmonic analysis in the classical (Lebesgue, Lorentz, Orlicz, Sobolev, Morrey) spaces and the variable exponent Lebesgue spaces. 2. Spaces with weights, properties of weighted classes, boundedness of operators in the weighted spaces. 3. Approximation theory problems in various function spaces. 4. Spaces of functions with Hölder exponent varying from point to point.
Information: http://www.crm.cat/cspaces/.

26–30 (NEW DATE) **IMA Workshop: High Dimensional Phenomena**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota. (Oct. 2010, p. 1166)
Description: The time is ripe to foster a direct cross-fertilization between the communities in geometric functional analysis, high dimensional geometry and probability and various information theory communities. This workshop will bring together researchers from these communities, including those already at work at the interface, as well as young investigators entering one of the fields.
Information: See http://www.ima.umn.edu/2011-2012/W9.26-30.11/.

* 26–30 **International Conference on Function Spaces, Weights, and Variable Exponent Analysis (An i-MATH activity)**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: This international conference aims to promote research in the theory of function spaces and related topics (operator theory, variable exponent analysis, etc.), by bringing together world-leading experts and young scholars. This event provides an excellent opportunity to disseminate the latest major achievements and to explore new directions and perspectives, and is expected to have a broad international appeal dealing with topics of fundamental importance.
Information: http://www.crm.cat/cspaces.

26–30 **Mathematical Oncology: New Challenges for Systems Biomedicine**, "Ettore Majorana" Foundation and Centre for Scientific Culture Erice, Sicily, Italy. (Jun/Jul. 2011, p. 858)
Description: Tumors are dynamical diseases characterized by multiple scales. The complexity of clinical-genomic tumor-related data implies that biostatistics and bioinformatics analyses are no more sufficient to cope with such data in order to explain them and to produce predictions. Mechanistic models of biomedical phenomena with complex outputs must be built, to open the road for tailored therapies. This is a huge challenge for contemporary mathematics. Infos to submit contributed talks, registration etc.: http://www.dm.unipi.it/~erice2011/.
Invited Speakers: Z. Agur, R. Barbuti, N. Bellomo, F. Bonino, H. Byrne, V. Capasso, F. Castiglione, O. Demin, A. d'Onofrio, D. Drasdo, H. Enderling, A. Fasano, G. Finocchiaro, A. Friedman, K. Hicks, A. Iudice, B. Kholodenko, U. Ledzewicz, A. Palladini, L. Preziosi, A. Radunskaya, P. T. Ram, B. Ribba, A. Sigal, R. V. Solé, P. Ubezio.
Organizers: Z. Agur, P. Cerrai, A. d'Onofrio, A. Gandolfi.
Information: http://www.dm.unipi.it/~erice2011/.

28–30 **Balance, Boundaries and Mixing in the Climate Problem**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, 2920, Chemin de la tour, 5th floor, Montréal, Québec, H3T 1J4 Canada. (Jun/Jul. 2011, p. 858)
Description: Turbulent mixing in the atmosphere and oceans will be the focus. Although crucial to coarse-resolution numerical modelling efforts, much of it really occurs below typical grid scales. Recent progress in geophysical fluid dynamics will be brought to the community that can benefit from it to improve their integrated studies of complex environmental systems.
Information: http://www.crm.umontreal.ca/Mix11/index_e.php.

October 2011

1–2 **History and Pedagogy of Mathematics (HPM), Americas Section 2011, West Coast Meeting**, Point Loma Nazarene University, San Diego, California. (Aug. 2011, p. 1011)
First Notice and Call for Papers: HPM seeks a variety of talks on the history of mathematics, the teaching of mathematics, and the history of teaching mathematics. Talks directly relevant to mathematics classrooms are especially welcome. Talks will be 30-40 minutes long.
Information: Prospective speakers should send a title and abstract, as well as their own contact information to Kathy Clark at: drkclark@gmail.com. Further details on this meeting should be available by midsummer. For now, please Save the Date. For updated information check, and to read about past meetings, see http://www.hpm-americas.org.

3 **Philosophy of Information**, American University, Washington, District of Columbia. (Mar. 2011, p. 496)
Description: The overall objective of this workshop is to study some of the open questions within philosophy of information. Interest in the philosophy and meaning of information goes back half a century but has rapidly increased recently with many new directions of research into the meaning, quantification and measures of information and complexity as well as a vast range of applications across

the scientific spectrum. In this conference we will focus on just one aspect of the philosophy of information: the different techniques to measure information and to identify meaningful information.
Hosts: The workshop is hosted by the Info-Metrics Institute. The co-chairs are Amos Golan (AU), and Pieter Adriaans (Univ. Amsterdam).
Information: http://www.american.edu/cas/economics/info-metrics/workshop/workshop-2011-fall.cfm.

3–7 **Geometric structures on complex manifolds**, Laboratory of Algebraic Geometry, Higher School of Economics, Moscow, Russia. (Aug. 2011, p. 1011)
Description: Differential-geometric structures play an important role in the study of complex geometry. After Kodaira, Kaehler structures became central in the study of deformation theory and the classification problems. More recently, the non-Kaehler metrics on complex manifolds started to be important in string theory. The manifolds with special holonomy become central in string theory due to advances in supersymmetry. The notion of calibrations, due to Harvey and Lawson, gives a unifying differential-geometric mechanism encompassing the complex geometry and its many generalizations to quaternionic and octonionic domains. We are planning to bring together specialists on complex geometry, potential theory and calibrations, to explore the recent advances in differential geometry of complex manifolds.
Information: http://bogomolov-lab.ru/GS/.

4–6 **Sixth International Workshop Meshfree Methods for Partial Differential Equations**, Universitätsclub Bonn, Bonn, Germany. (Apr. 2011, p. 628)
Description: While contributions in all aspects of meshfree and particle methods are invited, some of the key topics to be featured are: Application of meshfree, particle, generalized/extended finite element methods e.g. to, multiscale problems, problems with multiple discontinuities and singularities, problems in high-dimensions, coupling of meshfree methods, finite element methods, particle methods, and finite difference methods, parallel computation in meshfree methods, mathematical theory of meshfree, generalized finite element, and particle methods, fast and stable domain integration methods, enhanced treatment of boundary conditions, identification and characterization of problems where meshfree methods have clear advantage over classical approaches
Sponsor: Sonderforschungsbereich 611, Universität Bonn.
Information: http://wissrech.ins.uni-bonn.de/meshfree.

7–9 **ICMA2011: The Third Conference on Mathematical Modeling and Analysis of Populations in Biological Systems**, Trinity University, San Antonio, Texas. (May 2011, p. 743)
Description: This conference will build upon the success of the previous two conferences that were held on the campuses of the University of Arizona in 2007 and University of Alabama Huntsville in 2009. Furthermore, the proceedings of ICMA I were published in two issues of the *Journal of Biological Dynamics* and one issue in the *Journal of Difference equations*. The proceedings of ICMA II will be published in two issues of the *Journal of Biological Dynamics*. The main focus of this conference will be on ecology and evolution. In addition, there will be a focus on ecological and evolutionary problems in related fields, such as environmental science, epidemiology, etc. We will invite researchers working on model derivation and analysis, data testing, and model simulations in these fields.
Scientific Committee: Chris Cosner, Jim Cushing (chair), Maia Martcheva, Gail Wolkowicz, and Sebastian Schrieber.
Organizing Committee: Saber Elaydi (chair), Jim Cushing, Jia Li, David Ribble, Peter Olofsson, and Cabral Balreira.
Information: For more information contact Dr. Saber Elaydi, Conference Director (email: selaydi@trinity.edu) and visit http://web.trinity.edu/x8339.xml.

10–14 **AIM Workshop: Weighted singular integral operators and non-homogenous harmonic analysis**, American Institute of Mathematics, Palo Alto, California. (May 2011, p. 744)
Description: This workshop, sponsored by AIM and the NSF, will focus on recent developments on weighted inequalities for singular integral operators and the connection with questions in geometric measure theory and PDEs.
Information: http://aimath.org/ARCC/workshops/singularintops.html.

10–14 **International conference "Kolmogorov Readings: General control problems and their applications (GCP - 2011)"**, Tambov State University named after G. R. Derzhavin, Tambov, Russia. (Jun/Jul. 2011, p. 859)
Description: The conference is the 5th one in the series "Kolmogorov readings" gathering international scientists in the city where the outstanding mathematician, A. N. Kolmogorov, was born. Traditionally the conference will mainly focus on general control problems and their applications in natural and human sciences, optimization theory, differential equations and inclusions. There are planned plenary (40 min.) and sectional (20 min.) talks, as well as a school on optimal control aimed to Ph.D. students and young researches.
Information: http://www.tambovopu2011.narod.ru/.

10–14 **International Conference on Scientific Computing 2011 (SC2011) dedicated to Claude Brezinski and Sebastiano Seatzu on the occasion of their 70th birthday**, S. Margherita di Pula, Sardinia, Italy. (Mar. 2011, p. 496)
Description: We are organizing an international conference in October 2011 to celebrate the 70th birthday of Claude Brezinski and Sebastiano Seatzu, and, at the same time, the 20th anniversary of the Springer journal *Numerical Algorithms*. The themes of the conference will cover all aspects of numerical analysis and applied mathematics. Special sessions will be devoted to selected topics. The conference will be held at Hotel Flamingo (http://www.hotelflamingo.it/), a tourist resort located in S. Margherita di Pula, Sardinia, Italy. An agreement has been reached with the Hotel to obtain special reduced prices for full board accommodation. We are asking people interested in attending the Conference and receiving more information, to fill out the preregistration form available at the web page http://bugs.unica.it/SC2011/preregistration/. Those requesting more information can contact us at the email address: sc2011@bugs.unica.it. The web site of the event is http://bugs.unica.it/SC2011/.
Information: http://bugs.unica.it/SC2011/.

11–14 **Mal'tsev Meeting**, Sobolev Institute of Mathematics, Novosibirsk, Russia. (Apr. 2011, p. 628)
Description: Mal'tsev Meeting is an annual conference on algebra, mathematical logic, and applications organized by Sobolev Institute of Mathematics and Novosibirsk State University. In 2011, the meeting is dedicated to the 60th birthday of Sergei Goncharov. The programme of the conference will consist of invited talks and contributions in sections.
Main topics: Include computability theory, theoretical computer science, mathematical logic, group theory, ring theory, universal algebra, and related areas of mathematics.
Information: http://www.math.nsc.ru/conference/malmeet/11/index.html.

* 12–13 **International Conference on Mathematics and Science (ICOMSc)**, Majapahit Hotel, Surabaya, Indonesia.
Description: As a part of the activities to celebrate the 51st anniversary of the Institute of Technology Sepuluh Nopember (ITS) Surabaya, the Faculty of Mathematics and Natural Sciences will organize an international conference on Mathematics and Sciences.
Organizer: The conference is organized by Faculty of Mathematics and Natural Science-Institute Technology Sepuluh Nopember, Surabaya, Indonesia.

Deadline: For abstracts/proposals: August 14, 2011.
Information: http://www.icomsc.its.ac.id.

* 13–16 **Incompressible Fluids, Turbulence and Mixing. In honor of Peter Constantin's 60th birthday**, Carnegie Mellon University, Pittsburgh, Pennsylvania.
Invited speakers: Claude Bardos, Henri Berestycki, Andrea Bertozzi, Alexandre Chorin, Camillo De Lellis, Charlie Doering, Ciprian Foias, Susan Friedlander, John Gibbon, Darryl Holm, William Layton, Andrew Majda, Nader Masmoudi, Koji Ohkitani, Jean-Claude Saut, Panagiotis Souganidis, Vladimir Šverák, Eitan Tadmor, Roger Temam, Noel Walkington. Graduate students and young researchers are encouraged to contribute a poster or short talk. Funds are available to support graduate students and young researchers.
Deadline: The registration deadline is August 1, 2011.
Information: http://www.math.cmu.edu/cna/fluids2011/index.html.

14–16 **AMS Central Section Meeting**, University of Nebraska-Lincoln, Lincoln, Nebraska. (Sept. 2010, p. 1036)
Information: http://www.ams.org/meetings/sectional/sectional.html.

* 17–21 **Embedding Problems in Banach Spaces and Group Theory**, Mathematical Sciences Research Institute, Berkeley, California.
Description: This workshop is devoted to various kinds of embeddings of metric spaces into Banach spaces, including biLipschitz embeddings, uniform embeddings, and coarse embeddings, as well as linear embeddings of finite dimensional spaces into low dimensional ℓ_p^n spaces. There will be an emphasis on the relevance to geometric group theory, and an exploration into the use of metric differentiation theory to effect embeddings.
Information: http://www.msri.org/web/msri/scientific/workshops/programmatic-workshops/show/-/event/Wm575.

17–21 **Workshop: Applications of Kinetic Theory and Computation**, ICERM, Providence, Rhode Island. (Jun/Jul. 2011, p. 859)
Description: There are several fundamental applications involving kinetic theory and computations. They range from semiconductor modeling involving kinetic and quantum charged transport, radiative transfer in cosmology, conservative and dissipative phenomena in rarefied gas dynamics in mixtures, and grain and polymer flows.
Information: http://icerm.brown.edu/sp-f11/workshop-2.php.

19–21 **Celebration of Mathematical Sciences in Commemoration of the Centennial of the Birth of Shiing-Shen Chern**, Institute of Mathematics, Academia Sinica, 6F, Astronomy-Mathematics Building, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan 10617. (Aug. 2011, p. 1011)
Description: Professor Shiin-Shen Chern was one of the founding fathers of the Institute of Mathematics of the Academia Sinica, and had remained one of its leading supporters his entire life. On the occasion of his 100th birthday, the Institute of Mathematics, Academia Sinica, Taipei, will hold the International conference "Celebration of Mathematical Sciences in Commemoration of the Centennial of the Birth of Shiing-Shen Chern".
Plenary speakers: Luis Caffarelli (Texas), Jih-Hsin Cheng (Academia Sinica), Kenji Fukaya (Kyoto), Gerhard Huisken (Max Planck), Maxim Kontsevich (IHES), Ko-Wei Lih (Academia Sinica), Richard Schoen (Stanford), Yum-Tong Siu (Harvard), Chuu-Liang Terng (UC Irvine), Cedric Villani (Institute H. Poincare).
Scientific committee: K. Fukaya (Kyoto), T.-P. Liu (Academia Sinica), R. Schoen (Stanford), Y.-T. Siu (Harvard). Local organizing committee: J.-H. Cheng (Academia Sinica), J.-N. Wang (NTU), C. Chen (NCTU), M.-K. Chuah (NTHU), R.-L. Sheu (NCKU).
Local organizing committee: J.-H. Cheng (Academia Sinica), J.-N. Wang (NTU), C. Chen (NCTU), M.-K. Chuah (NTHU), R.-L. Sheu (NCKU).
Information: http://www.math.sinica.edu.tw.

* 21–22 **Eleventh Annual Prairie Analysis Seminar**, Department of Mathematics, Kansas State University, Manhattan, Kansas.
Description: The conference features Andrea Bertozzi, University of California, Los Angeles, who will give two one-hour talks, and Thomas Laurent, University of California at Riverside, and Dejan Slepcev, Carnegie Mellon University, who will each give a one-hour talk.
Topics: Include aggregation equations involving ideas from fluid dynamics and optimal transport. There is time scheduled for contributed talks; all participants, especially mathematicians early in their careers, are encouraged to contribute a 20-minute talk. The conference is supported by the NSF and funding is available with priority given to students, postdocs and those early in their careers.
Organizers: Marianne Korten, Charles Moore, Kansas State University; and Estela Gavosto, Rodolfo Torres, University of Kansas.
Information: http://www.math.ksu.edu/pas/2011/.

21–22 **National Conference on "Role of Mathematical and Physical Sciences in Engineering and Technology"**, Government Degree College Karanprayag (Chamoli), Uttarakhand, India.
Description: The conference provides a unique opportunity for in-depth technical discussions and exchange of ideas in mathematical and physical sciences, as well as their role in natural and social sciences, engineering and technology, industry and finance. It offers to researchers, industrialists, engineers and students from different parts of the country as well as from the remote part of the Uttarakhand state to present their latest research, to interact with the experts in the field, and to foster interdisciplinary collaborations required to meet the challenges of modern science, technology, and society.
Information: http://sites.google.com/site/drgauraviitr/homepage/activities.

22–23 **AMS Western Section Meeting**, University of Utah, Salt Lake City, Utah. (Sept. 2010, p. 1036)
Information: http://www.ams.org/meetings/sectional/sectional.html.

22–24 **The 5th International Conference on Research and Education in Mathematics (ICREM5)**, Institut Teknologi Bandung, Bandung, Indonesia. (Aug. 2011, p. 1011)
Description: The International Conference on Research and Education in Mathematics (ICREM) is a biennial conference, started in 2001. It covers all aspects of mathematical sciences as well as mathematical education. It is jointly organized by Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Institute for Mathematical Research, Universiti Putra Malaysia INSPEM), and Institute of Mathematics, Vietnam Academy of Science & Technology (IMVAST).
Keynote Speaker: Cedric Villani (Institute Henri Poincare, France), Fields Medalist 2010, supported by International Mathematics Union (IMU); Abdus Salam International Centre for Theoretical Physics (ICTP); United Nations Educational, Scientific and Cultural organization (UNESCO); Indonesian Combinatorial Society (InaCombS); and Indonesian Mathematical Society (IndoMS) (IndoMS).
Information: http://www.math.itb.ac.id/~icrem5/.

24–26 **Algebra Geometry Mathematical Physics**, University of Haute Alsace, Mulhouse, France. (May 2011, p. 744)
Main topics: Include, but are not limited to: Deformation theory and quantization, Hom-algebras and n-ary algebraic structures, Hopf algebra, quantum algebra, Integrable systems, Jet theory and Weil bundles, Lie theory and applications, Noncommutative and nonassociative algebra, Representation theory, Number theoretical methods in string theory, Quantum geometry, Spectral and computational methods for Maxwell equations, Ternary algebras and applications.
Information: http://www.agmp.eu/mul11/.

24–27 **SIAM Conference on Geometric and Physical Modeling (GD/SPM11)**, Wyndham Orlando Resort, Orlando, Florida. (Jun/Jul. 2011, p. 859)

Description: The 2011 SIAM Conference on Geometric and Physical Modeling seeks high quality, original research contributions that strive to advance all aspects of geometric and physical modeling, and their application in design, analysis and manufacturing, as well as in biomedical, geophysical, digital entertainment, and other areas. A shared objective of both the SIAM GD and ACM SPM communities is a desire to highlight work of the highest quality on the problems of greatest relevance to industry and science. In ACM SPM tradition, the conference will include a track for submission of peer-reviewed technical papers for those wishing rigorous peer review and published proceedings. In addition, in the tradition of previous SIAM GD events, abstracts for minisymposia and contributed talks/posters are solicited.
Information: `http://www.siam.org/meetings/gdspm11/`.

24–28 **AIM Workshop: The Kardar-Parisi-Zhang equation and universality class**, American Institute of Mathematics, Palo Alto, California. (May 2011, p. 744)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the study of the the Kardar-Parisi-Zhang equation and universality class.
Information: `http://aimath.org/ARCC/workshops/kpzequation.html`.

24–28 **Galois Conference: Bicentennial of Evariste Galois's birth Colloque Galois—Bicentenaire de la naissance d'Évariste Galois**, Institut Henri Poincaré, Paris, France. (Jun/Jul. 2011, p. 859)
Description: Institut Henri Poincaré and Société Mathématique de France will organize a conference to illustrate the heritage of E. Galois's work, both from a mathematical and an historical point of view.
Information: `http://www.galois.ihp.fr/`.

24–28 **IMA Workshop: Large Graphs: Modeling, Algorithms and Applications**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota. (Oct. 2010, p. 1166)
Description: The focus of the workshop will be on the mathematical, algorithmic, and statistical questions that arise in graph-based machine learning and data analysis, with an emphasis on graphs that arise in the above settings, as well as the corresponding algorithms and motivating applications. Thus, this workshop will be an opportunity for researchers from diverse fields to get together and share problems and techniques for handling these graph structures. The connections "mathematical, computational, and practical" that arise between these seemingly diverse problems and approaches will be emphasized.
Information: See `http://www.ima.umn.edu/2011-2012/W10.24-28.11/`.

24–28 **Heritage of E. Galois's work**, Institut Henri Poincaré, Paris, France. (Jun/Jul. 2011, p. 859)
Description: Institut Henri Poincaré and Société Mathématique de France will organize a conference to illustrate the heritage of E. Galois's work, both from a mathematical and an historical point of view.
Information: `http://www.galois.ihp.fr/`.

24–28 **Optimization, Theory, Algorithms and Applications in Economics**, Centre de Recerca Matematica, Universitat Autonoma de Barcelona, Barcelona, Spain. (Jun/Jul. 2011, p. 859)
Description: This international conference is a tribute to Juan-Enrique Martinez-Legaz on the occasion of his 60th birthday. It has the aim of a top-level scientific meeting to promote a broad exchange of information and new developments in the areas of Functional and Variational Analysis, Control, Optimization and Applications in Economics. The event will include two half-day mini workshops (Nuclei) in Economics and a mini-workshop in applications of Optimization in Engineering.
Information: `http://mat.uab.cat/~opt2011`.

26–29 **Integers Conference 2011**, University of West Georgia, Carrollton, Georgia. (Jun/Jul. 2011, p. 859)
Description: The editors of Integers are pleased to announce the Integers Conference 2011. 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.
Plenary Speakers: Ken Ono, Emory University; Carla Savage, North Carolina State University; Laszlo Szekely, University of South Carolina; Frank Thorne, University of South Carolina; Julia Wolf, Ecole Polytechnique. Organizers: Bruce Landman, Melvyn Nathanson, Jaroslav Nesetril, Richard Nowakowski, Carl Pomerance.
Information: `http://www.westga.edu/~math/IntegersConference2011/`.

30–November 5 **Chern Centennial Conference**, Mathematical Sciences Research Institute, Berkeley, California.
Description: The Mathematical Sciences Research Institute (MSRI) in conjunction with the Chern Institute of Mathematics (CIM) in Tianjin, China, celebrates the centennial of the birth of Shiing-Shen Chern, one of the greatest geometers of the 20th century and MSRI's co-founder. In commemoration of Chern's work, MSRI and CIM will implement an international mathematics conference. During the first week, October 24 to 28, 2011, the conference will take place at CIM in Tianjin, China and during the second week, October 30 to November 5, 2011, the conference will be at the MSRI in Berkeley, USA.
Information: Further information about the first week at CIM can be found here: `http://www.nim.nankai.edu.cn/activites/conferences/Chern-Centennial-20111024/index.htm`. For general information visit: `http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm555`.

