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of the American Mathematical Society

November 2012

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About the Cover:
Irrational Symmetry
(see page 1390)

INSTITUTE FOR PURE AND APPLIED MATHEMATICS
Los Angeles, California

Materials for a Sustainable Energy Future

September 9 – December 13, 2013

ORGANIZING COMMITTEE: Martin Bazant (MIT), Giulia Galli (UC Davis), Graeme Henkelman (University of Texas at Austin), Keith Promislow (Michigan State University), Matthias Scheffler (Fritz-Haber-Institut der Max-Planck-Gesellschaft)

Scientific Overview

A secure and sustainable energy future that is not based on a fossil-fuel based infrastructure requires the design of new materials for efficient energy conversion, transport, and storage. Indeed, materials development is a rate limiting step in many potential new energy conversion strategies, impacting the efficiency of photovoltaic solar cells, the storage capacity and power density of batteries for automobile applications, the synthesis of liquid fuels, and the catalysis and durability of energy conversion in fuel cells. A key bottleneck in this historic transition is the wide range of length scales present in the morphology and time scales in the transport phenomena. Serious progress in the development of new materials requires predicative modeling which surmounts the particle-continuum divide. Recent developments in macro-micro modeling, incorporating machine and manifold learning, combined with new classes of continuum models and increases in computational resources, provide a new framework with which to develop a fundamental understanding of complex materials. This program is part of the international initiative "Mathematics of Planet Earth."

Workshop Schedule

- Materials for a Sustainable Energy Future Tutorials. September 9 - 13, 2013
- Workshop I: Solar Cells. September 23 - 27, 2013
- Workshop II: Fuels from Sunlight. October 14 - 18, 2013
- Workshop III: Batteries and Fuel Cells. November 4 - 8, 2