31–November 4 **AIM Workshop: Geometry of large networks**, American Institute of Mathematics, Palo Alto, California. (May 2011, p. 744)
Description: This workshop, sponsored by AIM and the NSF, is devoted to geometric models of large networks. It intends to bring together mathematicians, computer scientists, and engineers.
Information: `http://aimath.org/ARCC/workshops/largenetworks.html`.

* 31–November 4 **The hyperbolic and Riemannian geometry of surfaces and other manifolds**, Centro Stefano Franscini, Ascona, Switzerland.
Description: The hyperbolic and Riemannian geometry of surfaces and other manifolds, a conference in honor of the mathematics of Peter Buser. The aim of this conference is to bring together people working on the geometry of surfaces and Teichmüller spaces, the spectrum of the Laplacian, and global Riemannian geometry.
Information: `http://homeweb.unifr.ch/parlierh/pub/Buser/welcome.html`.

November 2011

1–3 **Central and Eastern European Software Engineering Conference in Russia (CEE-SECR 2011)**, Moscow, Russian Federation. (Jun/Jul. 2011, p. 859)
Description: CEE-SECR is the premier software engineering conference in Russia. Up to 1000 participants from over 20 countries are expected to attend the event in 2011, presenting and discussing innovations, trends, results, experiences and concerns in the field of software engineering. The conference will be composed of research presentations, experience reports, poster presentations, panel discussions, workshops, invited presentations, and keynote lectures. At previous conferences, keynote/invited/panel speakers have included: Bjarne Stroustrup, Thomas Erl, Richard Soley, Igor Agamirzian, Grady Booch, Lars Bak, Yuri Gurevich, Alexander L. Wolf, Erich Gamma, Victor Ivannikov, Stephen Mellor, Rick Kazman, Larry L. Constantine, Ivar Jacobson, Mark Paulk, Michael Cusumano, and other distinguished figures.

Information: http://www.cee-secr.org.

1–3 **International Seminar on the Application of Science and Mathematics 2011**, Putra World Trade Centre, Kuala Lumpur, Malaysia. (Jun/Jul. 2011, p. 860)
Description: Introduction ISASM 2011 aims to provide an international forum for researchers to present and discuss recent advances and new techniques in science and mathematics and its applications. Seminar Objectives (i) To provide a platform for the exchange of new ideas and interaction between local and international participants, updating the latest research in application of science and mathematics. (ii) To bring together researcher and scientist in promoting and enhancing research collaboration among local and international participants. (iii) To encourage and stimulate publications in the areas of application of science and mathematics.
Official Languages: English and Malay.
Information: http://uhsb.uthm.edu.my/isasm2011/.

1–5 **International conference of Settat on Operator algebras and applications**, Faculty of Sciences and Techniques, University Hassan I. Settat, Morocco. (Mar. 2011, p. 496)
Description: As a continuation of the first and the second international conferences on operator algebras and applications in Morocco, the 3rd conference ICSOAA2011, will be held in Settat November 1–5, 2011, with a similar structure. It would be a big pleasure for us to meet you there. ICSOAA 2011 in Morocco is intended to be a comprehensive, inclusive conference covering all aspects of theoretical and applied operator algebras.
Information: http://www.math.ist.utl.pt/~elharti/3rd/settat2011.htm.

* 1–5 **VI International Conference on Non Associative Algebra and its Applications**, Universidad de Zaragoza, Spain.
Description: This conference aims to bring together people working in nonassociative algebras and their applications. It will also serve to honor Santos Gonzalez on his 60th birthday.
Scientific Committee: Georgia Benkart (University of Wisconsin), Kevin McCrimmon (University of Virginia), Ivan Shestakov (Universidade de Sao Paulo) and Efim Zelmanov (University of California, San Diego). There will be plenary talks, four special sessions on "Lie algebras and superalgebras", "Jordan systems", "Other nonassociative systems", and "Applications", and poster sessions.
Information: http://iuma.unizar.es/~elduque/vinaaa.

5–6 **Second International Conference on Biologically Inspired Cognitive Architectures (BICA 2011)**, Holiday Inn Arlington, Arlington, VA, next to Washington DC. (Jun/Jul. 2011, p. 860)
Description: The challenge of creating a real-life computational equivalent of the human mind calls for our joint efforts to better understand at a computational level how natural intelligent systems develop their cognitive and learning functions.The focus of BICA 2011 includes: BICA models of robust learning mechanisms; models of perception, cognition and action; emotional and social intelligence in artifacts; vital constraints informed by neuroscience, human-like episodic and semantic memory; metacognition, human-like self-regulated learning, bootstrapped and meta-learning; language acquisition and symbol grounding; the "critical mass" for cognitive growth in a learning environment, scalability of learning; the roadmap to solving the challenge.
Information: http://bicasociety.org/2011/.

5–8 **ICMIS2011: 2nd International Conference on Mathematics & Information Science**, Sohag University, Sohag, Egypt. (Jun/Jul. 2011, p. 860)
Description: The conference will feature advances in mathematical science and technology presented by leading African and international researchers and will provide the opportunity to showcase research in mathematics, theoretical physics and information science and technology to engender dialogue and collaboration between Egyptian and international researchers. The conference is a part of a series of conferences dedicated to bringing top scientists and technologists to Egypt thereby helping to raise Egyptian science and technology to the highest international standard, raise awareness of governments and industry in Egypt of the importance and excitement of new research and development in technologies, and engender collaborations and research exchanges. The first conference of this Conference Series was "International Conference on Mathematics and Information Security, Sohag, Egypt, November 2009".
Information: http://www.naturalspublishing.com/sohag2011/.

* 7–10 **International Workshop on Theoretical Aspects of the Discrete Time Quantum Walk**, Instituto de Fi'sica Corpuscular, Valencia, Spain.
Aim: What are probability and stochastic processes in Quantum Mechanics? To study the foundations of stochastic processes in Quantum Mechanics, the discrete time quantum walk (DTQW), which is the quantum analogue of the classical random walk, may be useful. This has recently been a hot research field, especially in quantum information science, and has been experimentally realized. This workshop will bring the theoretical researchers in the DTQW. While this workshop is focused on the theoretical side, we also welcome experimentalists. The organizers strongly encourage young researchers to actively join us to this workshop.
Workshop Scopes: 1. Proposals on Physical Realizations of the DTQW 2. Asymptotic Behavior of DTQW 3. Decoherence in the DTQW 4. Applications to Quantum Information Science.
Invited Speakers: Frederick W. Strauch (Williams College, USA) Takuya Kitagawa (Harvard University, USA).
Important Date: Deadline of the abstract submission for the oral presentation: September 1, 2011.
Information: http://ific.uv.es/~perez/DTQW_Valencia.html.

* 7–11 **Advanced Course on Approximation Theory and Fourier Analysis**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: These courses consist of five series of lectures: 1. Variable Lebesgue Spaces: Foundations and Harmonic Analysis by David Cruz-Uribe, 2. Weighted polynomial approximation on the sphere and related domains by Feng Dai, 3. Pseudo-differential operators on compact Lie groups by Michael Ruzhansky, 4. Greedy Approximation by Vladimir Temlyakov, 5. Approximation Theory and Harmonic Analysis on the Unit Sphere by Yuan Xu.
Information: http://www.crm.cat/acfourier.

7–11 **AIM Workshop: The Klein project**, American Institute of Mathematics, Palo Alto, California. (May 2011, p. 744)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the development of the Klein Project, specifically to the preparation of "vignettes" that characterise important ideas within the field of the mathematical sciences using specific examples.
Information: http://aimath.org/ARCC/workshops/kleinproject.html.

7–11 **Workshop: Boltzmann Models in Kinetic Theory**, ICERM, Providence, Rhode Island. (Jun/Jul. 2011, p. 860)
Description: The focus of the program is to bring computational and theoretical people together to investigate problems of fundamental importance.
Information: http://icerm.brown.edu/sp-f11/workshop-3.php.

7–11 **Waves in Science and Engineering WISE 2011**, Mexico City, Mexico. (Jun/Jul. 2011, p. 860)
Description: It is intended to bring together experts from different fields of the general area of classical wave theory and applications including acoustic, electromagnetic, and elastic wave propagation. The mathematical and numerical modeling procedures in these fields contribute to a considerable number of applied physical and engineering problems, over a large range of length scales. Among

these are problems in sonar, radar, medical imaging, detection, materials, and wave interactions with surfaces and obstacles. The conference will cover many of the current mathematical and numerical techniques that are applied across disciplines. Mathematicians, physicists, and engineers of varying backgrounds and occupations will present recent developments in wave phenomena in science and engineering.
Information: `http://www.wise.ipn.mx`.

12 **Information Theory and Shrinkage Estimation**, American University, Washington, District of Columbia. (Mar. 2011, p. 496)
Description: Interest in shrinkage estimators goes back half a century but has rapidly increased recently with many new directions of research that cover a vast range of applications in different disciplines. Ongoing research on Information-Theoretic estimation and inference methods is similarly inter-disciplinary, involving information theory, engineering, mathematical statistics, econometrics and the natural sciences. This one day conference will address the various themes of shrinkage estimation, the inter-connections between shrinkage estimation methodology and info-metrics, and explore recent advances in shrinkage methods and applications.
Information: `http://www.american.edu/cas/economics/info-metrics/workshop/workshop-2011-november.cfm`.

14–18 **IMA Workshop: Large Data Sets in Medical Informatics**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota. (Nov. 2010, p. 1349)
Description: The goal of this workshop is to bring together mathematicians, statisticians, engineers, and scientists working on particular aspects of medical informatics or related areas. A careful look at the literature in any of the subfields of medical informatics reveals specialized approaches and philosophies combined with a lack of knowledge of other potentially useful methodologies that have been developed in other subfields of medical informatics. Furthermore, results and methodologies discovered in pertinent subfields of mathematics and statistics remain unknown in medical informatics. Conversely, researchers in real analysis, differential equations, algebraic geometry, and statistics are unaware of the characteristics of the challenges in medical informatics that limit the applicability of generic approaches.
Information: See `http://www.ima.umn.edu/2011-2012/W11.14-18.11/`.

17–18 **Jornadas de Criptografía (Spanish Cryptography Days)**, Murcia, Spain. (May 2011, p. 744)
Description: As part of the activities of the Centenary of the Real Sociedad Española de Matemáticas the Algebra Group of Murcia organize the Jornadas de Criptografía SCD2011 with the aim of bringing together researchers in cryptography, including mathematicians and computer scientists, as well as industrial and government organizations interested in new developments and applications of cryptography.
Information: `http://www.um.es/docencia/jsimon/CongresoCripto/CryptographyMeeting.html`.

19–21 **International Conference on Analysis and its Applications**, Department of Mathematics, Aligarh Muslim University, Aligarh, India. (Dec. 2010, p. 1498)
Description: The main aim of the conference is to promote, encourage, cooperate, and bring together theoreticians and multi–disciplinary and inter–disciplinary researchers in the fields of nonlinear analysis; operator theory; fixed point theory; set-valued analysis; variational analysis including variational inequalities; convex analysis; smooth and nonsmooth analysis; wavelet analysis; Fourier analysis; modern methods in summability and approximation theory; sequence spaces and matrix transformations.
Information: `http://www.amu.ac.in/conference/icaa2011`.

28–December 2 **School of Applied Mathematics and Innovation 2010: Celestial Mechanics and Computing Orbits**, Campus Rodrigo Noguera Laborde of Universidad Sergio Arboleda, Carrera 29D 30 - 207 Troncal del Caribe Santa Marta, Colombia. (Jun/Jul. 2011, p. 860)
Description: This doctoral school will be devoted to study of techniques in Celestial Mechanics and Computer Orbits.
Lecturers: Alain Chenciner, Observatoire de Paris, Paris, France. Rafael Ortega, Universidad de Granada, Granada, Spain. Juan Ramón Pacha, Universitat Politécnica de Catalunya, Barcelona, Spain.
Organizing Committee: Luz Myriam Echeverry, Universidad Sergio Arboleda, Universidad de los Andes, Colombia. Andres Mauricio Rivera, Pontificia Universidad Javeriana, Cali, Colombia.
Scientific Committee: Primitivo Acosta-Humánez, IMA-Universidad Sergio Arboleda, Colombia. Amadeu Delshams, Universitat Politécnica de Catalunya, España. Juan Morales-Ruiz, Universidad Politécnica de Madrid, España.
Information: `http://ima.usergioarboleda.edu.co/SAMI/SAMI2011.htm`.

* 28–December 2 **Workshop on Computational Security**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: In the current information society, security and integrity and crucial topics. Since the appearance of Information Theory with Claude E. Shannon at the end of the 1940s, secure transmission and correct reception of information were the most studied problems by the scientific community. The mathematical theories necessary to develop cryptography, coding theory and computer security provide tools used with two main purposes: protect the privacy of the information and guarantee its integrity when possible alterations may occur. The need of information security in public and private institutions has changed in the last years; it has grown from something exclusive of intelligence services to become something common that affects the whole society.
Information: `http://www.crm.cat/wksecurity`.

December 2011

* 1–14 **US-Africa Advanced Study Institute on Analysis, Dynamical Systems, and Mathematical Biology and Research Workshop on Mathematical Modeling of Biological Systems**, Livingstone, Zambia.
Description: The first five days of the ten-day Institute are devoted to reviewing background material on analysis, linear algebra, dynamical systems, mathematical biology, and requisite software. The last five days of the Institute will consist of research lectures and intense group research activities on new and emerging topics in mathematical modeling of biological systems. The Institute will be followed by a Workshop on mathematical modeling of biological systems consisting of presentations of research programs of experienced researchers with extended follow-up discussion periods. Participants will also have an opportunity to attend a one-day Career Development Workshop. Space is limited and registration is open only to graduate students and early career faculty (rank less than associate professor.)
Deadline: For receipt of applications is Thursday, July 28, 2011.
Information: `http://www.dms.auburn.edu/~jendaov/masamu.html`.

1–April 1 **Call for papers: A special issue of *Symmetry* (ISSN 2073-8994) "Symmetry in Probability and Inference", *Symmetry Journal***, MDPI Publishing, Basel, Switzerland. (Mar. 2011, p. 497)
Guest Editor: M. Viana.
Deadline: April 1st, 2011.
Description: Papers should address any aspects of symmetry arguments in probability and statistical inference, such as, but not limited to: Constructive rules of probability and inference derived from symmetry arguments; relative probabilities; symmetric probability measures, symmetry in probability distributions, symmetry-related arguments in entropy (probabilistic) laws; epistemic probabilities and symmetry principles, symmetry arguments in the cognitive

foundations of probability, statistical inference under symmetry, quantum statistical inference, asymmetric inference (in Markov processes), exchangeability and symmetry. Group-theoretic approaches to probability and inference, including those discussing aspects of symmetry invariance derived from symmetry arguments will be considered. Papers discussing covariance structures derived from symmetry arguments, for example, will also be considered. Annotated reviews may also be considered.
Information: `http://www.mdpi.com/journal/symmetry/special_issues/probability/`.

2–4 **Introduction to Neutrosophic Physics: Unmatter & Unparticle**, The University of New Mexico, Mathematics & Sciences Department, 200 College Rd., Gallup, New Mexico. (Mar. 2011, p. 497)
Description: This idea of unparticle was first considered by F. Smarandache in 2004, 2005 and 2006, when he uploaded a paper on CERN web site and he published three papers about what he called 'unmatter', which is a new form of matter formed by matter and antimatter that bind together. In 2006 E. Goldfain introduced the concept of "fractional number of field quanta" and he conjectured that these exotic phases of matter may emerge in the near or deep ultraviolet sector of quantum field theory. H. Georgi proposed the theory of unparticle physics in 2007 that conjectures matter that cannot be explained in terms of particles using the Standard Model of particle physics, because its components are scale invariant. Fragments from Wikipedia Papers on current trends in High Energy Physics about exotic matter, about connections between unmatter and unparticle, about Neutrosophic Logic as new research in Theoretical Physics, should be sent to the organizer preferably by email.
Information: `http://www.gallup.unm.edu/~smarandache/unmatter.htm`.

4–9 **LISA'11: 25th Large Installation System Administration Conference**, Sheraton Boston Hotel at 39 Dalton St., Boston, Massachusetts. (Feb. 2011, p. 336)
Description: System administrators of all specialties and levels of expertise meet at LISA to exchange ideas, sharpen old skills, learn new techniques, debate current issues, and meet colleagues, vendors, and friends. Talks, presentations, posters, WiPs, and BoFs address a wide range of administration specialties, including system, network, storage, and security administration on a variety of platforms including Linux, BSD, Solaris, and OS X.
Information: `http://www.usenix.org/events/lisa11`.

5–7 **International symposium on recurrence plots**, Hong Kong Polytechnic University, Hong Kong, China. (Jun/Jul. 2011, p. 860)
Description: The objective of the symposium is to encourage the exchange of knowledge among scientists working in the disciplines of time and spatial series analyses. Recurrence plots and recurrence quantifications are general methods for visualising and analysing both linear and nonlinear time series data. We continue to witness many new technical developments related to recurrence plots. Some of these include: a framework to treat recurrence plots as a network from which one can obtain network-related statistics; inferring directional couplings; obtaining confidence intervals. In addition, applications of recurrence plots are increasing in many areas ranging from, e.g., physiology over climate to financial systems. This symposium will provide a unique forum to help combine the recent theoretical developments in recurrence science with applications from various fields. We welcome both theoretical and applied contributions that use recurrence related methodologies.
Information: `http://symposium.recurrence-plot.tk`.

5–9 **AIM Workshop: Stability, hyperbolicity, and zero localization of functions**, American Institute of Mathematics, Palo Alto, California. (May 2011, p. 744)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the emerging theory of stability and hyperbolicity of functions, in particular the cases of polynomials and analytic functions of one or several variables.
Information: `http://aimath.org/ARCC/workshops/hyperbolicpoly.html`.

* 9–11 **International Conference on Recent Advances in Mathematical Sciences & Applications**, Calcutta Mathematical Society AE-374, Sector-I, Salt Lake city, Kolkata-700064, West Bengal, India.
Description: The main objective of ICRAMSA-2011 is to promote mathematical research and to focus the recent advances in Mathematics and Mathematical Sciences along with their applications. The conference will provide ideal platform for the young researchers throughout the globe to interact with senior scientists, to exchange their views and ideas, also to make possible scientific collaboration with the recent developments in different areas of Mathematics and their applications. The participants will certainly be benefited from this conference as it provides a great opportunity to foster the friendship among them. The programme consists of plenary invited lectures by eminent mathematicians and scientists, contributed papers in various technical sessions. Speaker list will be announced soon.
Information: `http://calmathsoc.org/icramsa.php`.

12–16 **AIM Workshop: Singular learning theory, connecting algebraic geometry and model selection in statistics**, American Institute of Mathematics, Palo Alto, California. (Jun/Jul. 2011, p. 861)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to singular learning theory, the application of algebraic geometry to problems in statistical model selection and machine learning.
Information: `http://www.aimath.org/ARCC/workshops/modelselection.html`.

12–16 **ICREA Conference on Approximation Theory and Fourier Analysis**, Centre de Recerca Matemàtica (CRM), Bellaterra, Barcelona, Spain. (Jun/Jul. 2011, p. 861)
Description: The key idea of the conference is the interdisciplinary connection between Fourier Analysis and Approximation Theory. The main goal of this conference is to reveal new (and clarify known) relations between problems and methods of Fourier Analysis and Approximation Theory and to promote the integration of these areas.
Information: `http://www.crm.cat/icreaapproximation`.

14–16 **5th Indian International Conference on Artificial Intelligence**, Tumkur (near Bangalore), India. (Mar. 2011, p. 497)
Description: 5th Indian International Conference on Artificial Intelligence (IICAI-11) will be held during December 14-16, 2011, in Tumkur (near Bangalore), India. IICAI is a series of high quality technical events in Artificial Intelligence (AI) and is also one of the major AI events in the world.
Information: `http://www.iiconference.org/`.

15–17 **Applied Mathematics & Stochastic Processes**, Sacred Heart College, Tamilnadu, India. (Jun/Jul. 2011, p. 861)
Description: International conference on stochastic processes was proposed by the department of mathematics.
Information: `http://www.shctpt.edu`.

16–18 **The International Congress on Science and Technology**, Allahabad, U.P., INDIA (Oct. 2009, p. 1148)
Description: The ICST-2011 is organized by the CWS, a non-profit society for the scientists and the technocrats and will take place in Allahabad, U.P., INDIA, from Dec. 16–18, 2011. The conference has the focus on the current trends on frontier topics of the science and technology (Applied Engineering) subjects. The ICST conferences serve as good platforms for our members and the entire science and technological community to meet with each other and to exchange ideas.
Deadline: Submission of abstracts with full-length paper to `complexgeometry18@yahoo.com` with a cc: to `ss123a@rediffmail.com` by August 25, 2011.

Registration: Acknowledgement of accepted papers by email: September 5, 2011. Registration of accepted papers: September 25, 2011. All submitted papers will be under peer review and accepted papers will be published in the conference proceeding. Shekhar (N.S.) Int. J. of Sci. and Tech., http://sites.google.com/site/shekharnsintjofsciandtech/.
Contact: http://sites.google.com/site/intcongressonsciandtech/ complexgeometry18@yahoo.com. Sushil Shukla (ss123a@rediffmail.com).

17–18 **1st International Conference on Mathematical Sciences and Applications**, India Habitat Centre, Lodhi Road, New Delhi, India. (Jun/Jul. 2011, p. 861)
Call for Papers: The International Conference on Mathematical Science and Applications (ICMSA-2011) is a premier forum for the presentation of new advances and research results in all areas of Mathematical Sciences and Applications. ICMSA-2011 will bring together leading researchers, engineers and scientists in the domain of interest from around the world. Leading Mathematicians around the world shall deliver Key Note Addresses and chair sessions.
Information: http://ijmsa.yolasite.com/conference-announcement.php.

17–18 **The International Symposium on Biomathematics and Ecology: Education and Research (BEER-2011)**, University of Portland, Portland, Oregon. (Apr. 2011, p. 628)
Description: The main objective of this meeting is to provide a forum for researchers, educators, students and industries to exchange ideas, to communicate and discuss research findings in the fields of mathematics, biology, ecology and statistics.
Topics: Biomathematics, Mathematics, Biology, Ecology, Biostatistics.
Organizers: Olcay Akman, Hannah Callender, Timothy Comar, Steven A. Juliano.
Information: http://www.biomath.ilstu.edu/beer.

18–20 **The 5th International Conference of IMBIC on "Mathematical Sciences for Advancement of Science and Technology" (MSAST 2011)**, Institute for Mathematics, Bioinformatics, Information Technology and Computer Science (IMBIC), Salt Lake, Kolkata, India. (Jun/Jul. 2011, p. 861)
Description: All the authors are requested to submit the full original papers related to the Theme of the Conference: "Mathematical Sciences for Advancement of Science and Technology" to the Secretary of IMBIC: Dr Avishek Adhikari; email: avishek.adh@gmail.com, by September 1, 2011. All the papers are to be screened for presentation in the Conference.
Information: http://imbic.org/forthcoming.html.

January 2012

4–7 **Joint Mathematics Meetings**, Boston, Massachusetts. (May 2011, p. 744)
Information: http://www.ams.org/meetings/national/jmm/2138_intro.html.

9–13 **AIM Workshop: Mapping theory in metric spaces**, American Institute of Mathematics, Palo Alto, California. (Jun/Jul. 2011, p. 861)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to mappings between metric spaces and the recent advances on basic questions concerning uniqueness, extendability, embeddability, uniformization and extremality of mappings in a variety of regularity classes.
Information: http://aimath.org/ARCC/workshops/mappingmetric.html.

9–July 6 **Semantics and Syntax: A Legacy of Alan Turing**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Apr. 2011, p. 629)
Description: In several mathematical areas of Theoretical Computer Science, we perceive a distinction between research focusing on symbolic manipulation of language and structures (independent of meaning) and research dealing with interpreted computational meaning of structures. In mathematical logic, the distinction is known as syntax (symbolic manipulation) versus semantics (interpreted structures). This distinction recurs in many research areas, often under different (and sometimes incompatible) names. For research in these fields, both views are important and fundamental for gaining full understanding of the formal issues involved. This programme will bring together researchers from both sides of the syntax-semantics divide. We shall focus on four mathematical areas bordering computer science: logic, complexity, cryptography, and randomness.
Organizers: Dr. A. Beckmann, Professor S. B. Cooper, Professor B. Löwe, Professor E. Mayordomo and Professor N. Smart.
Information: http://www.newton.ac.uk/programmes/SAS/.

16–20 **Introductory Workshop: Lattice Models and Combinatorics**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1012)
Description: Research at the interface of lattice statistical mechanics and combinatorial problems of "large sets" has been an exciting and fruitful field in the last decade or so. In this workshop we plan to develop a broad spectrum of methods and applications, spanning the spectrum from theoretical developments to the numerical end. This will cover the behaviour of lattice models at a macroscopic level (scaling limits at criticality and their connection with SLE) and also at a microscopic level (combinatorial and algebraic structures), as well as efficient enumeration techniques and Monte Carlo algorithms to generate these objects.
Information: http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm578.

17–19 **ACM-SIAM Symposium on Discrete Algorithms (SODA12)**, The Westin Miyako, Kyoto, Japan. (Apr. 2011, p. 628)
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/da12/.

23–27 **AIM Workshop: Set theory and C^*-algebras**, American Institute of Mathematics, Palo Alto, California. (May 2011, p. 744)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to applications of set theory to C^*-algebras.
Information: http://aimath.org/ARCC/workshops/settheorycstar.html.

30–May 4 **ICERM Semester Program: Complex and Arithmetic Dynamics**, ICERM, Providence, Rhode Island. (Jun/Jul. 2011, p. 861)
Description: The goal of this program is to bring together researchers in complex dynamics, arithmetic dynamics, and related fields, with the purpose of stimulating interactions, promoting collaborations, making progress on fundamental problems, and developing theoretical and computational foundations on which future work will build.
Information: http://icerm.brown.edu/sp-s12/.

February 2012

* 6–10 **Hot Topics: Thin Groups and Super-strong Approximation**, Mathematical Sciences Research Institute, Berkeley, California.
Description: Will focus on recent developments concerning quantitative aspects of "thin groups". These are discrete subgroups of semisimple Lie groups which are both (i.e., Zariski dense) and (i.e., of infinite co-volume). This dual nature leads to intricate questions. Many new ideas and techniques, arising in particular from arithmetic combinatorics, have been involved in the study of such groups,

leading for instance to far-reaching generalizations of the strong approximation theorem in which congruence quotients are shown to exhibit a spectral gap. A variety of experts from group theory, number theory, ergodic theory and harmonic analysis will present the accomplishments to date to a broad audience and discuss directions for further study.

Information: `http://www.msri.org/web/msri/scientific/show/-/event/Wm9222`.

13–17 **Conference and MAGMA Workshop on "Symmetries of Discrete Objects"**, Rydges Lakeland Resort Hotel, Queenstown, New Zealand. (Aug. 2011, p. 1012)

Description: This event will be a combination of a research conference on symmetries of discrete objects (such as graphs, maps/dessins, polytopes, Riemann surfaces and other complexes), and a MAGMA workshop, including some instructional courses (well suited for graduate students) on the MAGMA package and its capabilities (especially for handling discrete structures and their automorphisms). The aim of the conference is to bring together researchers working in various inter-related fields, introduce their approaches and discoveries to one another, and to promote joint research in and between these fields. To achieve this we will have a small number of keynote talks, several contributed talks, at least one open problem session, and ample time for discussions and problem solving. Anyone with interest in automorphisms of discrete structures is welcome to consider attending.

Information: `http://www.math.auckland.ac.nz/~conder/SODO-2012/`.

13–17 **ICERM Workshop: Complex and p-adic Dynamics**, ICERM, Providence, Rhode Island. (Jun/Jul. 2011, p. 861)

Description: This workshop will bring together researchers working in classical complex dynamics and in the newer area of p-adic (nonarchimedean) dynamics. It will promote interactions between the two groups by highlighting the similarities and differences between complex and p-adic dynamics. In particular, it will address Berkovich space, whose introduction has greatly enhanced the exchange of ideas between complex and p-adic dynamics.

Information: `http://icerm.brown.edu/sp-s12/workshop-1.php`.

13–17 **The 10th International Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing (MCQMC 2012)**, The University of New South Wales, Sydney, NSW, Australia. (Apr. 2011, p. 629)

Description: MCQMC is a biennial conference devoted to Monte Carlo and quasi-Monte Carlo methods and their interactions and applications. (In brief, quasi-Monte Carlo methods replace the random choices that characterize the Monte Carlo method by well chosen deterministic choices.) For more information, click on the "Background" tab on the web site. This will be the first MCQMC conference to be held in the southern hemisphere. (Northerners may like to be reminded that February is summertime in Sydney!).

Plenary speakers: P. Del Moral, M. Giles, F. J. Hickernell, A. Hinrichs, M. Lacey, K. Mengersen, A. Neuenkirch, A. B. Owen, L. Plaskota, E. Platen. To receive further announcements please go the web site, click on the "mailing list" tab, and sign up. The web site includes a call for special sessions.

Information: `http://www.mcqmc2012.unsw.edu.au/`.

20–24 **AIM Workshop: Stochastic dynamics of small networks of neurons**, American Institute of Mathematics, Palo Alto, California. (Jun/Jul. 2011, p. 861)

Description: This workshop, sponsored by AIM and the NSF, will be devoted to the area between carefully crafted stochastic models of single neurons and large networks of simpler ones.

Information: `http://www.aimath.org/ARCC/workshops/neuronnetwork.html`.

20–24 **Percolation and Interacting Systems**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1012)

Description: Over the last ten years there has been spectacular progress in the understanding of geometrical properties of random processes. Of particular importance in the study of these complex random systems is the aspect of their phase transition (in the wide sense of an abrupt change in macroscopic behavior caused by a small variation in some parameter) and critical phenomena, whose applications range from physics, to the performance of algorithms on networks, to the survival of a biological species. The aim of this workshop is to share and attempt to push forward the state-of-the-art understanding of the geometry and dynamic evolution of these models, with a main focus on percolation, the random cluster model, Ising and other interacting particle systems on lattices.

Information: `http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm579`.

27–March 2 **IMA Workshop: Network Links: Connecting Social, Communication and Biological Network Analysis**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota. (Jan. 2011, p. 85)

Description: Networks occur in a large variety of disciplines, e.g. social networks, communication networks, gene regulatory networks, disease transmission networks, financial networks, power networks, etc. Common problems are how to model, map and measure the network, how to understand and adjust to network evolution and dynamics, and how network structure affects information flow and robustness/resilience of networks. These problems have often been studied in each discipline individually. In this workshop, we bring together researchers and methodologies of network analysis from three disciplines, to build on the similarities and contrasts among their approaches.

Information: `http://www.ima.umn.edu/2011-2012/W2.27-3.2.12/`.

March 2012

3–4 **AMS Western Section Meeting**, University of Hawaii, Honolulu, Hawaii. (May 2011, p. 744)

Information: `http://www.ams.org/meetings/sectional/sectional.html`.

5–9 **5th International Conference on High Performance Scientific Computing**, Institute of Mathematics, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet Road, Hanoi, Vietnam. (Dec. 2010, p. 1498)

Description: Mathematical modelin, numerical simulation, methods for optimization and control, parallel computing: architectures, algorithms, tools, and environments, software development, applications of scientific computing in physics, mechanics, hydrology, chemistry, biology, medicine, transport, logistics, site location, communication, scheduling, industry, business, finance, etc.

Plenary Speakers: Frank Allgoewer (Stuttgart), Ralf Borndoerfer (Berlin), Ingrid Daubechies (Princeton), Mats Gyllenberg (Helsinki), Karl Kunisch (Graz), Bob Russell (Burnaby), Volker Schulz (Trier), Christoph Schwab (Zurich), Tamas Terlaky (Bethlehem, PA).

Deadlines: Deadline for registration and submission of abstracts: September 29, 2011. Notification of acceptance for presentation: December 21, 2011. Deadline for submission of data to apply for a business visa: January 6, 2012. Deadline for hotel reservation: January 6, 2012. Deadline for submission of full papers for the conference proceedings: May 12, 2012.

Information: `http://hpsc.iwr.uni-heidelberg.de/HPSCHanoi2012`.

10–11 **AMS Southeastern Section Meeting**, University of South Florida, Tampa, Florida. (May 2011, p. 744)

Information: `http://www.ams.org/meetings/sectional/sectional.html`.

12–15 **Computational Methods in High Energy Density Plasmas**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Mar. 2011, p. 497)
Description: High energy density physics (HEDP) is a rapidly growing field. HEDP conditions are typically from Mbar to tens of Gbar pressures and temperatures ranging from eV to GeV. This long program will focus on the computational approaches to the modeling of these extreme states of matter. It will address the scientific challenges facing the computational HEDP community and discuss the successes and failures of various methods. The long program will establish an interdisciplinary forum for researchers in HEDP.Funding for participants is available at all academic levels, though recent PhD's, graduate students, and researchers in the early stages of their career are especially encouraged to apply. Enhancing the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications. An application is available online. Applications will be accepted through November 12, 2011 but decisions will be made starting in June.
Information: `http://www.ipam.ucla.edu/programs/pl2012/`.

12–June 16 **AIM Workshop: Classifying fusion categories**, American Institute of Mathematics, Palo Alto, California. (May 2011, p. 744)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the classification problem for fusion categories, including those with additional structure, e.g., ribbon and modular fusion categories. More specifically, we will focus on the development and application of both theoretical and computational techniques for classifying fusion categories that are "small" in various senses.
Information: `http://aimath.org/ARCC/workshops/fusioncat.html`.

12–16 **ICERM Workshop: Global Arithmetic Dynamics**, ICERM, Providence, Rhode Island. (Jun/Jul. 2011, p. 862)
Description: The aim of this workshop is to bring together leading researchers in global arithmetic dynamics and related fields to discuss recent result. In particular, we hope to attract researchers who work in arithmetic geometry, algebraic geometry, model theory, and computational algebra and number theory, with the dual goals of introducing the field of arithmetic dynamics and encouraging interactions among people working in these varied fields.
Information: `http://icerm.brown.edu/sp-s12/workshop-2.php`.

14–16 **IAENG International Conference on Operations Research 2012**, Royal Garden Hotel, Kowloon, Hong Kong.
Description: The conference ICOR'12 is held under the International MultiConference of Engineers and Computer Scientists 2012. The IMECS 2012 is organized by the International Association of Engineers (IAENG), a non-profit international association for the engineers and the computer scientists. The topics of the ICOR'12 include, but are not limited to, the following: management science, managerial economics, systems thinking and analysis, optimization integer programming, linear programming, nonlinear programming, assignment problem, transportation network design, simulation, statistical, analysis, stochastics, modelling reliability and maintenance, queueing theory, game theory, graph theory, OR algorithms and software developments, OR applications and case studies.
Information: `http://www.iaeng.org/IMECS2012/ICOR2012.html`.

17–18 **AMS Eastern Section Meeting**, George Washington University, Washington, District of Columbia. (May 2011, p. 744)
Information: `http://www.ams.org/meetings/sectional/sectional.html`.

* 24–25 **36th Annual SIAM Southwestern Atlantic Section Conference**, University of Alabama in Huntsville, Huntsville, Alabama.
Description: This two day conference will consist of a combination of plenary talks, parallel sessions, and poster sessions to exchange recent advances and future trends in applied and computational mathematics. There will be awards for best student presentation and best poster presentation. Graduate and undergraduate students who wish to be eligible for this award must indicate so via email to the organizers when they submit their abstracts. Both pre-registration and on-site registration will be available, entitling everyone who is registered to attend all talks Saturday and Sunday. The registration fee includes lunch on Saturday. Follow the links at the left to find information aboutv the conference, including conference program, registration, student paper competition, lodging, driving directions, and more.
Plenary speakers: H. T. Banks, North Carolina State University; Susanne C. Brenner, Michael F. and Roberta Nesbit McDonald, Lousiana State University; Jerrold R. Griggs, University of South Carolina; Max D. Gunzburger, Francis Eppes, Florida State University.
Deadline: Minisymposium proposals: February 1, 2012. Abstracts for contributed and minisymposium speakers: February 15, 2012.
Conference chair: Prof. S. S. Radindran; email: `ravinds@uah.edu`.
Information: `http://mullai.uah.edu/~ravindra/SEAS2012.html`.

25–28 **Conference on Partial Differential Equations and Applications**, Vietnam National University, Hanoi, Vietnam. (Jun/Jul. 2011, p. 862)
Description: The conference on partial differential equations and applications aims to present a broad and interdisciplinary overview of the current, state-of-the-art methods and techniques for characterizing PDEs. Moreover, various application areas will be highlighted where such techniques play critical roles in solving fundamental problems of interest to the broader scientific community. The conference will be preceded by a workshop aimed at graduate students and postdocs in the mathematical sciences who have a fundamental interest in PDE methods and applications.
Plenary Speakers: Marsha Berger (Courant, NYU), Peter Constantin (Chicago), Craig Evans (Berkeley), Tom Hou (Caltech), Carlos Kenig (Chicago), Sergiu Klainerman (Princeton), Randall LeVeque (Washington), Louis Nirenberg (Courant, NYU), Atsushi Yagi (Osaka).
Information: `http://www.amath.washington.edu/events/vietnam2012/`.

26–30 **AIM Workshop: Cohomological methods in abelian varieties**, American Institute of Mathematics, Palo Alto, California. (Aug. 2011, p. 1012)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the integral motive, Chow groups and etale cohomology of abelian varieties, and applications to arithmetic geometry.
Information: `http://www.aimath.org/ARCC/workshops/cohomabelian.html`.

26–30 (NEW DATE) **IMA Workshop: Machine Learning: Theory and Computation**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota. (Jan. 2011, p. 85)
Topics: Topics to be discussed at the workshop include the interplay between machine learning (kernel learning, graphical models, online learning, active learning) with (a) statistical modeling and learning theory, (b) theoretical computer science, (c) numerical optimization, (d) topological methods, (e) tensor methods, and (f) sparse methods.
Information: `http://www.ima.umn.edu/2011-2012/W3.26-30.12/`.

30–31 **Information and Econometrics of Networks**, American University, Washington, District of Columbia. (Mar. 2011, p. 497)
Description: Social and economic networks are everywhere: from Facebook to the more complex global financial network or to networks connecting economic agents or to other complex and dynamic economic networks. The study of these networks is crucial for both academics and policy makers and presents a host of new theoretical and econometric challenges. This conference will concentrate on studying the information and econometrics of networks.

Hosts: The two-day conference is hosted by the Info-Metrics Institute and supported (partially) by the *Journal of Applied Econometrics* and will be organized jointly by Amos Golan (AU) and Essie Maasoumi (Emory).
Information: http://www.american.edu/cas/economics/info-metrics/workshop/workshop-2012-sprin g.cfm.

30–April 1 **AMS Central Section Meeting**, University of Kansas, Lawrence, Kansas. (May 2011, p. 744)
Information: http://www.ams.org/meetings/sectional/sectional.html.

April 2012

1–4 **The 8th International Conference on Scientific Computing and Applications (SCA2012)**, University of Nevada Las Vegas (UNLV), Las Vegas, Nevada. (Aug. 2011, p. 1012)
Description: This will be the 8th of the sequences of conferences on Scientific Computing and Applications (SCA) held in the Pacific Rim region (held previously in China, Canada, Hong Kong, Korean). This is the first time to be held in USA. The purpose of the meeting is to provide a forum for researchers working on various aspects of Scientific Computing and Applications to meet and move this area forward.
Co-Chairs of local organize committee: Jichun Li and Hongtao Yang (Univ of Nevada Las Vegas, USA).
Important Deadlines: November 1, 2011: Mini-symposium proposal due. December 1, 2011: Abstracts for all talks due.
Information: http://www.unlv.edu/centers/cams/sca2012/sca2012.html.

2–4 **SIAM Conference on Uncertainty Quantification (UQ12)**, Raleigh Marriott City Center Hotel, Raleigh, North Carolina. (Aug. 2011, p. 1012)
Description: Uncertainty quantification is key for achieving validated predictive computations in a wide range of scientific and engineering applications. The field relies on a broad range of mathematics and statistics groundwork, with associated algorithmic and computational development. This conference strives to bring together an interdisciplinary mix of mathematicians, statisticians, scientists, and engineers with an interest in development and implementation of uncertainty quantification methods. The goal of the meeting is to provide a forum for the sharing of ideas, and to enhance communication among this diverse group of technical experts, thereby contributing to future advances in the field.
Information: http://www.siam.org/meetings/uq12/.

2–6 **AIM Workshop: Vector equilibrium problems and their applications to random matrix models**, American Institute of Mathematics, Palo Alto, California. (Aug. 2011, p. 1013)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the study of vector equilibrium problems and their application to the asymptotic analysis of random matrix models.
Information: http://aimath.org/ARCC/workshops/vectorequilib.html.

16–20 **ICERM Workshop: Moduli Spaces Associated to Dynamical Systems**, ICERM, Providence, Rhode Island. (Jun/Jul. 2011, p. 862)
Description: The set of rational self-maps of Pn of degree d, which is denoted Ratdn, has a natural structure as an affine variety. The group PGLn+1 acts by conjugation on Ratdn, and the quotient space is the dynamical moduli space Mdn.
Information: http://icerm.brown.edu/sp-s12/workshop-3.php.

* 20–22 **The Fifteenth Riviere-Fabes Symposium on Analysis and PDE**, School of Mathematics, University of Minnesota, Minneapolis, Minnesota.
Information: http://www.math.umn.edu/. Additional information on previous conferences in this series can be found on http://www.math.umn.edu/conferences/riv fabes/.

30–May 5 **Random Walks and Random Media**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1013)
Description: The field of random media has been the object of intensive mathematical research over the last thirty years. It covers a variety of models, mainly from condensed matter physics, physical chemistry, and geology, where one is interested in materials which have defects or inhomogeneities. These features are taken into account by letting the medium be random. It has been found that this randomness can cause very unexpected effects in the large scale behavior of these models; on occasion these run contrary to the prevailing intuition. A feature of this area, which it has in common with other areas of statistical physics, is that what was initially thought to be just a simple toy model has turned out to be a major mathematical challenge.
Information: http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm581.

May 2012

7–11 **IMA Workshop: User-Centered Modeling**, Institute for Mathematics and its Applications (IMA), University of Minnesota, Minneapolis, Minnesota.
Description: This data-driven workshop will explore the challenges for inference, models, algorithms and graphical and analytical tools that these different aspects of user-centered modeling raise. The plan is to start with enabling, evaluating, and analyzing data that users actively contribute in citizen science, taking into account thorny issues like data aggregation, selection bias, data quality, and inferential uncertainty, then move on to data that users passively contribute or leave behind on the Web, even when they are trying to hide, and asking the same questions in that context.
Information: See http://www.ima.umn.edu/2011-2012/W5.7-11.12/.

14–18 **AIM Workshop: ACC for minimal log discrepancies and termination of flips**, American Institute of Mathematics, Palo Alto, California. (Aug. 2011, p. 1013)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to two closely connected conjectures in the minimal model program.
Information: http://www.aimath.org/ARCC/workshops/accflips.html.

17–19 **International Conference on "Applied Mathematics and Approximation Theory 2012"**, TOBB University of Economics and Technology, Ankara, Turkey. (Aug. 2011, p. 1013)
Description: Celebrating the 60th birthday of Professor George Anastassiou.
Organizer: Oktay Duman, oduman@etu.edu.tr.
Topics: Applied Mathematics and Approximation Theory in the broad sense.
Plenary Speakers: George Anastassiou, Martin Bohner, Dimitru Baleanu, Heiner Gonska, Weimin Han, Cihan Orhan.
International Organizing Committee: Jerry Bona, Sever Dragomir, Sorin Gal, Narenda Govil, Anna Kaminska, Ram Mohapatra, Gaston N'Guerekata, Richard Zalik.
Information: http://amat2012.etu.edu.tr/.

20–22 **SIAM Conference on Imaging Science (IS12)**, Doubletree Hotel Philadelphia, Philadelphia, Pennsylvania.
Description: This conference is sponsored by the SIAM Activity Group on Imaging Science. The call for papers will be posted online in July 2011.
Information: See http://www.siam.org/meetings/is12/.

20–25 **7th European Conference on Elliptic and Parabolic Problems**, Gaeta, Italy. (May 2011, p. 744)

Description: Besides Elliptic and Parabolic issues, the topics of the conference include Geometry, Free Boundary Problems, Fluid Mechanics, Evolution Problems in general, Calculus of Variations, Homogenization, Control, Modeling and Numerical Analysis. In addition to the plenary talks parallel sessions and minisymposia will be organized.
Information: http://www.math.uzh.ch/gaeta2012.

21–25 **AIM Workshop: Contact topology in higher dimensions**, American Institute of Mathematics, Palo Alto, California. (Aug. 2011, p. 1013)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to developing high dimensional contact topology.
Information: http://www.aimath.org/ARCC/workshops/contacttop.html.

28–June 3 **International Conference "Theory of Approximation of Functions and its Applications"**, Kamianets-Podilsky Ivan Ohienko National University, Kamianets-Podilsky, Ukraine. (Jun/Jul. 2011, p. 862)
Description: International Conference "Theory of Approximation of Functions and its Applications" dedicated to the 70th anniversary of corresponding member of National Academy of Sciences of Ukraine, Professor O. I. Stepanets (1942–2007).
Information: http://www.imath.kiev.ua/~funct/stepconf2012/en/.

* 30–June 2 **12th Viennese Workshop on Optimal Control, Dynamic Games and Nonlinear Dynamics**, Vienna University of Technology, Vienna, Austria.
Description: As the preceding meetings in this series, the workshop aims at bringing together researchers in optimal control, dynamic games and nonlinear dynamical systems, as well as in economics, management, environment, population dynamics and social sciences. The topics of the workshop will include, but are not limited to, the theory and numerical methods of optimal control, differential games, bifurcation theory, and a broad spectrum of applications involving dynamic economic models (including heterogeneous/distributed ones), dynamic models in population and health economics, economic geography, demography, epidemiology, social sciences, etc.
Information: http://orcos.tuwien.ac.at/events/ocdgnd_2012/#c29435.

June 2012

12–15 **"The Incomputable" — A workshop of the 6-month Isaac Newton Institute programme — "Semantics and Syntax: A Legacy of Alan Turing" (SAS)**, Kavli Royal Society International Centre, Chicheley Hall, Newport Pagnell MK16 9JJ, United Kingdom. (Aug. 2011, p. 1013)
Description: The Incomputable is one of a series of special events, running throughout the Alan Turing Year, celebrating Turing's unique impact on mathematics, computing, computer science, informatics, morphogenesis, philosophy and the wider scientific world. It is held in association with the Turing Centenary Conference (CiE 2012) in Cambridge the following week, which will run up to the June 23rd centenary of Turing's birth, and will culminate with a birthday celebration at Turing's old college, King's College, Cambridge. The Incomputable is unique in its focus on the mathematical theory of incomputability, and its relevance for the real world. This is a core aspect of Turing's scientific legacy — and this meeting for the first time reunites (in)computability theory and 'big science' in a way not attempted since Turing's premature passing. In 2012, the annual Workshop on Computability Theory is being held in conjunction with The Incomputable.
Contact: S. Barry Cooper; email: pmt6sbc@leeds.ac.uk.
Information: http://www.mathcomp.leeds.ac.uk/turing2012/inc/.

* 13–16 **SIAM Conference on Nonlinear Waves and Coherent Structures (NW12)**, The University of Washington, Seattle, Washington.
Call for Papers/Information: The call for papers for this conference will be available in August 2011 at http://www.siam.org/meetings/nw12/.

* 18–22 **AIM Workshop: Dynamics of the Weil-Petersson geodesic flow**, American Institute of Mathematics, Palo Alto, California.
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the study of recent advances in understanding deformations of Riemann surfaces via the Weil-Petersson metric on Teichmuller and moduli spaces.
Information: http://www.aimath.org/ARCC/workshops/weilpetersson.html.

18–23 **Turing Centenary Conference (CiE 2012): How the World Computes**, University of Cambridge, Cambridge, United Kingdom. (Aug. 2011, p. 1013)
Description: CiE 2012 is one of a series of special events, running throughout the Alan Turing Year, celebrating Turing's unique impact on mathematics, computing, computer science, informatics, morphogenesis, philosophy and the wider scientific world. Its central theme is the computability-theoretic concerns underlying the broad spectrum of Turing's interests, and the contemporary research areas founded upon and animated by them. In this sense, CiE 2012, held in Cambridge in the week running up to the centenary of Turing's birthday, deals with the essential core of what made Turing's contribution so influential and long-lasting. CiE 2012 promises to be an event worthy of the remarkable scientific career it commemorates.
Invited speakers: Veronica Becher, Lenore Blum, Rodney Downey, Yuri Gurevich, Juris Hartmanis, Andrew Hodges, Richard Jozsa, Stuart Kauffman, Paul Smolensky, James Murray, Leslie Valiant.
Deadline: For submissions: January 27, 2012.
Contact: email: anuj.dawar@cl.cam.ac.uk.
Information: http://www.cie2012.eu.

July 2012

* 1–5 **9th AIMS conference on Dynamical Systems, Differential Equations and Applications**, Orlando, Florida.
Plenary speakers: Andrea Bertozzi, Michael Dellnitz, Eduard Feireisl, Avner Friedman, Yuan Lou, Andrew Majda, J. M. Sanz-Serna, Jianhong Wu.
Format: Plenary talks; 30-minute special session talks; 20-minute contributed talks. Proposals to organize a special session are welcome. The Proceedings will be published.
Topics: Keeping the tradition of the AIMS Conference Series, the conference covers all major areas of analysis and dynamics, with emphases on theory, methods, application, modeling and computations.
Organizer: The American Institute of Math Sciences.
Information: http://www.aimsciences.org.

9–15 **The 10th International Conference on Fixed Point Theory and its Applications (ICFPTA-2012)**, Faculty of Mathematics and Computer Science, Babes, Bolyai University, Cluj-Napoca, Romania. (Jun/Jul. 2011, p. 862)
Description: The purpose of the conference is to bring together leading experts and researchers in fixed point theory and to assess new developments, ideas and methods in this important and dynamic field. A special emphasis will be put on applications in related areas, as well as other sciences, such as the natural sciences, medicine, economics and engineering. The conference will continue the tradition of the previous fixed point theory meetings which were held in Marseille (1989), Halifax (1991), Seville (1995), Kazimierz Dolny (1997), Haifa (2001), Valencia (2003), Guanajuato (2005), Chiang Mai (2007) and Changhua (2009). The conference will honour Professor Kazimierz Goebel, on the occasion of his retirement, and Professors Ljubomir Ciric, William Art Kirk and Ioan A. Rus, on the occasion of their 75th birthday.

Information: http://www.cs.ubbcluj.ro/~fptac/.

16–December 21 **Topological Dynamics in the Physical and Biological Sciences**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (April 2011, p. 629)
Description: The programme is intended to stimulate interaction between applied mathematicians, biologists and physicists who frequently encounter dynamical problems that have some explicit or implicit topological content. We use the term 'topological' to convey the idea of structures, e.g. knots, links or braids in 3D, that exhibit some measure of invariance under continuous deformation. Dynamical evolution is then subject to the topological constraints that express this invariance. A basic common problem is to determine minimum energy structures (and routes towards these structures) permitted by such constraints; and to explore mechanisms, e.g.diffusive, by which such constraints may be broken. Workshops: A number of workshops will take place during the programme. For full details please see: http://www.newton.ac.uk/events.html.
Organizers: Professor K. Bajer (Warsaw), Professor T. W. Kephart (Vanderbilt), Professor Y. Kimura (Nagoya), Professor H. K. Moffatt (Cambridge) and Professor A. Stasiak (Lausanne).
Information: http://www.newton.ac.uk/programmes/TOD/.

23–August 17 **Spectral Theory of Relativistic Operators**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.
Description: Relativistic operators are used to model important physical systems which include transport properties of graphene, and relativistic quantum field theory. This meeting will focus on the following areas of current research interest in such operators applied to mathematical physics. 1. For classical (one-particle) Dirac operators, current topics of interest include the Weyl-type theory, dissolution of eigenvalues of corresponding relativistic systems into resonances, asymptotics of the spectral function and spectral concentration as well as the role of the mass term of Dirac operators. 2. Stability of matter and asymptotic behaviour of the ground state energy for relativistic many-particle systems. 3. The interaction of photons with fast moving (relativising) electrons, positrons, and photons.
Organizers: Professor M. Brown (Cardiff), Professor M. J. Esteban (Ceremade), Dr. K. M. Schmidt (Cardiff) and Professor H. Siedentop (Munich).
Information: http://www.newton.ac.uk/programmes/SRO/.

30–August 3 **Iwasawa 2012**, Heidelberg University, Heidelberg, Germany. (Feb. 2011, p. 336)
Description: The Mathematics Center Heidelberg (MATCH) will host the conference "Iwasawa 2012" which is the fifth conference in a bi-annual series. The conference aims to provide a platform to present and discuss the latest developments of research in the area of Iwasawa theory.
Information: http://www.mathi.uni-heidelberg.de/~iwasawa2012/.

August 2012

6–11 **XVII International Congress on Mathematical Physics (ICMP12)**, Aalborg Kongress og Kultur Center, Europa Plads 4, 9000 Aalborg, Denmark. (Aug. 2011, p. 1013)
Description: The International Association of Mathematical Physics (IAMP) and the Local Organizing Committee invite you to participate in the XVII International Congress on Mathematical Physics (ICMP12). It will be held in Aalborg, Denmark, August 6-11, 2012. The International Congress on Mathematical Physics is held every three years. It is a major event in the mathematical physics community. The congress will present new results and future challenges, in a series of plenary lectures and topical sessions.
Information: http://www.icmp12.com/.

20–24 **AIM Workshop: Invariants in convex geometry and Banach space theory**, American Institute of Mathematics, Palo Alto, California. (Aug. 2011, p. 1013)
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the study of invariants related to a few important problems at the intersection of geometric analysis and Banach space theory.
Information: http://www.aimath.org/ARCC/workshops/convexbanach.html.

27–September 7 **Joint Introductory Workshop: Cluster Algebras and Commutative Algebra**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1013)
Description: This workshop will take place at the opening of the MSRI special programs on Commutative Algebra and on Cluster Algebras. It will feature lecture series at different levels, to appeal to a wide variety of participants. There will be minicourses on the basics of cluster algebras, and others developing particular aspects of cluster algebras and commutative algebra.
Information: http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm557.

September 2012

3–7 **International Conference on Differential-Difference Equations and Special Functions**, University of Patras, Patras, Greece. (Aug. 2011, p. 1014)
Description: The conference is dedicated to the memory of Professor Panayiotis D. Siafarikas, who left so early in 2010 and its main aim is to bring together experts working in all areas (including numerical investigations and applications) of differential equations, difference equations and special functions and to promote the research in these areas.
Information: http://www.icddesf.upatras.gr.

22–23 **AMS Eastern Section Meeting**, Rochester Institute of Technology, Rochester, New York.
Information: http://www.ams.org/meetings/sectional/sectional.html.

October 2012

2–4 **SIAM Conference on Mathematics for Industry: Challenges and Frontiers (MI12)**, The Curtis, A Doubletree by Hilton, Denver, Colorado. (Aug. 2011, p. 1014)
Description: The SIAM conferences on Mathematics for Industry focus attention on the many and varied opportunities to promote applications of mathematics to industrial problems. From the start of planning for these conferences, the major objective has been the development and encouragement of industrial, government and academic collaboration. The format of this conference provides a forum for industrial and government engineers and scientists to communicate their needs, objectives and visions, to the broad mathematical community.
Information: http://www.siam.org/meetings/mi12/.

13–14 **AMS Southeastern Section Meeting**, Tulane University, New Orleans, Louisiana. (Aug. 2011, p. 1014)
Information: http://www.ams.org/meetings/sectional/sectional.html.

20–21 **AMS Central Section Meeting**, University of Akron, Akron, Ohio. (Aug. 2011, p. 1014)
Information: http://www.ams.org/meetings/sectional/sectional.html.

27–28 **AMS Western Section Meeting**, University of Arizona, Tucson, Arizona. (Aug. 2011, p. 1014)
Information: http://www.ams.org/meetings/sectional/sectional.html.

Mathematics Calendar

January 2013

24–25 **Connections for Women: Noncommutative Algebraic Geometry and Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1014)
Description: The Connections for Women workshop associated with the MSRI program in noncommutative algebraic geometry and representation theory is intended to bring together women who are working in these areas in all stages of their careers. As the first event in the semester, this workshop will feature a "tapas menu" of current research and open questions: light but intriguing tastes, designed to encourage further exploration and interest. Talks will be aimed at a fairly general audience and will cover diverse topics within the theme of the program. In addition, there will be a poster session for graduate students and recent Ph.D. recipients and a panel discussion on career issues, as well as free time for informal discussion.
Information: `http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm9061`.

28–February 1 **Introductory Workshop: Noncommutative Algebraic Geometry and Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1014)
Description: This workshop will provide several short lecture series consisting of two or three lectures each to introduce postdocs, graduate students and non-experts to some of the major themes of the conference. While the precise topics may change to reflect developments in the area, it is likely that we will run mini-series in the following subjects: noncommutative algebraic geometry; D-module theory; derived categories; noncommutative resolutions of singularities; deformation-quantization; symplectic reflection algebras; growth functions of infinite dimensional algebras.
Information: `http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm9062`.

April 2013

8–12 **Interactions between Noncommutative Algebra, Representation Theory, and Algebraic Geometry**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1014)
Description: In recent years there have been increasing interactions between noncommutative algebra/representation theory on the one hand and algebraic geometry on the other. This workshop would aim to examine these interactions and, as importantly, to encourage the interactions between the three areas. The precise topics will become more precise nearer the time, but will certainly include: Noncommutative algebraic geometry; noncommutative resolutions of singularities and Calabi-Yau algebras; symplectic reflection and related algebras; D-module theory; deformation-quantization.
Information: `http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm9063`.

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.

July 2013

* 29–August 2 **36th Conference on Stochastic Processes and their Applications**, Boulder, Colorado.
Information: More information will be provided at a future date; email: `brian.rider@colorado.edu`.

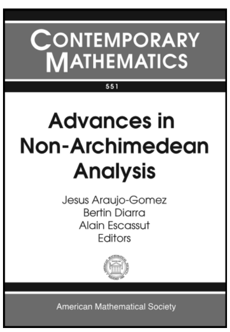
August 2013

5–9 **XXII Rolf Nevanlinna Colloquium**, Helsinki, Finland. (Aug. 2011, p. 1014)
Description: For further information, please contact Kirsi Peltonen, Aalto University; email: `kirsi.peltonen@tkk.fi`.

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



Advances in Non-Archimedean Analysis

Jesus Araujo-Gomez, *Universidad de Cantabria, Santander, Spain*, **Bertin Diarra**, *Université Blaise Pascal, Aubière, France*, and **Alain Escassut**, *Université Blaise Pascal, Aubière, France*, Editors

This volume contains papers based on lectures given at the Eleventh International Conference on p-adic Functional Analysis, which was held from July 5–9, 2010, in Clermont-Ferrand, France.

The articles collected here feature recent developments in various areas of non-Archimedean analysis: Hilbert and Banach spaces, finite dimensional spaces, topological vector spaces and operator theory, strict topologies, spaces of continuous functions and of strictly differentiable functions, isomorphisms between Banach function spaces, and measure and integration.

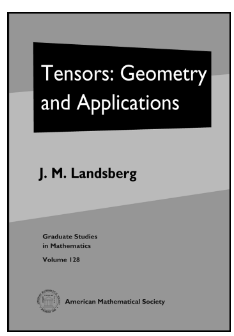
Other topics discussed in this volume include p-adic differential and q-difference equations, rational and non-Archimedean analytic functions, the spectrum of some algebras of analytic functions, and maximal ideals of the ultrametric corona algebra.

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

Contents: C. Perez-Garcia and **W. H. Schikhof**, Remembering Nicole De Grande-De Kimpe (1936-2008); **V. Anashin**, **A. Khrennikov**, and **E. Yurova**, Using van der Put basis to determine if a 2-adic function is measure-preserving or ergodic w.r.t. Haar measure; **N. Boudjerida**, **A. Boutabaa**, and **S. Medjerab**, q-difference equations in ultrametric fields; **K. Boussaf**, **A. Escassut**, and **J. Ojeda**, Primitives of p-adic meromorphic functions; **W. Cherry**, Existence of GCD's and factorization in rings of non-Archimedean entire functions; **G. Christol**, The radius of convergence function for first order differential equations; **B. Diarra**, The Lipschitz condition for rational functions on ultrametric valued fields; **A. Escassut**, Differential and maximal ideals of the ultrametric Corona algebra; **A. K. Katsaras**, Linear topologies on non-Archimedean function spaces; **A. K. Katsaras**, **L. A. Khan**, and **A. R. Khan**, On maximal closed ideals in topological algebras of continuous vector-valued functions over non-Archimedean valued fields; **H. A. Keller** and **H. Ochsenius**, Perturbations of bounded linear operators on orthomodular Hilbertian spaces; **A. Kubzdela**, On some geometrical properties of linear subspaces of l^∞; **M. L. Lapidus** and **L. Hùng**, The geometry of p-adic fractal strings: A comparative survey; **H. Maïga**, Identities and congruences for Genocchi numbers; **H. M. Moreno**, Toward an ultrametric calculus in a field K with an infinite rank valuation; **E. Olivos** and **W. H. Schikhof**, Extending the multiplication of a totally ordered group to its completion; **S. Priess-Crampe**, Norm Hilbert spaces with uncountable orthogonal basis; **K. Shamseddine**, Absolute and relative extrema, the mean value theorem and the inverse function theorem for analytic functions on a Levi-Civita field; **F. Tangara**, Some p-adic q-difference equations on $C(\mathbb{Z}_p, K)$.

Contemporary Mathematics, Volume 551

September 2011, 280 pages, Softcover, ISBN: 978-0-8218-5291-0, LC 2011018720, 2010 *Mathematics Subject Classification:* 11D88, 11S80, 12J25, 15A63, 26E30, 32P05, 44A10, 46S10, 47S10, 81Q65, **AMS members US$79.20**, List US$99, Order code CONM/551



Tensors: Geometry and Applications

J. M. Landsberg, *Texas A&M University, College Station, TX*

Tensors are ubiquitous in the sciences. The geometry of tensors is both a powerful tool for extracting information from data sets, and a beautiful subject in its own right. This book has three intended uses: a classroom textbook, a reference work for researchers in the sciences, and an account of classical and modern results in (aspects of) the theory that will be of interest to researchers in geometry. For classroom use, there is a modern introduction to multilinear algebra and to the geometry and representation theory needed to study tensors, including a large number of exercises. For researchers in the sciences, there is information on tensors in table format for easy reference and a summary of the state of the art in elementary language.

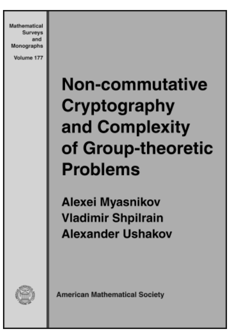
This is the first book containing many classical results regarding tensors. Particular applications treated in the book include the complexity of matrix multiplication, **P** versus **NP**, signal processing, phylogenetics, and algebraic statistics. For geometers, there is material on secant varieties, *G*-varieties, spaces with finitely many orbits and how these objects arise in applications, discussions of numerous open questions in geometry arising in applications, and expositions of advanced topics such as the proof of the Alexander-Hirschowitz theorem and of the Weyman-Kempf method for computing syzygies.

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

Contents: *Motivation from applications, multilinear algebra and elementary results:* Introduction; Multilinear algebra; Elementary results on rank and border rank; *Geometry and representation theory:* Algebraic geometry for spaces of tensors; Secant varieties; Exploiting symmetry: Representation theory for spaces of tensors; Tests for border rank: Equations for secant varieties; Additional varieties useful for spaces of tensors; Rank; Normal forms for small tensors; *Applications:* The complexity of matrix multiplication; Tensor decomposition; **P** v. **NP**; Varieties of tensors in phylogenetics and quantum mechanics; *Advanced topics:* Overview of the proof of the Alexander-Hirschowitz theorem; Representation theory; Weyman's method; Hints and answers to selected exercises; Bibliography; Index.

Graduate Studies in Mathematics, Volume 128

December 2011, approximately 438 pages, Hardcover, ISBN: 978-0-8218-6907-9, 2010 *Mathematics Subject Classification:* 15-01, 15A69, 68Q17, 14M17, 94A12, 94A13, 20G05, 62E10, 14N05, **AMS members US$59.20**, List US$74, Order code GSM/128



Non-Commutative Cryptography and Complexity of Group-Theoretic Problems

Alexei Myasnikov, *Stevens Institute of Technology, Hoboken, NJ*, **Vladimir Shpilrain**, *City College of New York, NY*, and **Alexander Ushakov**, *Stevens Institute of Technology, Hoboken, NJ*
with an Appendix by Natalia Mosina

This book is about relations between three different areas of mathematics and theoretical computer science: combinatorial group theory, cryptography, and complexity theory. It explores how non-commutative (infinite) groups, which are typically studied in combinatorial group theory, can be used in public key cryptography. It also shows that there is remarkable feedback from cryptography to combinatorial group theory because some of the problems motivated by cryptography appear to be new to group theory, and they open many interesting research avenues within group theory.

In particular, a lot of emphasis in the book is put on studying search problems, as compared to decision problems traditionally studied in combinatorial group theory. Then, complexity theory, notably generic-case complexity of algorithms, is employed for cryptanalysis of various cryptographic protocols based on infinite groups, and the ideas and machinery from the theory of generic-case complexity are used to study asymptotically dominant properties of some infinite groups that have been applied in public key cryptography so far.

This book also describes new interesting developments in the algorithmic theory of solvable groups and another spectacular new development related to complexity of group-theoretic problems, which is based on the ideas of compressed words and straight-line programs coming from computer science.

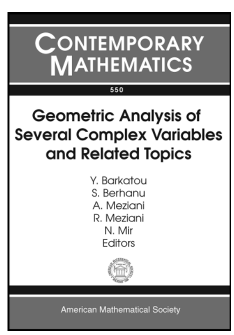
This item will also be of interest to those working in applications.

Contents: Introduction; *Background on groups, complexity, and cryptography:* Background on public key cryptography; Background on combinatorial group theory; Background on computational complexity; *Non-commutative cryptography:* Canonical non-commutative cryptography; Platform groups; More protocols; Using decision problems in public key cryptography; Authentication; *Generic complexity and cryptanalysis:* Distributional problems and the average case complexity; Generic case complexity; Generic complexity of NP-complete problems; Generic complexity of undecidable problems; Strongly, super, and absolutely undecidable problems; *Asymptotically dominant properties and cryptanalysis:* Asymptotically dominant properties; Length based and quotient attacks; *Word and conjugacy search problems in groups:* Word search problem; Conjugacy search problem; *Word problem in some special classes of groups:* Free solvable groups; Compressed words; Probabilistic group-based cryptanalysis; Bibliography; Abbreviations and notation; Index.

Mathematical Surveys and Monographs, Volume 177

November 2011, approximately 413 pages, Hardcover, ISBN: 978-0-8218-5360-3, LC 2011020554, 2010 *Mathematics Subject Classification:* 94A60, 20F10, 68Q25, 94A62, 11T71, **AMS members US$84**, List US$105, Order code SURV/177

Analysis



Geometric Analysis of Several Complex Variables and Related Topics

Y. Barkatou, *Université de Poitiers, Futuroscope, France*, **S. Berhanu**, *Temple University, Philadelphia, PA*, **A. Meziani**, *Florida International University, Miami, FL*, **R. Meziani**, *Ibn Tofail University, Kenitra, Morocco*, and **N. Mir**, *University of Rouen, France*, Editors

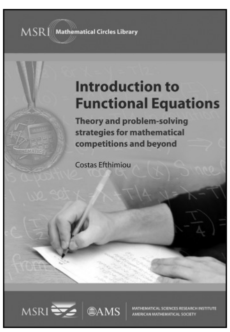
This volume contains the proceedings of the Workshop on Geometric Analysis of Several Complex Variables and Related Topics, which was held from May 10–14, 2010, in Marrakesh, Morocco.

The articles in this volume present current research and future trends in the theory of several complex variables and PDE. Of note are two survey articles: The first presents recent results on the solvability of complex vector fields with critical points while the second concerns the Lie group structure of the automorphism groups of CR manifolds. The other articles feature original research in major topics of analysis dealing with analytic and Gevrey regularity, existence of distributional traces, the $\bar{\partial}$-Neumann operator, automorphisms of hypersurfaces, holomorphic vector bundles, spaces of harmonic forms, and Gysin sequences.

Contents: R. F. Barostichi, **P. D. Cordaro**, and **G. Petronilho**, Analytic vectors in locally integrable structures; **M. Derridj** and **B. Helffer**, Subellipticity and maximal hypoellipticity for two complex vector fields in $(2+2)$-variables; **J. Hounie** and **E. R. da Silva**, Existence of trace for solutions of locally integrable systems of vector fields; **M. Kolář** and **F. Meylan**, Chern-Moser operators and weighted jet determination problems; **B. Lamel**, Jet embeddability of local automorhpism groups of real-analytic CR manifolds; **J. Leiterer**, Splitting of holomorphic cocycles with estimates. Several variables; **G. A. Mendoza**, A Gysin sequence for manifolds with $\mathbb{R}$-action; **S. Şahutoğlu**, A potential theoretic characterization of compactness of the $\bar{\partial}$-Neumann problem; **M.-C. Shaw**, Duality between harmonic and Bergman spaces; **F. Treves**, On the solvability and hypoellipticity of complex vector fields.

Contemporary Mathematics, Volume 550

September 2011, 196 pages, Softcover, ISBN: 978-0-8218-5257-6, LC 2011014591, 2010 *Mathematics Subject Classification:* 32L05, 32Q99, 32V20, 32W05, 35A07, 35B20, 35B65, 35F05, 35F15, **AMS members US$55.20**, List US$69, Order code CONM/550



Introduction to Functional Equations

Theory and problem-solving strategies for mathematical competitions and beyond

Costas Efthimiou, *University of Central Florida, Orlando, FL*

Functions and their properties have been part of the rigorous precollege curriculum for decades. And functional equations have been a favorite topic of the leading national and international mathematical competitions. Yet the subject has not received equal attention by authors at an introductory level. The majority of the books on the topic remain unreachable to the curious and intelligent precollege student. The present book is an attempt to eliminate this disparity.

The book opens with a review chapter on functions, which collects the relevant foundational information on functions, plus some material potentially new to the reader. The next chapter presents a working definition of functional equations and explains the difficulties in trying to systematize the theory. With each new chapter, the author presents methods for the solution of a particular group of equations. Each chapter is complemented with many solved examples, the majority of which are taken from mathematical competitions and professional journals. The book ends with a chapter of unsolved problems and some other auxiliary material.

The book is an invaluable resource for precollege and college students who want to deepen their knowledge of functions and their properties, for teachers and instructors who wish to enrich their curricula, and for any lover of mathematical problem-solving techniques.

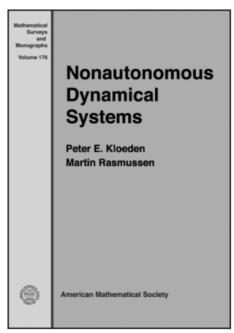
Titles in this series are co-published with the Mathematical Sciences Research Institute (MSRI).

Contents: *Background:* Functions; *Basic equations:* A primer on functional relations; Equations for arithmetic functions; Equations reducing to algebraic systems; Cauchy's equations; Cauchy's $\mathbb{NQR}$ method; Equations for trigonometric functions; *Generalizations:* The Pexider, Vincze and Wilson equations; Vector and matrix variables; Systems of equations; *Changing the rules:* Less than continuity; More than continuity; Functional equations for polynomials; Conditional functional equations; Functional inequalities; *Equations with no parameters:* Iterations; Solving by invariants and linearization; More on fixed points; *Getting additional experience:* Miscellaneous problems; Additional problems; *Auxiliary material:* Acronyms and abbreviations; Set conventions; Named equations; Bibliography; Index.

MSRI Mathematical Circles Library, Volume 6

October 2011, approximately 346 pages, Softcover, ISBN: 978-0-8218-5314-6, LC 2011020089, 2010 *Mathematics Subject Classification:* 00-01, 00A07, 26-01, 26A06, 26A18, 26B05, **AMS members US$41.60**, List US$52, Order code MCL/6

Differential Equations



Nonautonomous Dynamical Systems

Peter E. Kloeden, *Goethe University Frankfurt am Main, Germany*, and **Martin Rasmussen**, *Imperial College, London, England*

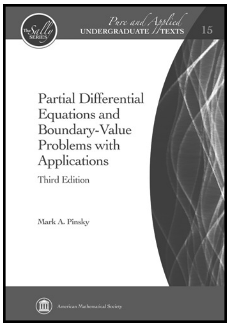
The theory of nonautonomous dynamical systems in both of its formulations as processes and skew product flows is developed systematically in this book. The focus is on dissipative systems and nonautonomous attractors, in particular the recently introduced concept of pullback attractors. Linearization theory, invariant manifolds, Lyapunov functions, Morse decompositions and bifurcations for nonautonomous systems and set-valued generalizations are also considered as well as applications to numerical approximations, switching systems and synchronization. Parallels with corresponding theories of control and random dynamical systems are briefly sketched.

With its clear and systematic exposition, many examples and exercises, as well as its interesting applications, this book can serve as a text at the beginning graduate level. It is also useful for those who wish to begin their own independent research in this rapidly developing area.

Contents: Autonomous dynamical systems; Nonautonomous dynamical systems; Attractors; Morse decompositions; Linear systems; Invariant manifolds; Lyapunov functions; Bifurcations; Set-valued nonautonomous dynamical systems; Nonautonomous semi-dynamical systems; Approximation and perturbation of attractors; Infinite-dimensional systems; Switching and control systems; Random dynamical systems; Synchronization; Appendix; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 176

September 2011, 264 pages, Hardcover, ISBN: 978-0-8218-6871-3, LC 2011020550, 2010 *Mathematics Subject Classification:* 37B55, 37C60, 37H05, 37B25, 37C75, 37D10, 37G35, **AMS members US$67.20**, List US$84, Order code SURV/176



Partial Differential Equations and Boundary-Value Problems with Applications

Third Edition

Mark A. Pinsky, *Northwestern University, Evanston, IL*

Building on the basic techniques of separation of variables and Fourier series, the book presents the solution of boundary-value problems for basic partial differential equations: the heat equation, wave equation, and Laplace equation, considered in various standard coordinate systems—rectangular, cylindrical, and spherical. Each of the equations is derived in the three-dimensional context; the solutions are organized according to the geometry of the coordinate system, which makes the mathematics especially transparent. Bessel and Legendre functions are studied and used whenever appropriate throughout the text. The notions of steady-state solution of closely related stationary solutions are developed for the heat equation; applications to the study of heat flow in the earth are presented. The problem of the vibrating string is studied in detail both in the Fourier transform setting and from the viewpoint of the explicit representation (d'Alembert formula). Additional chapters include the numerical analysis of solutions and the method of Green's functions for solutions of partial differential equations. The exposition also includes asymptotic methods (Laplace transform and stationary phase).

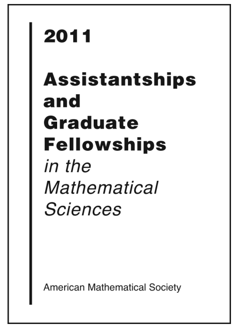
With more than 200 working examples and 700 exercises (more than 450 with answers), the book is suitable for an undergraduate course in partial differential equations.

Contents: Preliminaries; Fourier series; Boundary-value problems in rectangular coordinates; Boundary-value problems in cylindrical coordinates; Boundary-value problems in spherical coordinates; Fourier transforms and applications; Asymptotic analysis; Numerical analysis; Green's functions; Appendixes; Answers to selected exercises; Index.

Pure and Applied Undergraduate Texts, Volume 15

August 2011, 526 pages, Hardcover, ISBN: 978-0-8218-6889-8, LC 2011012736, 2010 *Mathematics Subject Classification:* 35-01, **AMS members US$63.20**, List US$79, Order code AMSTEXT/15

General Interest



Assistantships and Graduate Fellowships in the Mathematical Sciences, 2011

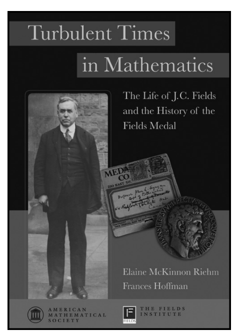
From a review of a previous edition:

This directory is a tool for undergraduate mathematics majors seeking information about graduate programs in mathematics. Although most of the information can be gleaned from the Internet, the usefulness of this directory for the prospective graduate student is the consistent format for comparing different mathematics graduate programs without the hype. Published annually, the information is up-to-date, which is more than can be said of some websites. Support for graduate students in mathematics is a high priority of the American Mathematical Society … The book is highly recommended for academic and public libraries.

– ***American Reference Books Annual***

This valuable reference source brings together a wealth of information about resources available for graduate study in mathematical sciences departments in the U.S. and Canada.

November 2011, approximately 80 pages, Softcover, ISBN: 978-0-8218-6897-3, **Individual member US$19.20**, List US$24, Order code ASST/2011



Turbulent Times in Mathematics

The Life of J. C. Fields and the History of the Fields Medal

Elaine McKinnon Riehm and **Frances Hoffman**

Despite the renown of the Fields Medals, J. C. Fields has been until now a rather obscure figure, and recovering details about his professional activities and personal life was not at all a simple task. This work is a triumph of persistence with far-flung archival and documentary sources, and provides a rich non-mathematical portrait of the man in all aspects of his life and career. Highly readable and replete with period detail, the book sheds useful light on the mathematical and scientific world of Fields' time, and is sure to remain the definitive biographical study.

—***Tom Archibald, Simon Fraser University, Burnaby, BC, Canada***

Drawing on a wide array of archival sources, Riehm and Hoffman provide a vivid account of Fields' life and his part in the founding of the highest award in mathematics. Filled with intriguing detail—from a childhood on the shores of Lake Ontario, through the mathematics seminars of late 19th century Berlin, to the post-WW1 *years of the fragmented international mathematical community—it is a richly textured story engagingly and sympathetically told. Read this book and you will understand why Fields never wanted the medal to bear his name and yet why, quite rightly, it does.*

—***June Barrow-Green, Open University, Milton Keynes, United Kingdom***

One of the little-known effects of World War I was the collapse of international scientific cooperation. In mathematics, the discord continued after the war's end and after the Treaty of Versailles had been signed in 1919. Many distinguished scientists were involved in the war and its aftermath, and from their letters and papers, now almost a hundred years old, we learn of their anguished wartime views and their struggles afterwards either to prolong the schism in mathematics or to end it.

J. C. Fields, the foremost Canadian mathematician of his time, was educated in Canada, the United States, and Germany, and championed an international spirit of cooperation to further the frontiers of mathematics. It was during the awkward post-war period that J. C. Fields established the Fields Medal, an international prize for outstanding research, which soon became the highest award in mathematics. J. C. Fields intended it to be an international medal, and a glance at the varying backgrounds of the fifty-two Fields medallists shows it to be so.

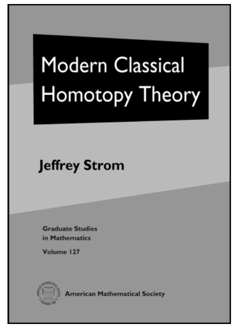
Who was Fields? What carried him from Hamilton, Canada West, where he was born in 1863, into the middle of this turbulent era of international scientific politics? A modest mathematician, he was an unassuming man. This biography outlines Fields' life and times and the difficult circumstances in which he created the Fields Medal. It is the first such published study.

A co-publication of the AMS and Fields Institute.

Contents: Childhood of John Charles Fields; Toronto and Baltimore; Post-doctoral years in Europe, 1892–1900; Return to Canada; Fields and research; Mathematics before 1914: The golden years; Science responds to war; The politics of avoidance; International Mathematical Congress, Toronto 1924; "Sub-turbulent politics": Pincherle and Bologna; The Fields Medal; Late years; Publications of J. C. Fields; Fields Medallists, 1936–2010; Fields' colleagues and friends; Bibliography; Acknowledgments; Index.

October 2011, approximately 255 pages, Softcover, ISBN: 978-0-8218-6914-7, 2010 *Mathematics Subject Classification:* 01-XX, 01A05, 01A55, 01A60, 01A70, 01A73, 01A99, 97-02, 97A30, 97A80, 97A40, **AMS members US$36**, List US$45, Order code MBK/80

Geometry and Topology



Modern Classical Homotopy Theory

Jeffrey Strom, *Western Michigan University, Kalamazoo, MI*

The core of classical homotopy theory is a body of ideas and theorems that emerged in the 1950s and was later largely codified in the notion of a model category. This core includes the notions of fibration and cofibration; CW complexes; long fiber and cofiber sequences; loop spaces and suspensions; and so on. Brown's representability theorems show that homology and cohomology are also contained in classical homotopy theory.

This text develops classical homotopy theory from a modern point of view, meaning that the exposition is informed by the theory of model categories and that homotopy limits and colimits play central roles. The exposition is guided by the principle that it is generally preferable to prove topological results using topology (rather than algebra). The language and basic theory of homotopy limits and colimits make it possible to penetrate deep into the subject with just the rudiments of algebra. The text does reach advanced territory, including the Steenrod algebra, Bott periodicity, localization, the Exponent Theorem of Cohen, Moore, and Neisendorfer, and Miller's Theorem on the Sullivan Conjecture. Thus the reader is given the tools needed to understand and participate in research at (part of) the current frontier of homotopy theory. Proofs are not provided outright. Rather, they are presented in the form of directed problem sets. To the expert, these read as terse proofs; to novices they are challenges that draw them in and help them to thoroughly understand the arguments.

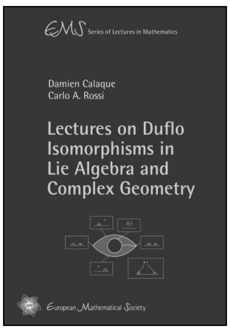
Contents: *The language of categories:* Categories and functors; Limits and colimits; *Semi-formal homotopy theory:* Categories of spaces; Homotopy; Cofibrations and fibrations; Homotopy limits and colimits; Homotopy pushout and pullback squares; Tools and techniques; Topics and examples; Model categories; *Four topological inputs:* The concept of dimension in homotopy theory; Subdivision of disks; The local nature of fibrations; Pullbacks of cofibrations; Related topics; *Targets as domains, domains as targets:* Constructions of spaces and maps; Understanding suspension; Comparing pushouts and pullbacks; Some computations in homotopy theory; Further topics; *Cohomology and homology:* Cohomology; Homology; Cohomology operations; Chain complexes; Topics, problems and projects; *Cohomology, homology and fibrations:* The Wang sequence; Cohomology of filtered spaces; The Serre filtration of a fibration; Application: Incompressibility; The spectral sequence of a filtered space; The Leray-Serre spectral sequence; Application: Bott periodicity; Using the Leray-Serre spectral sequence; *Vistas:* Localization and completion; Exponents for homotopy groups; Classes of spaces; Miller's theorem; Some algebra; References; Index.

Graduate Studies in Mathematics, Volume 127

January 2012, approximately 834 pages, Hardcover, ISBN: 978-0-8218-5286-6, LC 2011019677, 2010 *Mathematics Subject Classification:* 55Nxx, 55Pxx, 55Qxx, 55Sxx, 55Uxx, **AMS members US$76**, List US$95, Order code GSM/127

New AMS-Distributed Publications

Algebra and Algebraic Geometry



Lectures on Duflo Isomorphisms in Lie Algebra and Complex Geometry

Damien Calaque, *ETH, Zurich, Switzerland*, and **Carlo A. Rossi**, *Max Planck Institute for Mathematics, Bonn, Germany*

The Duflo isomorphism first appeared in Lie theory and representation theory. It is an isomorphism between invariant polynomials of a Lie algebra and the center of its universal enveloping algebra, generalizing the pioneering work of Harish–Chandra on semi-simple Lie algebras. Kontsevich later refined Duflo's result in the framework of deformation quantization and also observed that there is a similar isomorphism between Dolbeault cohomology of holomorphic polyvector fields on a complex manifold and its Hochschild cohomology. This book, which arose from a series of lectures by Damien Calaque at ETH, derives these two isomorphisms from a Duflo-type result for Q-manifolds.

All notions mentioned above are introduced and explained in this book. The only prerequisites are basic linear algebra and differential geometry. In addition to standard notions such as Lie (super) algebras, complex manifolds, Hochschild and Chevalley–Eilenberg cohomologies, spectral sequences, Atiyah and Todd classes, the graphical calculus introduced by Kontsevich in his seminal work on deformation quantization is addressed in detail.

This book is well suited for graduate students in mathematics and mathematical physics as well as researchers working in Lie theory, algebraic geometry, and deformation theory.

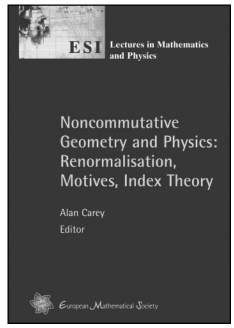
A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: Lie algebra cohomology and the Duflo isomorphism; Hochschild cohomology and spectral sequences; Dolbeault cohomology and the Kontsevich isomorphism; Superspaces and Hochschild cohomology; The Duflo–Kontsevich isomorphism for Q-spaces; Configuration spaces and integral weights; The map $\mathcal{U}_Q$ and its properties; The map $\mathcal{H}_Q$ and the homotopy argument; The explicit form of $\mathcal{U}_Q$; Fedosov resolutions; Appendix: Deformation-theoretical interpretation of Hochschild cohomology; Bibliography; Index.

EMS Series of Lectures in Mathematics, Volume 14

May 2011, 114 pages, Softcover, ISBN: 978-3-03719-096-8, 2010 *Mathematics Subject Classification:* 13D03, 17B56, 14F43, **AMS members US$25.60**, List US$32, Order code EMSSERLEC/14

Analysis



Noncommutative Geometry and Physics: Renormalisation, Motives, Index Theory

Alan Carey, *Australian National University, Canberra, Australia*, Editor

This collection of expository articles grew out of the workshop "Number Theory and Physics" held in March 2009 at The Erwin Schrödinger International Institute for Mathematical Physics, Vienna. The common theme of the articles is the influence of ideas from noncommutative geometry (NCG) on subjects ranging from number theory to Lie algebras, index theory, and mathematical physics.

Matilde Marcolli's article gives a survey of relevant aspects of NCG in number theory, building on an introduction to motives for beginners by Jorge Plazas and Sujatha Ramdorai. A mildly unconventional view of index theory, from the viewpoint of NCG, is described in the article by Alan Carey, John Phillips, and Adam Rennie. As developed by Alain Connes and Dirk Kreimer, NCG also provides insight into novel algebraic structures underlying many analytic aspects of quantum field theory. Dominique Manchon's article on pre-Lie algebras fits into this developing research area. This interplay of algebraic and analytic techniques also appears in the articles by Christoph Bergbauer, who introduces renormalization theory and Feynman diagram methods, and Sylvie Paycha, who focuses on relations between renormalization and zeta function techniques.

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

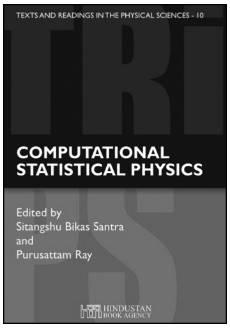
A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: **C. Bergbauer**, Notes on Feynman integrals and renormalization; **S. Ramdorai**, **J. Plazas**, and **M. Marcolli**, Introduction to motives. With an appendix by Matilde Marcolli; **D. Manchon**, A short survey on pre-Lie algebras; **S. Paycha**, Divergent multiple sums and integrals with constraints: A comparative study; **A. Carey**, **J. Phillips**, and **A. Rennie**, Spectral triples: Examples and index theory; List of contributors; Index.

ESI Lectures in Mathematics and Physics, Volume 8

June 2011, 280 pages, Softcover, ISBN: 978-3-03719-008-1, 2010 *Mathematics Subject Classification:* 58B34, 11M55, 11G09, 11M06, 11M32, 47G30, 81T15, 17A30, 16T30, 18D50, 46L80, 46L87, 19K33, 19K56, 58J42, 58J20, 81Q30, **AMS members US$62.40**, List US$78, Order code EMSESILEC/8

Mathematical Physics



Computational Statistical Physics

Lecture Notes, Guwahati SERC School

Sitangshu Bikas Santra, *Indian Institute of Technology, Guwahati, India*, and **Purusattam Ray**, *Institute of Mathematical Sciences, Chennai, India*, Editors

This book is a result of the SERC School on Computational Statistical Physics, held at the Indian Institute of Technology, Guwahati.

Numerical experimentation has played an extremely important role in statistical physics in recent years. Lectures given at the school covered a large number of topics of current and continuing interest.

Based on lectures by active researchers in the field—Bikas Chakrabarti, Samrath Lal Chaplot, Deepak Dhar, Sanjay Kumar, Prabal Maiti, Sanjay Puri, Purusattam Ray, Sitangshu Santra, and Subir Sarkar—the book's nine chapters deal with topics that range from the fundamentals of the field to problems and questions that are at the very forefront of current research.

This book aims to expose graduate students to basic as well as advanced techniques in computational statistical physics. Following a general introduction to statistical mechanics and critical phenomena, the various chapters cover Monte Carlo and molecular dynamics simulation methodology, along with a variety of applications. These include the study of coarsening phenomena and diffusion in zeolites.

In addition, graphical enumeration techniques are covered in detail, with applications to percolation and polymer physics. Methods for optimization are also discussed.

Beginning graduate students and young researchers in the area of statistical physics will find this book useful. In addition, it will also be a valuable general reference for students and researchers in other areas of science and engineering.

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

A publication of Hindustan Book Agency. Distributed on an exclusive basis by the AMS in North America. Online bookstore rights worldwide.

Contents: S. B. Santra and **P. Ray**, Statistical mechanics and critical phenomena: A brief overview; **D. Dhar**, Graphical enumeration techniques: Series expansions and animal problems; **S. Kumar**, Graphical enumeration techniques: Application to polymers; **S. B. Santra** and **P. Ray**, Classical Monte Carlo simulation; **S. Puri**, Kinetics of phase transitions: Numerical techniques and simulations; **H. Kumar** and **P. K. Maiti**, Introduction to molecular dynamics simulation; **S. Mitra** and **S. L. Chaplot**, Applications of molecular dynamics simulations; **S. K. Sarkar**, The conjugate gradient method for unconstrained minimization; **A. K. Chandra** and **B. K. Chakrabarti**, Optimization and quantum annealing; List of authors; Index.

Hindustan Book Agency

July 2011, 298 pages, Softcover, ISBN: 978-93-80250-15-1, 2010
Mathematics Subject Classification: 82-XX, 82-02, 82-08, **AMS members US$44**, List US$55, Order code HIN/49

Classified Advertisements

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

CALIFORNIA

MATHEMATICAL SCIENCES RESEARCH INSTITUTE
Berkeley, CA

MSRI invites applications for 40 Research Professors, 200 Research Members, and 30 semester-long Post-Doctoral Fellows in the following programs: Cluster Algebras (August 20 to December 21, 2012), Commutative Algebra (August 20, 2012, to May 24, 2013), and Noncommutative Algebraic Geometry and Representation Theory (January 14, 2013, to May 24, 2013). Research Professorships are intended for senior researchers who will be making key contributions to a program, including the mentoring of postdoctoral fellows, and who will be in residence for three or more months. Research Memberships are intended for researchers who will be making contributions to a program and who will be in residence for one or more months. Post-Doctoral Fellowships are intended for recent Ph.D.s. Interested individuals should carefully describe the purpose of their proposed visit, and indicate why a residency at MSRI will advance their research program. To receive full consideration, application must be complete, including all letters of support by the following deadlines: Research Professorships, October 01, 2011; Research Memberships, December 01, 2011; Post-doctoral Fellowships, December 01, 2011. It is the policy of MSRI actively to seek to achieve diversity in its programs and workshops. Thus, a strong effort is made to remove barriers that hinder equal opportunity, particularly for those groups that have been historically underrepresented in the mathematical sciences. Application information: `http://www.msri.org/propapps/applications/application_material`.

000038

UNIVERSITY OF CALIFORNIA, BERKELEY
Department of Mathematics

We invite applications for the following positions:
1. One or more tenure-track positions
2. Charles B. Morrey, Jr. Assistant Professorship
3. Visiting Assistant Professorships (partially funded by the NSF).

These positions begin July 1, 2012. For more information on these positions and how to apply for them, please go to: `http://math.berkeley.edu/employment_academic.html`.

000042

HAWAII

UNIVERSITY OF HAWAII
Department of Mathematics

The University of Hawaii at Manoa, Department of Meteorology, invites applications for two full-time tenure-track positions supported by general funds at the Assistant Professor level (appointment at the Associate Professor level may be considered in cases where the applicant has a proven record of outstanding research and teaching), to begin approximately January 1, 2012, subject to position clearance. The department seeks candidates with demonstrated research expertise preferably in the areas of physical, satellite, boundary layer or tropical meteorology. Candidates with outstanding track records in other areas are also encouraged to apply. In addition, candidates will be expected to teach undergraduate and graduate courses preferably in one or more of the areas of radiative transfer, cloud physics, satellite meteorology, meteorological instrumentation, air-sea interaction, synoptic, tropical, and boundary layer meteorology. A Ph.D. earned no later than January 1, 2012, in the area of meteorology or a closely related field is required, as are excellent communication skills; a demonstrated capability for creative, high quality research; and evidence of effectively teaching and mentoring undergraduate and graduate students. For the Associate Professor level, a minimum of four years teaching and research experience is also required. Applicants should submit curriculum vitae; detailed statement of research and teaching interests; and the names, addresses, phone numbers, and email addresses of at least three references to: Prof. Bin Wang, Chair, Department of Meteorology, University of Hawaii, 2525 Correa Rd., Hawaii Institute of Geophysics Building Room 350, Honolulu, HI 96822. Inquiries: phone (808) 956-8775; fax (808) 956-2877; email: `metdept@hawaii.edu`. Review of applications will begin August 15, 2011, and will continue until the positions are filled. The University of Hawaii is an Equal Employment Opportunity/Affirmative Action institution.

000043

Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 2011 rate is \$3.25 per word. No discounts for multiple ads or the same ad in consecutive issues. For an additional \$10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

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

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

Upcoming deadlines for classified advertising are as follows: October 2011 issue–July 28, 2011; November 2011 issue–August 30, 2011; December 2011 issue–September 28, 2011; January 2012 issue–October 31, 2011; February 2012 issue–November 28, 2011; March 2012 issue–December 28, 2011.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 667 (vol. 56).

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

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940; or via fax: 401-331-3842; or send email to `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 20904. Advertisers will be billed upon publication.

NEW YORK

CORNELL UNIVERSITY
Department of Mathematics

The Department of Mathematics at Cornell University invites applications for two tenure-track Assistant Professor positions, or higher rank, pending administrative approval, starting July 1, 2012. The searches are open to all areas of mathematics with an emphasis on the areas of probability, number theory, and PDE. The department actively encourages applications from women and minority candidates.

Applicants must apply electronically at: `http://www.mathjobs.org`.

For information about our positions and application instructions; see: `http://www.math.cornell.edu/Positions/facpositions.html`. Applicants will be automatically considered for all eligible positions. Deadline: November 1, 2011. Early applications will be regarded favorably. Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

000040

OKLAHOMA

OKLAHOMA STATE UNIVERSITY
Mathematics Department Head

The OSU Mathematics Department invites applications for the position of Department Head and Professor of Mathematics. Applicants must qualify for the rank of professor in the Mathematics Department and have an established record of success in research, teaching, outreach, and in securing external research funding.

The OSU Mathematics Department is strongly committed to excellence in research, teaching, and outreach. It offers B.S., B.A., M.S., and Ph.D. degrees in Pure Mathematics, Applied Mathematics, and Mathematics Education. The department has 31 tenure-track faculty lines serving about 30 graduate students and about 50 undergraduate majors. See our website, `http://www.math.okstate.edu`.

If interested in being considered, use `mathjobs.org` or send a cover letter and curriculum vitae to: Dr. John Mintmire; Chair, Mathematics Head Search Committee; OSU Department of Physics; 145 PSB; Stillwater, OK 74078. The Dean of Arts and Sciences, Dr. Peter Sherwood, also welcomes direct inquiries at (405) 744-5663 or `peter.sherwood@okstate.edu`. For full consideration applications must be received by October 31, 2011. However, we will continue to accept and consider applications until the position is filled. Filling of this position is contingent upon availability of funding. Oklahoma State University is an AA/EEO/E-Verify employer committed to diversity. OSU-Stillwater is a tobacco-free campus.

000041

TEXAS

TEXAS A&M UNIVERSITY
Department of Mathematics

The Department of Mathematics anticipates several openings for postdoctoral positions at the level of Visiting Assistant Professor, subject to budgetary approval. Our Visiting Assistant Professor positions are three-year appointments and carry a three-course-per-year teaching load. They are intended for those who have recently received their Ph.D. and preference will be given to mathematicians whose research interests are close to those of our regular faculty members. We also anticipate several short-term (semester or year-long) visiting positions at various ranks, depending on budget. A complete dossier should be received by December 15, 2011. Early applications are encouraged since the department will start the review process in October 2011. Applicants should send the completed "AMS Application Cover Sheet", a vita, a summary statement of research and teaching experience, and arrange to have letters of recommendation sent to: Faculty Hiring, Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, Texas 77843-3368. Further information can be obtained from: `http://www.math.tamu.edu/hiring`.

Texas A&M University is an Equal Opportunity Employer. The university is dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment and strongly encourages applications from women, minorities, individuals with disabilities, and veterans. The university is responsive to the needs of dual career couples.

000044

DENMARK

DENMARK
Aarhus University
Centre for Quantum Geometry of Moduli Spacd (QGM)

Applications are invited for a two-year postdoctoral position starting August 2012 with an opportunity to spend 1/2 year at one of the following partner institutions; UC Berkeley, Oxford University, or IHÉS, Paris. Qualified candidates will have a strong background in mathematics. Ph.D. degree and teaching experience is required. QGM focuses on the geometrical quantization of moduli spaces of various structures on two-dimensional surfaces and their mapping class groups. It is a collaborative project involving algebraic topology, algebraic geometry, quantum algebra, Riemann surface theory, gauge theory and Berezin-Toeplitz quantization together with mathematical aspects of quantum field theory and string theory. We are seeking an outstanding scholar with excellent research potential and teaching skills within this field. See `http://www.qgm.au.dk`. The positions are made possible by a grant from the Danish National Research Foundation. Interested candidates should apply online. The positions will be online from the fall at: `http://science.au.dk/en/positions-and-fellowships/academic-positions/`. Application deadline will be December 10, 2011.

000039

KOREA

KOREA INSTITUTE FOR ADVANCED STUDY (KIAS)
Postdoctoral Research Fellowships

The School of Mathematics at the Korea Institute for Advanced Study (KIAS) invites applicants for the positions at the level of postdoctoral research fellows in pure and applied mathematics. KIAS, founded 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 from approximately 37,000,000 Korean won–70,000,000 Korean won (equivalent to US$ 34,000–US$ 64,000). In addition, research fund in the amount of approximately 10,000,000 Korean won–15,000,000 Korean won (equivalent to US$ 9,0000–US$ 14,000) is provided each year.

Appointments may start as early as March 1, 2012. The initial appointment will be for two years with a possibility of renewal for two additional years. Those interested are encouraged to contact a faculty member in their research areas at: `http://www.kias.re.kr/en/about/members.jsp`. Also, for more information please visit `http://www.kias.re.kr/en/notice/job_opportunity.jsp`. Applicants should send a cover letter specifying the research area, a curriculum vita with a list of publications, and a summary of research plan, and arrange for three recommendation letters to be sent to:

School of Mathematics
Mr. Kang Won Lee (`kwlee@kias.re.kr`)
KIAS, 207-43 Cheongnyangni-dong
Dongdaemun-gu, Seoul, 130-722,
Korea

Email applications are strongly encouraged. We review the applications twice a year; the deadlines are June 30 and December 31.

000037

Mathematical Sciences Employment Center

Hynes Convention Center, Boston, Massachusetts
January 4–7, 2012

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

Employment Center Web Services

New this year, the Employment Center information will be accessed through the `Mathjobs.org` system. For those who do not have existing `Mathjobs.org` accounts, it will be possible to set up special Employment Center accounts on `Mathjobs.org`. The website and all information will be available beginning in early October 2011, and will remain accessible through the period of the Employment Center. While some schools may delay appointment-setting until late December, virtually all scheduling will be done before travel takes place, so applicants should expect few or no further appointments after arrival. Registering on site, for applicants, serves no real purpose.

There will be no printed books or paper forms. Also, there will be no paper message center since the new electronic system allows for interview arrangements.

Computer scheduling is no longer provided at the Employment Center.

No Admittance Without a JMM Badge

All applicants and employers planning to enter the Employment Center—even just for one interview—must present a 2012 Joint Meeting Registration badge or they will be denied admittance. This is not a new policy, but it is now strictly enforced. Meeting badges are obtained by registering for the Joint Mathematics Meetings and paying a meeting registration fee. See the JMM website at: `http://jointmathematicsmeetings.org/meetings/national/jmm2012/2138_intro` for registration instructions and rates.

2012 Employment Center Schedule:

November 15, 2011–Suggested deadline for electronic forms submission to allow for advanced scheduling.

December 15, 2011–Advance registration deadline for JMM. Meeting badge will be required for admittance. After this date, meeting registration fees go up and meeting registration may only happen on site in Boston.

OPEN HOURS (NO access before opening time):

Wednesday, January 4, 2012–8:00 a.m.–6:00 p.m.

Thursday, January 5, 2012–8:00 a.m.–6:00 p.m.

Friday, January 6, 2012–8:00 a.m.–6:00 p.m.

Saturday, January 7, 2012–9:00 a.m.–12:00 noon.

Location: Exhibit Hall C, Hynes Convention Center, 900 Boylston St., Boston, Massachusetts

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

Note: When deciding on travel dates, keep in mind that employers may wish to conduct interviews on any of the days listed above.

Employers: Choose a Table

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

• one or two interviewers per table in the "Quiet Area" (US$285), additional table (US$110).

• three to six interviewers per table in the "Committee Table" area (US$365), additional table (US$110).

• All Employment Center information is now housed on the `Mathjobs.org` site. An existing account can be used for accessing Employment Center services and paying appropriate fees, or if no account exists, participants can start an account solely for Employment Center use.

Please note, individual registration for the JMM is also required for all interviews and no admittance is possible without a JMM badge.

Employers: How to Register

• Registration runs from early October 2011 through January 4, 2012, at the following website: `www.Mathjobs.org`. The suggested deadline is November 15 if possible.

• Use your existing `Mathjobs.org` account or create a new Employer account at `Mathjobs.org`. Once a table is reserved, the ad can be placed at any time (or never) and will run until late January.

• Each person who will need to enter the Employment Center area must have a meeting badge (obtained by registering for the JMM and paying a meeting registration fee).

Once registered, employers will gain access to applicant data as it is submitted to the site. There will be applicant resumes on the site, but employers will want to notice especially the resumes marked "Employment Center" (EC logo). There is no automated scheduling system in `Mathjobs.org`, so participants will be making their own arrangements privately.

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

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

Applicants: Making the Decision to Attend

• The Employment Center offers no guarantees of interviews or jobs. Hiring decisions are not made during or immediately following interviews. In the current job market, the ratio of applicants to employers is about 10:1, and many applicants go completely unnoticed.

• There will ordinarily be no research-oriented postdoctoral positions listed or discussed at the Employment Center.

• Interviews will go to applicants who applied to jobs during the fall and are now being sought out by the institutions for in-person meetings during the JMM.

• There will be no opportunity to speak to employers without a pre-arranged interview, and no walk-up job information tables.

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

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

Past attendees have pointed out that all interviews are arranged in advance, and there is no opportunity to make connections on site if it has not happened before the meeting. In a recent survey, fifty percent of applicants responding reported being invited for at least one on-campus visit to an employer they had interviewed with at the Employment Center. Please visit the Employment Center website

About the Cover

The magical Coxeter transformation

This month's cover was suggested by David Borthwick and Skip Garibaldi's article on the root system E_8 in this issue.

A finite Coxeter group is a subgroup of an orthogonal group O(n) generated by reflections. Its fundamental domain is a simplicial cone cutting out a spherical simplex, and its transforms are called *chambers*. The set of reflections s_i in the n walls of one of these generate the group. Any product $s_{i_1}\ldots s_{i_n}$ of distinct reflections is called a **Coxeter transformation**, and its conjugacy class is independent of the order in which the product is taken. The order h of any of these is called the **Coxeter number** of the group. The Coxeter plane in $\mathbb{R}^n$ is one on which a given Coxeter transformation acts by rotation through $2\pi/h$. The cover illustrates how this works for the isometry group of the icosahedron, for which h=10. The colored triangles illustrate how the action of a Coxeter transformation on certain equatorial chambers, tracking along what Coxeter called a Petrie polygon of the icosahedron. The chambers of a given color form the orbit of the transformation.

The Weyl group of any integral root system is a Coxeter group, and Borthwick and Garibaldi's article explains how the lengths of the projection of roots onto a Coxeter plane is related to both the masses of a certain physical system as well as the eigenvectors of the Cartan matrix of the system. To an arbitrary Coxeter group is associated a set of roots equal to the normalized perpendiculars to chamber walls. A Coxeter transformation acts simply on the roots. For the icosahedron there are 30 roots and therefore 3 orbits, which project to three circles in the cover figure. The associated Cartan matrix is $(\langle \alpha_i, \alpha_j \rangle)$, where α_i gives rise to s_i. As far as I can tell the literature does not point out that the relation between the root projection lengths and the Cartan matrix is valid for non-crystallographic groups, but it can be experimentally verified for the exceptional groups H_3 and H_4.

Properties of Coxeter transformation are well known, but they are still capable of offering surprises. They do not seem yet to be perfectly understood.

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

for further advice, information, and program updates at www.ams.org/emp-reg/.

Applicants: How to Register

• Early registration is vital since most employers will finalize schedules before arriving in Boston.

• Register for the JMM by completing a meeting registration form and paying a meeting registration fee. No admittance without a meeting badge.

• Create an Applicant account on the Employment Center by using your Mathjobs.org account. Review job ads with the "EC" logo, upload documents, and apply for jobs.

There are no Employment Center fees for applicants; however, admission to the Employment Center room requires a 2012 JMM badge, obtainable by registering (and paying a fee) for the Joint Mathematics Meetings. To register for the meeting, go to http://jointmathematicsmeetings.org/meetings/national/jmm2012/2138_intro.

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

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

Questions about the Employment Center registration and participation can be directed to Steve Ferrucci, AMS Membership and Programs Department, at 800-321-4267, ext. 4113, or by e-mail to emp-info@ams.org.

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.

Ithaca, New York

Cornell University

September 10–11, 2011

Saturday – Sunday

Meeting #1072

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: July 2011
Program first available on AMS website: July 28, 2011
Program issue of electronic *Notices*: September 2011
Issue of *Abstracts*: Volume 32, Issue 4

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

Mladen Bestvina, University of Utah, *Topology and geometry of out(F_n).*

Nigel Higson, Pennsylvania State University, *C*-algebras and group representations.*

Gang Tian, Princeton University, *Geometric analysis on symplectic manifolds.*

Katrin Wehrheim, Massachusetts Institute of Technology, *How to construct topological invariants via decompositions and the symplectic category.*

Special Sessions

Analysis, Probability, and Mathematical Physics on Fractals, **Luke Rogers**, University of Connecticut, **Robert Strichartz**, Cornell University, and **Alexander Teplyaev**, University of Connecticut.

Difference Equations and Applications, **Michael Radin**, Rochester Institute of Technology.

Gauge Theory and Low-dimensional Topology, **Weimin Chen**, University of Massachusetts-Amherst, and **Daniel Ruberman**, Brandeis University.

Geometric Aspects of Analysis and Measure Theory, **Leonid Kovalev** and **Jani Onninen**, Syracuse University, and **Raanan Schul**, State University of New York at Stony Brook.

Geometric Structures on Manifolds with Special Holonomy, and Applications in Physics, **Tamar Friedmann**, University of Rochester, **Colleen Robles**, Texas A&M University, and **Sema Salur**, University of Rochester.

Geometric and Algebraic Topology, **Boris Goldfarb** and **Marco Varisco**, University at Albany, SUNY.

Geometry of Arithmetic Groups, **Mladen Bestvina**, University of Utah, and **Ken Brown**, **Martin Kassabov**, and **Tim Riley**, Cornell University.

Kac-Moody Lie Algebras, Vertex Algebras, and Related Topics, **Alex Feingold**, Binghamton University, and **Antun Milas**, State University of New York at Albany.

Mathematical Aspects of Cryptography and Cyber Security, **Benjamin Fine**, Fairfield University, **Delaram Kahrobaei**, City University of New York, and **Gerhard Rosenberger**, Passau University and Hamburg University, Germany.

Multivariable Operator Theory, **Ronald G. Douglas**, Texas A&M University, and **Rongwei Yang**, State University of New York at Albany.

Parabolic Evolution Equations of Geometric Type, **Xiaodong Cao**, Cornell University, and **Bennett Chow**, University of California San Diego.

Partial Differential Equations of Mixed Elliptic-Hyperbolic Type and Applications, **Marcus Khuri**, Stony Brook University, and **Dehua Wang**, University of Pittsburgh.

Representations of Local and Global Groups, **Mahdi Asgari**, Oklahoma State University, and **Birgit Speh**, Cornell University.

Set Theory, **Paul Larson**, Miami University, Ohio, **Justin Moore**, Cornell University, and **Ernest Schimmerling**, Carnegie Mellon University.

Species and Hopf Algebraic Combinatorics, **Marcelo Aguiar**, Texas A&M University, and **Samuel Hsiao**, Bard College.

Symplectic Geometry and Topology, **Tara Holm**, Cornell University, and **Katrin Wehrheim**, Massachusetts Institute of Technology.

Winston-Salem, North Carolina

Wake Forest University

September 24–25, 2011

Saturday – Sunday

Meeting #1073

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: June 2011
Program first available on AMS website: August 11, 2011
Program issue of electronic *Notices*: September 2011
Issue of *Abstracts*: Volume 32, Issue 4

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

Benjamin B. Brubaker, Massachusetts Institute of Technology, *Square ice, symmetric functions, and their connections to automorphic forms.*

Shelly Harvey, Rice University, *4-dimensional equivalence relations on knots.*

Allen Knutson, Cornell University, *Modern developments in Schubert calculus.*

Seth M. Sullivant, North Carolina State University, *Algebraic statistics.*

Special Sessions

Algebraic and Geometric Aspects of Matroids, **Hoda Bidkhori**, **Alex Fink**, and **Seth Sullivant**, North Carolina State University.

Applications of Difference and Differential Equations to Biology, **Anna Mummert**, Marshall University, and **Richard C. Schugart**, Western Kentucky University.

Combinatorial Algebraic Geometry, **W. Frank Moore**, Wake Forest University and Cornell University, and **Allen Knutson**, Cornell University.

Extremal Combinatorics, **Tao Jiang**, Miami University, and **Linyuan Lu**, University of South Carolina.

Geometric Knot Theory and its Applications, **Yuanan Diao**, University of North Carolina at Charlotte, **Jason Parsley**, Wake Forest University, and **Eric Rawdon**, University of St. Thomas.

Low-Dimensional Topology and Geometry, **Shelly Harvey**, Rice University, and **John Etnyre**, Georgia Institute of Technology.

Modular Forms, Elliptic Curves, and Related Topics, **Matthew Boylan**, University of South Carolina, and **Jeremy Rouse**, Wake Forest University.

New Developments in Graph Theory, **Joshua Cooper** and **Kevin Milans**, University of South Carolina, and **Carlos Nicolas** and **Clifford Smyth**, University of North Carolina at Greensboro.

Noncommutative Algebra, **Ellen E. Kirkman** and **James J. Kuzmanovich**, Wake Forest University.

Nonlinear Boundary Value Problems, **Maya Chhetri**, University of North Carolina at Greensboro, and **Stephen B. Robinson**, Wake Forest University.

Nonlinear Dispersive Equations, **Sarah Raynor**, Wake Forest University, **Jeremy Marzuola**, University of North Carolina at Chapel Hill, and **Gideon Simpson**, University of Toronto.

Recent Advances in Infectious Disease Modeling, **Fred Chen** and **Miaohua Jiang**, Wake Forest University.

Set Theoretic Topology, **Peter Nyikos**, University of South Carolina.

Symmetric Functions, Symmetric Group Characters, and Their Generalizations, **Sarah Mason**, Wake Forest University, **Aaron Lauve**, Loyola University-Chicago, and **Ed Allen**, Wake Forest University.

Lincoln, Nebraska

University of Nebraska-Lincoln

October 14–16, 2011

Friday – Sunday

Meeting #1074

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: August 2011
Program first available on AMS website: September 1, 2011
Program issue of electronic *Notices*: October 2011
Issue of *Abstracts*: Volume 32, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 23, 2011

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

Invited Addresses

Lewis P. Bowen, Texas A&M University, *Entropy theory for actions of sofic groups*.

Emmanuel Candes, Stanford University, *Recovering the unseen: Some recent advances in low-rank matrix reconstruction* (Erdős Memorial Lecture).

Alina Cojocaru, University of Illinois at Chicago and Mathematics Institute of the Romanian Academy, *Questions about the reductions modulo primes of an elliptic curve*.

Michael Zieve, University of Michigan, *The happy marriage between arithmetic geometry and dynamical systems*.

Special Sessions

Algebraic Geometry and Graded Commutative Algebra (Code: SS 8A), **Susan Cooper** and **Brian Harbourne**, University of Nebraska-Lincoln.

Algorithmic and Geometric Properties of Groups and Semigroups (Code: SS 10A), **Susan Hermiller** and **John Meakin**, University of Nebraska-Lincoln.

Association Schemes and Related Topics (Code: SS 1A), **Sung Y. Song**, Iowa State University, and **Paul Terwilliger**, University of Wisconsin Madison.

Asymptotic Behavior and Regularity for Nonlinear Evolution Equations (Code: SS 4A), **Petronela Radu** and **Lorena Bociu**, University of Nebraska-Lincoln.

Coding Theory (Code: SS 7A), **Christine Kelley** and **Judy Walker**, University of Nebraska-Lincoln.

Commutative Algebra (Code: SS 16A), **Christina Eubanks-Turner**, University of Louisiana at Lafayette, and **Aihua Li**, Montclair State University.

Computational and Applied Mathematics (Code: SS 13A), **Ludwig Kohaupt**, Beuth University of Technology Berlin, Germany, and **Yan Wu**, Georgia Southern University.

Continuous and Numerical Analysis in the Control of PDE's (Code: SS 9A), **George Avalos**, **Mohammad Rammaha**, and **Daniel Toundykov**, University of Nebraska-Lincoln.

Discrete Methods and Models in Biomathematics (Code: SS 18A), **Dora Matache** and **Jim Rogers**, University of Nebraska-Omaha, and **Alan Veliz-Cuba**, University of Nebraska-Lincoln.

Dynamic Systems on Time Scales with Applications (Code: SS 3A), **Lynn Erbe** and **Allan Peterson**, University of Nebraska-Lincoln.

Dynamical Systems and Operator Algebras (Code: SS 15A), **Lewis Bowen**, Texas A&M University, and **David Kerr**, Texas A&M University at Galveston.

Extremal and Probabilistic Combinatorics (Code: SS 5A), **Stephen Hartke** and **Jamie Radcliffe**, University of Nebraska-Lincoln.

Invariants in Knot Theory and Low-dimensional Topology (Code: SS 14A), **Mark Brittenham**, University of Nebraska-Lincoln, and **Robert Todd**, University of Nebraska-Omaha.

Local Commutative Algebra (Code: SS 11A), **H. Ananthnarayan**, University of Nebraska-Lincoln, **Inês B. Henriques**, University of California Riverside, and **Hamid Rahmati**, Syracuse University.

Matrices and Graphs (Code: SS 12A), **In-Jae Kim**, Minnesota State University, **Adam Berliner**, St. Olaf College, **Leslie Hogben**, Iowa State University, and **Bryan Shader**, University of Wyoming.

Quantum Groups and Representation Theory (Code: SS 2A), **Jonathan Kujawa**, University of Oklahoma, and **Natasha Rozhkovskaya**, Kansas State University.

Recent Directions in Number Theory (Code: SS 17A), **Alina Cojocaru**, University of Illinois at Chicago, and **Michael Zieve**, University of Michigan.

Recent Progress in Operator Algebras (Code: SS 6A), **Allan P. Donsig** and **David R. Pitts**, University of Nebraska-Lincoln.

Salt Lake City, Utah

University of Utah

October 22–23, 2011

Saturday – Sunday

Meeting #1075

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2011
Program first available on AMS website: September 8, 2011
Program issue of electronic *Notices*: October 2011
Issue of *Abstracts*: Volume 32, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 30, 2011

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

Invited Addresses

Graeme Milton, University of Utah, *Metamaterials: High contrast composites with unusual properties*.

Lei Ni, University of California San Diego, *Gap theorems on Kähler manifolds*.

Igor Pak, University of California Los Angeles, *The future of combinatorial bijections*.

Monica Visan, University of California Los Angeles, *Dispersive partial differential equations at critical regularity*.

Special Sessions

Algebraic Geometry (Code: SS 8A), **Tommaso de Fernex** and **Christopher Hacon**, University of Utah.

Applied Analysis (Code: SS 15A), **Marian Bocea**, North Dakota State University, and **Mihai Mihailescu**, University of Craiova Romania.

Category Theory in Graphs, Geometry and Inverse Problems (Code: SS 12A), **Robert Owczarek**, Enfitec. Inc., and **Hanna Makaruk**, Los Alamos National Laboratory NM.

Celestial and Geometric Mechanics (Code: SS 5A), **Lennard Bakker** and **Tiancheng Ouyang**, Brigham Young University.

Commutative Algebra (Code: SS 3A), **Chin-Yi Jean Chan**, Central Michigan University, and **Lance E. Miller** and **Anurag K. Singh**, University of Utah.

Computational and Algorithmic Algebraic Geometry (Code: SS 17A), **Zach Teitler**, Boise State University, and **Jim Wolper**, Idaho State University.

Electromagnetic Wave Propagation in Complex and Random Environments (Code: SS 4A), **David Dobson**, University of Utah, and **Peijun Li**, Purdue University.

Geometric Evolution Equations and Related Topics (Code: SS 2A), **Andrejs Treibergs**, University of Utah Salt Lake City, **Lei Ni**, University of California San Diego, and **Brett Kotschwar**, Arizona State University.

Geometric, Combinatorial, and Computational Group Theory (Code: SS 1A), **Eric Freden**, Southern Utah University, and **Eric Swenson**, Brigham Young University.

Harmonic Analysis and Dispersive Partial Differential Equations (Code: SS 6A), **Xiaoyi Zhang**, University of Iowa, and **Monica Visan** and **Betsy Stovall**, University of California Los Angeles.

Hypergeometric Functions and Differential Equations (Code: SS 13A), **Laura F. Matusevich**, Texas A&M University, and **Christine Berkesch**, Stockholm University.

Inverse Problems and Homogenization (Code: SS 10A), **Elena Cherkaev** and **Fernando Guevara Vasquez**, University of Utah.

Noncommutative Geometry and Algebra (Code: SS 11A), **Kenneth R. Goodearl**, University of California Santa Barbara, and **Milen Yakimov**, Louisiana State University.

Nonlinear Waves (Code: SS 7A), **Zhi-Qiang Wang** and **Nghiem Nguyen**, Utah State University.

Recent Progress in Numerical Partial Differential Equations (Code: SS 9A), **Jichun Li**, University of Nevada, Las Vegas, and **Shue-Sum Chow**, Brigham Young University.

Reductive Groups and Hecke Algebras (Code: SS 14A), **Dan Ciubotaru**, University of Utah, **Cathy Kriloff**, Idaho State University, and **Peter Trapa**, University of Utah.

Understanding Bio-fluids via Modeling, Simulation and Analysis (Code: SS 16A), **Christel Hohenegger**, University of Utah.

Port Elizabeth, Republic of South Africa

Nelson Mandela Metropolitan University

November 29 – December 3, 2011

Tuesday – Saturday

Meeting #1076

First Joint International Meeting between the AMS and the South African Mathematical Society.
Associate secretary: Matthew Miller
Announcement issue of *Notices*: July 2011
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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

Invited Addresses

Mark J. Ablowitz, University of Colorado, *Nonlinear systems—from oceans to number theory*.

Zoltan Furedi, University of Illinois, Urbana-Champaign, *Title to be announced*.

Mikhail Petrov, University of Swaziland, *Title to be announced*.

James Raftery, University of Kwazulu Natal, *Title to be announced*.

Daya Reddy, University of Cape Town, *Title to be announced*.

Peter Sarnak, Princeton University, *Mobius randomness and dynamics*.

Lindi Tshabalala, Thuthuzekani Primary School, *Title to be announced*.

Amanda Weltman, University of Cape Town, *Title to be announced*.

Special Sessions

Combinatorial and Computational Group Theory with Applications, **Gilbert Baumslag**, City College of New York, **Mark Berman**, University of Cape Town, and **Vladimir Shpilrain**, City College of New York.

Combinatorics and Graph Theory, **Michael Henning**, University of Johannesburg, **Robin Thomas**, Georgia Institute of Technology, and **Jacques Verstraete**, University of California, San Diego.

Finite Groups and Combinatorial Structures, **Jashmid Moori**, North-West University, Mafikeng, and **B. Rodrigues**, University of Kwazulu-Natal, Westville.

Geometry and Differential Equations, **Jesse Ratzkin**, University of Cape Town.

Computer Vision, High Performance Computing and Imaging, **Steven B. Damelin**, Georgia Southern University and University of the Witswatersrand, and **Hari Kumar**, University of the Witswatersrand.

Nonlinear Waves and Integrable Systems, **Mark Ablowitz**, University of Colorado at Boulder, and **Barbara Prinari**, University of Colorado at Colorado Springs.

Operator and Banach Algebras, and Noncommutative Analysis, **David Blecher**, University of Houston, **Garth Dales**, University of Leeds, **Louis Labuschagne**, North-West University, Potchefstroom Campus, and **Anton Stroh**, University of Pretoria.

Recent Advances in Computational Methods for Partial Differential Equations, **Kailash C. Patidar**, University of the Western Cape.

Theoretical and Numerical Aspects of Dynamical Systems, Partial Differential Equations, and Inequalities, Arising in Applications, **J. M.-S. Lubuma**, University of Pretoria, and **B. D. Reddy**, University of Cape Town.

Topology and Categories, **Hans-Peter Kuenzi**, University of Cape Town.

Boston, Massachusetts

John B. Hynes Veterans Memorial Convention Center, Boston Marriott Hotel, and Boston Sheraton Hotel

January 4–7, 2012

Wednesday – Saturday

Meeting #1077

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: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: September 22, 2011

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

Joint Invited Addresses

Erik Demaine, Massachusetts Institute of Technology, *Geometric puzzles: Algorithms and complexity* (AMS-MAA-SIAM Gerald and Judith Porter Public Lecture).

Allen Knutson, Cornell University, *Title to be announced* (AMS-MAA Invited Address).

Hee Oh, Brown University, *Title to be announced* (AMS-MAA Invited Address).

AMS Invited Addresses

George E. Andrews, Penn State University, *Title to be announced* (AMS Retiring Presidential Address).

Bradley Efron, Stanford University, *A 250-Year Argument (Belief, Behavior, and the Bootstrap)* (AMS Josiah Willard Gibbs Lecture).

Edward Frenkel, University of California Berkeley, *Langlands program, trace formulas, and their geometrization,* (AMS Colloquium Lectures).

Larry Guth, University of Toronto, *The polynomial method in combinatorial geometry*.

Assaf Naor, Courant Institute of Mathematical Sciences, *The Ribe program*.

Eric Rains, California Institute of Technology, *Beyond q: Special functions on elliptic curves*.

Wilhelm Schlag, University of Chicago, *Invariant manifolds and dispersive Hamiltonian evolution equations*.

AMS Special Sessions

Some sessions are cosponsored with other organizations. These are noted within the parenthesis at the end of each listing, where applicable.

Advanced Investigations on Applied Optimization and Multiple Fractional Programming (Code: SS 6A), **Ram U. Verma**, Texas A&M University, and **Alexander J. Zaslavski**, Technion, Israel.

Advances in Coding Theory (Code: SS 10A), **Sarah Spence Adams**, Olin College of Engineering, **Gretchen L. Matthews**, Clemson University, and **Judy L. Walker**, University of Nebraska-Lincoln.

Advances in Mathematical Biology (Code: SS 56A), **David Chan** and **Rebecca Segal**, Virginia Commonwealth University.

Algebraic and Geometric Aspects of Integrable Systems and Random Matrices (Code: SS 58A), **Anton Dzhamay**, University of Northern Colorado, and **Kenichi Maruno** and **Virgil Pierce**, University of Texas, Pan American.

Arithmetic Geometry (Code: SS 51A), **Bo-Hae Im**, Chung-Ang University, South Korea, **Jennifer Johnson-Leung**, University of Idaho, and **Jennifer Paulhus**, Grinnell College.

Calculus of Functors and Its Applications (Code: SS 11A), **Brian Munson** and **Ismar Volic**, Wellesley College.

Classical Fourier Analysis and Partial Differential Equations (Code: SS 27A), **William O. Bray**, University of Maine, and **Mark A. Pinsky**, Northwestern University.

Climate Modeling and Geophysical Fluid Dynamics (Code: SS 39A), **Qingshan Chen**, Florida State University, **Nathan Glatt-Holtz**, Indiana University, and **Mickael Chekroun**, University of California, Los Angeles.

Combinatorial Geometry of Polytopes (Code: SS 42A), **Egon Schulte**, Northeastern University, and **Asia Ivic Weiss**, York University.

Computational and Applied Topology (Mathematics Research Communities session) (Code: SS 61A), **Radmila Sazdonovic**, University of Pennsylvania, **Daniel Muellner**, Stanford University, and **Mikael Vejdemo-Johansson**, University of St. Andrews.

Control Theory and Inverse Problems for Partial Differential Equations (Code: SS 18A), **Shitao Liu**, University of Virginia, and **Ting Zhou**, University of California, Irvine.

Control of Biological and Physical Systems (Code: SS 36A), **Wandi Ding**, Middle Tennessee State University, **Volodymyr Hrynkiv**, University of Houston-Downtown, and **Suzanne Lenhart**, University of Tennessee, Knoxville, and NIMBioS.

Difference Equations and Applications (Code: SS 3A), **Michael Radin**, Rochester Institute of Technology.

Differential Algebraic Geometry and Galois Theory (in memory of Jerald Kovacic) (Code: SS 7A), **Phyllis Joan Cassidy**, Smith College and the City University of New York, **Richard Churchill**, Hunter College and Graduate Center at CUNY, **Claude Mitschi**, Université de Strasbourg, France, and **Michael Singer**, North Carolina State University.

Dynamical Systems in Algebraic and Arithmetic Geometry (Code: SS 19A), **Patrick Ingram**, University of Waterloo, Canada, **Michelle Manes**, University of Hawaii, Honolulu, and **Clayton Petsche**, Hunter College (CUNY).

Enumerative and Algebraic Combinatorics (Code: SS 40A), **Ira Gessel**, Brandeis University, and **Alexander Posnikov** and **Richard Stanley**, Massachusetts Institute of Technology.

Fractal Geometry in Pure and Applied Mathematics (in memory of Benoit Mandelbrot) (Code: SS 4A), **Michael L. Lapidus**, University of California, Riverside, **Erin Pearse**, University of Oklahoma, and **Machiel van Frankenhuijsen**, Utah Valley University.

Fractional, Hybrid, and Stochastic Dynamical Systems with Applications (Code: SS 12A), **John Graef**, University of Tennessee at Chattanooga, **Gangaram S. Ladde**, University of South Florida, Tampa, and **Aghala S. Vatsala**, University of Louisiana at Lafayette.

Frontiers in Geomathematics (Code: SS 55A), **Willi Freeden**, University of Kaiserslautern, **Volker Michel**, University of Siegen, and **M. Zuhair Nashed**, University of Central Florida.

Generalized Cohomology Theories in Engineering Practice (Code: SS 37A), **Robert Kotiuga**, Boston University.

Geometric Invariants of Groups and Related Topics (Code: SS 14A), **Nic Koban**, University of Maine, Farmington, and **Peter N. Wong**, Bates College.

Geometry of Real Projective Structures (Mathematics Research Communities session) (Code: SS 60A), **Jeffrey Danciger**, Stanford University, **Kelly Delp**, Buffalo State College, **Sean Lawton**, University of Texas, Pan American, and **Kathryn Mann**, University of Chicago.

Global Dynamics of Rational Difference Equations with Applications (Code: SS 33A), **Mustafa R. S. Kulenovic**, **Gerasimos Ladas**, and **Orlando Merino**, University of Rhode Island.

Groups, Algorithms, Complexity, and Theory of Security (Code: SS 28A), **Maggie Habeeb** and **Delaram Kahrobaei**, City University of New York.

History of Mathematics (Code: SS 65A), **Sloan Despeaux**, Western Carolina University, **Craig Fraser**, University of Toronto, and **Deborah Kent**, Hillsdale College (AMS-MAA).

Homotopy Theory (Code: SS 5A), **Mark Behrens**, Massachusetts Institute of Technology, **Mark W. Johnson**, Pennsylvania State University, Altoona, **Haynes R. Miller**, Massachusetts Institute of Technology, **James Turner**, Calvin College, and **Donald Yau**, Ohio State University.

Hyperbolicity in Manifolds and Groups (Code: SS 25A), **David Futer**, Temple University, and **Genevieve Walsh**, Tufts University.

Knot Theory (Code: SS 0A), **Tim Cochran** and **Shelly Harvey**, Rice University.

Linear Algebraic Groups: Their Arithmetic, Geometry, and Representations (Code: SS 49A), **R. Skip Garibaldi**, Emory University, and **George McNinch**, Tufts University.

Local Field Properties, Microstructure, and Multiscale Modeling of Heterogeneous Media (Code: SS 23A), **Silvia Jiménez** and **Bogdan Vernescu**, Worcester Polytechnic Institute.

Mathematical Principles and Theories of Integrable Systems (Code: SS 35A), **Wen-Ziu Ma**, University of South Florida, **Syed Tauseef Mohyud-Din**, HITEC University, and **Zhijun Qiao**, University of Texas, Pan American.

Mathematical Theory of Control of Quantum Systems (Code: SS 38A), **Francesca Albertini**, University of Padua, **Domenico D'Alessandro**, Iowa State University, **Raffaele Romano**, University of Trieste, and **Francesco Ticozzi**, University of Padua.

Mathematics and Education Reform (Code: SS 41A), **William Barker**, Bowdoin College, **William McCallum**, University of Arizona, and **Bonnie Saunders**, University of Illinois at Chicago (AMS-MAA-MER).

Mathematics and Statistics in Computational Biology. (Code: SS 52A), **Mark A. Kon**, Boston University.

Mathematics in Industry (Code: SS 34A), **Kirk E. Jordan**, IBM T. J. Watson Research, **Donald Schwendeman**, Renssalaer Polytechnic Institute, and **Burt S. Tilley** and **Suzanne L. Weekes**, Worcester Polytechnic Institute.

Mathematics in Natural Resource Modeling (Code: SS 9A), **Catherine Roberts**, College of the Holy Cross.

Mathematics of Computation: Algebra and Number Theory (Code: SS 16A), **Jean-Marc Couveignes**, Université de Toulouse, **Michael J. Mossinghoff**, Davidson College, and **Igor E. Shparlinski**, Macquarie University, Australia (AMS-SIAM).

Mathematics of Computation: Differential Equations, Linear Algebra, and Applications (Code: SS 26A), **Chi-Wang Shu**, Brown University (AMS-SIAM).

Mathematics of Decisions, Elections, and Games (Code: SS 57A), **Karl-Dieter Crisman**, Gordon College, **Michael Jones**, *Mathematical Reviews*, and **Michael Orrison**, Harvey Mudd College.

Matrices and Graphs (Code: SS 50A), **Leslie Hogben**, Iowa State University and American Institute of Mathematics, and **Bryan L. Shader**, University of Wyoming.

My Favorite Graph Theory Conjectures (Code: SS 29A), **Ralucca Gera**, Naval Postgraduate School, and **Craig Larson**, Virginia Commonwealth University.

Noncommutative Birational Geometry and Cluster Algebras (Code: SS 44A), **Arkady Berenstein**, University of Oregon, and **Vladimir Retakh**, Rutgers University.

Nonlinear Analysis of Partial Differential Equation Models in Biology and Chemical Physics (Code: SS 48A), **Zhonghai Ding**, University of Nevada, Las Vegas, and **Zhaosheng Feng**, University of Texas-Pan American.

Nonlinear Hyperbolic Partial Differential Equations (Code: SS 32A), **Barbara Lee Keyfitz** and **Charis Tsikkou**, Ohio State University (AMS-AWM).

Operator Theory on Analytic Function Spaces (Code: SS 43A), **Robert F. Allen**, University of Wisconsin, La Crosse, and **Katherine C. Heller** and **Matthew A. Pons**, North Central College.

Optimal Control in Applied Mathematical Modeling (Code: SS 45A), **Natali Hritonenko**, Prairie View A&M University, and **Yuri Yatsenko**, Houston Baptist University.

New Perspectives in Mulitplicative Number Theory (Mathematics Research Communities session) (Code: SS 62A), **Leo Goldmakher**, University of Toronto, **Jonathan Kish**, University of Colorado at Boulder, **Micah Millinovich**, University of Mississippi, and **Paul Pollack**, University of British Columbia/Simon Fraser University.

Progress in Free Analysis (Code: SS 46A), **J. William Helton**, University of California, San Diego, and **Paul S. Muhly**, University of Iowa.

Radon Transforms and Geometric Analysis (in honor of Sigurdur Helgason's 85th birthday) (Code: SS 17A), **Jens Christensen**, University of Maryland, and **Fulton Gonzalez** and **Todd Quinto**, Tufts University.

Rational Points on Varieties (Code: SS 30A), **Jennifer Balakrishnan** and **Bjorn Poonen**, Massachusetts Institute of Technology, **Bianca Viray**, Brown University, and **Kirsten Wickelgren**, Harvard University.

Reaction Diffusion Equations and Applications (Code: SS 31A), **Jerome Goddard II** and **Shivaji Ratnasingham**, Mississippi State University, and **Junping Shi**, College of William and Mary.

Recent Advances in Mathematical Biology, Ecology, and Epidemiology (Code: SS 21A), **Sophia R. Jang**, Texas Tech University, **Andrew L. Nevai**, University of Central Florida, and **Lih-Ing W. Roeger**, Texas Tech University.

Recent Trends in Graph Theory (Code: SS 24A), **Ralucca Gera**, Naval Postgraduate School.

Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs (Code: SS 66A), **Bernard Brooks** and **Jobby Jacob**, Rochester Institute of Technology, **Jacqueline Jensen**, Sam Houston State University, and **Darren A Narayan**, Rochester Institute of Technology (AMS-MAA).

Science for Policy and Policy for Science: Career Opportunities at the Intersection of Science and Policy (Code: SS 59A), **Cynthia Robinson** and **Shar Steed**, AAAS Science & Technology Fellowships (AMS-AAAS).

Set-Valued Optimization and Variational Problems (Code: SS 47A), **Andreas H. Hamel**, Yeshiva University, **Akhtar A. Khan**, Rochester Institute of Technology, and **Miguel Sama**, E.T.S.I. Industriales.

Several Complex Variables and Multivariable Operator Theory (Code: SS 8A), **Ronald Douglas**, Texas A&M University, and **John McCarthy**, Washington University.

Some Nonlinear Partial Differential Equations — Theory and Application (Code: SS 54A), **Jerry L. Bona**, University of Illinois, Chicago, and **Laihan Luo**, New York Institute of Technology.

Stability Analysis for Infinite Dimensional Hamiltonian Systems (Code: SS 63A), **Wilhelm Schlag**, University of Chicago, and **Gene Wayne**, Boston University.

Stochastic Analysis (in honor of Hui-Hsiung Kuo) (Code: SS 1A), **Julius Esunge**, University of Mary Washington, and **Aurel Stan**, Ohio State University.

Tensor Categories and Representation Theory (Code: SS 22A), **Deepak Naidu**, Texas A&M University, and **Dmitri Nikshych**, University of New Hampshire.

The Life and Legacy of Alan Turing (Code: SS 13A), **Damir Dzhafarov**, University of Chicago and University of Notre Dame, **Jeff Hirst**, Appalachian State University, and **Carl Mummert**, Marshall University (AMS-ASL).

Theory and Applications of Stochastic Differential and Partial Differential Equations (Code: SS 15A), **Edward Allen**, Texas Tech University, **Mahmoud Anabtawi**, American University of Sharjah, **Armando Arciniega**, University of Texas at San Antonio, **Gangaram S. Ladde**, University of South Florida, and **Sivapragasam Sathananthan**, Tennessee State University.

Topological Graph Theory: Structure and Symmetry (Code: SS 20A), **Jonathan L. Gross**, Columbia University, and **Thomas W. Tucker**, Colgate University.

Trends in Representation Theory (Code: SS 2A), **Donald King**, Northeastern University, and **Alfred Noel**, University of Massachusetts, Boston.

Uniformly and Partially Hyperbolic Dynamical Systems (Code: SS 53A), **Todd Fisher**, Brigham Young University, and **Boris Hasselblatt**, Tufts University.

Honolulu, Hawaii

University of Hawaii

March 3–4, 2012

Saturday – Sunday

Meeting #1078

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2012
Program first available on AMS website: January 26, 2012
Program issue of electronic *Notices*: March 2012
Issue of *Abstracts*: Volume 33, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: November 22, 2011
For abstracts: December 13, 2011

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

Invited Addresses

Zhiqin Lu, University of California Irvine, *Title to be announced*.

Peter Schroder, California Institute of Technology, *Title to be announced*.

Pham Tiep, University of Arizona, Tucson, *Title to be announced*.

Lauren Williams, University of California Berkeley, *Title to be announced*.

Special Sessions

Algebraic number theory, diophantine equations and related topics (Code: SS 6A), **Claude Levesque**, Université de Laval, Quebec, Canada.

Arithmetic Geometry (Code: SS 5A), **Xander Faber**, **Michelle Manes**, and **Gretel Sia**, University of Hawaii.

Automorphic and Modular Forms (Code: SS 4A), **Pavel Guerzhoy**, University of Hawaii, and **Zachary A. Kent**, Emory University.

Geometry and Analysis on Fractal Spaces (Code: SS 3A), **Michel Lapidus**, University of California, Riverside, **Hung Lu**, Hawaii Pacific University, **John A. Rock**, California State Polytechnic University, Pomona, and **Machiel van Frankenhuijsen**, Utah Valley University.

Holomorphic Spaces (Code: SS 8A), **Hyungwoon Koo**, Korea University, and **Wayne Smith**, University of Hawaii.

Kaehler Geometry and Its Applications (Code: SS 1A), **Zhiqin Lu**, University of California Irvine, **Jeff Streets**, Princeton University, **Li-Sheng Tseng**, Harvard University, and **Ben Weinkove**, University of California San Diego.

Linear and Permutation Representations (Code: SS 2A), **Robert Guralnick**, University of Southern California, and **Pham Huu Tiep**, University of Arizona.

Nonlinear Partial Differential Equations at the Common Interface of Waves and Fluids (Code: SS 9A), **Ioan Bejenaru** and **Vlad Vicol**, University of Chicago.

Nonlinear Partial Differential Equations of Fluid and Gas Dynamics (Code: SS 7A), **Elaine Cozzi**, Oregon State University, and **Juhi Jang** and **Jim Kelliher**, University of California Riverside.

Universal Algebra and Lattice Theory (Code: SS 10A), **Ralph Freese**, **William Lampe**, and **J. B. Nation**, University of Hawaii.

Tampa, Florida

University of South Florida

March 10–11, 2012

Saturday – Sunday

Meeting #1079

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: January
Program first available on AMS website: February 2, 2012
Program issue of electronic *Notices*: March 2012
Issue of *Abstracts*: Volume 33, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: November 29, 2011
For abstracts: January 18, 2012

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

Invited Addresses

Anne Condon, University of British Columbia, *Some why's and how's of programming DNA molecules*.

Mark Ellingham, Vanderbilt University, *Title to be announced*.

Mauro Maggioni, Duke University, *Digital data sets: Geometry, random walks, multiscale analysis, and applications*.

Weiqiang Wang, University of Virginia, *Title to be announced*.

Special Sessions

Algebraic and Combinatorial Structures in Knot Theory (Code: SS 2A), **J. Scott Carter**, University of South Alabama, and **Mohamed Elhamdadi** and **Masahico Saito**, University of South Florida.

Analysis in Metric Spaces (Code: SS 3A), **Thomas Bieske**, University of South Florida, and **Jason Gong**, University of Pittsburgh.

Applications of Complex Analysis in Mathematical Physics (Code: SS 9A), **Razvan Teodorescu**, University of South Florida, **Mihai Putinar**, University of California, Santa

Barbara, and **Pavel Bleher**, Indiana University-Purdue University Indianapolis.

Complex Analysis and Operator Theory (Code: SS 8A), **Sherwin Kouchekian**, University of South Florida, and **William Ross**, University of Richmond.

Discrete Models in Molecular Biology (Code: SS 1A), **Alessandra Carbone**, Université Pierre et Marie Curie and Laboratory of Microorganisms Genomics, **Natasha Jonoska**, University of South Florida, and **Reidun Twarock**, University of York.

Extremal Combinatorics (Code: SS 13A), **Brendan Nagle**, University of South Florida.

Finite Fields and Their Applications (Code: SS 15A), **Xiang-dong Hou**, University of South Florida, and **Gary Mullen**, Pennsylvania State University.

Graph Theory (Code: SS 14A), **Mark Ellingham**, Vanderbilt University, and **Xiaoya Zha**, Middle Tennessee State University.

Hopf Algebras and Galois Module Theory (Code: SS 7A), **James Carter**, College of Charleston, and **Robert Underwood**, Auburn University Montgomery.

Interaction between Algebraic Combinatorics and Representation Theory (Code: SS 4A), **Mahir Can**, Tulane University, and **Weiqiang Wang**, University of Virginia.

Modeling Crystalline and Quasi-Crystalline Materials (Code: SS 5A), **Mile Krajcevski** and **Gregory McColm**, University of South Florida.

Representations of Algebraic Groups and Related Structures (Code: SS 12A), **Joerg Feldvoss** and **Cornelius Pillen**, University of South Alabama.

Solvability and Integrability of Nonlinear Evolution Equations (Code: SS 6A), **Wen-Xiu Ma**, University of South Florida, and **Ahmet Yildirim**, Ege University and University of South Florida.

Spectral Theory (Code: SS 11A), **Anna Skripka** and **Maxim Zinchenko**, University of Central Florida.

Stochastic Partial Differential Equations and Random Global Dynamics (Code: SS 10A), **Yuncheng You**, University of South Florida, and **Shanjian Tang**, Fudan University.

Washington, District of Columbia

George Washington University

March 17–18, 2012

Saturday – Sunday

Meeting #1080

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2012
Program first available on AMS website: February 9, 2012
Program issue of electronic *Notices*: March 2012
Issue of *Abstracts*: Volume 33, Issue 2

Deadlines

For organizers: August 17, 2011
For consideration of contributed papers in Special Sessions: December 6, 2011
For abstracts: January 31, 2012

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

Invited Addresses

Jim Geelen, University of Waterloo, *Title to be announced*.

Boris Solomyak, University of Washington, *Title to be announced*.

Gunther Uhlmann, University of Washington, *Title to be announced* (Einstein Public Lecture in Mathematics).

Anna Wienhard, Princeton University, *Title to be announced*.

Special Sessions

Computable Mathematics (in honor of Alan Turing) (Code: SS 8A), **Douglas Cenzer**, University of Florida, **Valentina Harizanov**, George Washington University, and **Russell Miller**, Queens College and Graduate Center—City University of New York.

Convex and Discrete Geometry (Code: SS 9A), **Jim Lawrence** and **Valeriu Soltan**, George Mason University.

Dynamics of Complex Networks (Code: SS 7A), **Yongwu Rong**, **Guanyu Wang**, and **Chen Zeng**, George Washington University.

Homology Theories Motivated by Knot Theory (Code: SS 3A), **Jozef H. Przytycki**, George Washington University, **Radmila Sazdanovic**, University of Pennsylvania, and **Alexander N. Shumakovitch** and **Hao Wu**, George Washington University.

Matroid Theory (Code: SS 1A), **Joseph E. Bonin**, George Washington University, and **Sandra Kingan**, Brooklyn College.

Nonlinear Dispersive Equations (Code: SS 10A), **Manoussos Grillakis**, University of Maryland, **Justin Holmer**, Brown University, and **Svetlana Roudenko**, George Washington University.

Optimization: Theory and Applications (Code: SS 2A), **Roman Sznajder**, Bowie State University.

Self-organization Phenomena in Reaction Diffusion Equations (Code: SS 5A), **Xiaofeng Ren**, George Washington University, and **Junping Shi**, College of William and Mary.

Structural and Extremal Problems in Graph Theory (Code: SS 4A), **Daniel Cranston**, Virginia Commonwealth University, and **Gexin Yu**, College of William & Mary.

Tilings, Substitutions, and Bratteli-Vershik Transformations (Code: SS 6A), **E. Arthur Robinson**, George Washington University, and **Boris Solomyak**, University of Washington.

Lawrence, Kansas

University of Kansas

March 30 – April 1, 2012
Friday – Sunday

Meeting #1081

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: February 2012
Program first available on AMS website: March 8, 2012
Program issue of electronic *Notices*: March 2012
Issue of *Abstracts*: Volume 33, Issue 2

Deadlines

For organizers: August 31, 2011
For consideration of contributed papers in Special Sessions: December 20, 2011
For abstracts: February 14, 2012

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

Invited Addresses

Frank Calegari, Northwestern University, *Title to be announced.*

Christopher Leininger, University of Illinois at Urbana-Champaign, *Title to be announced.*

Alina Marian, University of Illinois at Chicago, *Title to be announced.*

Catherine Yan, Texas A&M University, *Title to be announced.*

Special Sessions

Combinatorial Commutative Algebra (Code: SS 1A), **Christopher Francisco** and **Jeffrey Mermin**, Oklahoma State University, and **Jay Schweig**, University of Kansas.

Enumerative and Geometric Combinatorics (Code: SS 5A), **Margaret Bayer**, University of Kansas, **Joseph P. King**, University of North Texas, **Svetlana Poznanovik**, Georgia Institute of Technology, and **Catherine Yan**, Texas A&M University.

Geometric Representation Theory (Code: SS 4A), **Zongzhu Lin**, Kansas State University, and **Zhiwei Yun**, Massachusetts Institute of Technology.

Invariants of Knots (Code: SS 3A), **Heather A. Dye**, McKendree University, and **Aaron Kaestner** and **Louis H. Kauffman**, University of Illinois at Chicago.

Partial Differential Equations (Code: SS 2A), **Milena Stanislavova** and **Atanas Stefanov**, University of Kansas.

Rochester, New York

Rochester Institute of Technology

September 22–23, 2012
Saturday – Sunday

Meeting #1082

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: May 2012
Program first available on AMS website: July 19, 2012
Program issue of electronic *Notices*: September 2012
Issue of *Abstracts*: Volume 33, Issue 3

Deadlines

For organizers: February 22, 2012
For consideration of contributed papers in Special Sessions: May 15, 2012
For abstracts: July 10, 2012

New Orleans, Louisiana

Tulane University

October 13–14, 2012
Saturday – Sunday

Meeting #1083

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: June 2012
Program first available on AMS website: September 6, 2012
Program issue of electronic *Notices*: October 2012
Issue of *Abstracts*: Volume 33, Issue 3

Deadlines

For organizers: March 13, 2012
For consideration of contributed papers in Special Sessions: July 3, 2012
For abstracts: August 28, 2012

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

Invited Addresses

Anita Layton, Duke University, *Title to be announced.*

Lenhard Ng, Duke University, *Title to be announced.*

Henry K. Schenck, University of Illinois at Urbana-Champaign, *From approximation theory to algebraic geometry: The ubiquity of splines.*

Milen Yakimov, Louisiana State University, *Title to be announced.*

Akron, Ohio

University of Akron

October 20–21, 2012
Saturday – Sunday

Meeting #1084
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: August 2012
Program first available on AMS website: September 27, 2012
Program issue of electronic *Notices*: October 2012
Issue of *Abstracts*: Volume 33, Issue 4

Deadlines
For organizers: March 22, 2012
For consideration of contributed papers in Special Sessions: July 10, 2012
For abstracts: September 4, 2012

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

Invited Addresses
Tanya Christiansen, University of Missouri, *Title to be announced*.

Tim Cochran, Rice University, *Title to be announced*.

Ronald Solomon, Ohio State University, *Title to be announced*.

Ben Weinkove, University of California San Diego, *Title to be announced*.

Tucson, Arizona

University of Arizona, Tucson

October 27–28, 2012
Saturday – Sunday

Meeting #1085
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2012
Program first available on AMS website: October 4, 2012
Program issue of electronic *Notices*: October 2012
Issue of *Abstracts*: Volume 33, Issue 4

Deadlines
For organizers: March 27, 2012
For consideration of contributed papers in Special Sessions: July 17, 2012
For abstracts: September 11, 2012
The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses
Michael Hutchings, University of California Berkeley, *Title to be announced*.

Kenneth McLaughlin, University of Arizona, Tucson, *Title to be announced*.

Ken Ono, Emory University, *Title to be announced* (Erdős Memorial Lecture).

Jacob Sterbenz, University of California San Diego, *Title to be announced*.

Goufang Wei, University of California, Santa Barbara, *Title to be announced*.

Special Sessions
Harmonic Maass Forms and q-Series (Code: SS 1A), **Ken Ono**, Emory University, **Amanda Folsom**, Yale University, and **Zachary Kent**, Emory University.

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 9–12, 2013
Wednesday – Saturday

Meeting #1086
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: Georgia Benkart
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

Oxford, Mississippi

University of Mississippi

March 1–3, 2013

Friday – 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 1, 2012
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Chestnut Hill, Massachusetts

Boston College

April 6–7, 2013

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: September 6, 2012
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Ames, Iowa

Iowa State University

April 27–28, 2013

Saturday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: April 2013
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 27, 2012
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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

Special Sessions

Operator Algebras and Topological Dynamics (Code: SS 1A), **Ken Ono**, Emory University, **Amanda Folsom**, Yale University, and **Zachary Kent**, Emory University.

Alba Iulia, Romania

June 27–30, 2013

Thursday – Sunday
First Joint International Meeting of the AMS and the Romanian Mathematical Society, in partnership with the "Simion Stoilow" Institute of Mathematics of the Romanian Academy.
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Louisville, Kentucky

University of Louisville

October 5–6, 2013

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: March 5, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

St. Louis, Missouri

Washington University

October 18–20, 2013

Friday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 20, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Riverside, California

University of California Riverside

November 2–3, 2013

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: April 2, 2013
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

Tel Aviv, Israel

Bar-Ilan University, Ramat-Gan and Tel-Aviv University, Ramat-Aviv

June 16–19, 2014

Monday – Thursday
The 2nd Joint International Meeting between the AMS and the Israel Mathematical Union.
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For 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

Porto, Portugal

University of Porto

June 11–14, 2015

Thursday – Sunday
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Seattle, Washington

Washington State Convention Center and the Sheraton Seattle Hotel

January 6–9, 2016

Wednesday – Saturday
Joint Mathematics Meetings, including the 122nd Annual Meeting of the AMS, 99th 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: Michel L. Lapidus
Announcement issue of *Notices*: October 2015
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2016
Issue of *Abstracts*: Volume 37, Issue 1

Deadlines

For organizers: April 1, 2015
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Atlanta, Georgia

Hyatt Regency Atlanta and Marriott Atlanta Marquis

January 4–7, 2017

Wednesday – Saturday
Joint Mathematics Meetings, including the 123rd Annual Meeting of the AMS, 100th 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: Georgia Benkart
Announcement issue of *Notices*: October 2016
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2017
Issue of *Abstracts*: Volume 38, Issue 1

Deadlines

For organizers: April 1, 2016
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 10–13, 2018

Wednesday – Saturday
Joint Mathematics Meetings, including the 124th Annual Meeting of the AMS, 101st 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: Matthew Miller
Announcement issue of *Notices*: October 2017
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2017
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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: Georgia Benkart, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388; e-mail: benkart@math.wisc.edu; telephone: 608-263-4283.

Eastern Section: Steven H. Weintraub, Department of Mathematics, Lehigh University, Bethlehem, PA 18105-3174; e-mail: steve.weintraub@lehigh.edu; telephone: 610-758-3717.

Southeastern Section: Matthew Miller, Department of Mathematics, University of South Carolina, Columbia, SC 29208-0001, e-mail: miller@math.sc.edu; telephone: 803-777-3690.

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 100 in the January 2011 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

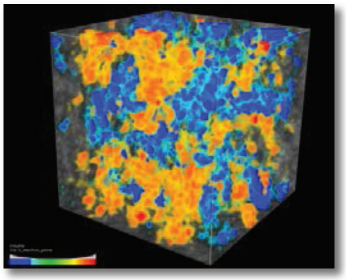
Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset 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.)

March 11–14, 2012: Fourth International Conference on Mathematical Sciences, United Arab Emirates (held in cooperation with the AMS). Please see http://icm.uaeu.ac.ae/ for more information.

INSTITUTE FOR PURE AND APPLIED MATHEMATICS

Los Angeles, California



Computational Methods in High Energy Density Plasmas

March 12 – June 15, 2012

ORGANIZING COMMITTEE: Tina Back (General Atomics), Andrew Christlieb (Michigan State), Jill Dahlburg (Naval Research Lab), Michael Desjarlais (Sandia), Frank Graziani (LLNL), Leslie Greengard (NYU), David Levermore (University of Maryland), Warren Mori (UCLA), Michael Murillo (LANL)

Scientific Overview

The long program will establish an interdisciplinary forum for researchers in HEDP. In particular, the long program will provide a channel by which experts in the diverse applications disciplines meet and openly discuss the merits and weaknesses of their approaches. In order for the HEDP community to meet the challenges facing it, it is important that mathematicians, physicists, computer scientists, computational chemists, experimentalists, and engineers be part of the dialogue taking place in this long program. Providing a forum where HEDP challenges are communicated to a wide community will set up a synergistic relationship between disciplines.

Workshop Schedule

- Computational Methods in High Energy Density Plasmas Tutorials. March 13 - 16, 2012
- Workshop I: Computational Challenges in Hot Dense Plasmas. March 26 - 30, 2012
- Workshop II: Computational Challenges in Magnetized Plasma. April 16 - 20, 2012
- Workshop III: Mathematical and Computer Science Approaches to High Energy Density Physics. May 7 - 11, 2012
- Workshop IV: Computational Challenges in Warm Dense Matter. May 21 - 25, 2012
- Culminating Workshop at Lake Arrowhead (by invitation only). June 10 - 15, 2012

Participation

This long program will involve a community of senior and junior researchers. The intent is for participants to have an opportunity to learn about the mathematics and science of high energy density plasmas, to meet a diverse group of scientists and to have an opportunity to form new collaborations. Full and partial support for long-term participants is available. We are especially interested in applicants who intend to participate in the entire program (March 12 – June 15, 2012), but will consider applications for shorter periods. Funding is available for participants at all academic levels, though graduate students and researchers in the early stages of their careers are especially encouraged to apply. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications. More information and an application is available online.

www.ipam.ucla.edu/programs/pl2012

NSF UCLA

IPAM is an NSF funded institute

Institute for Pure & Applied Mathematics IPAM University of California, Los Angeles

American Mathematical Society Distribution Center
35 Monticello Place, Pawtucket, RI 02861 USA

0002-9920(201109)58:8;1-C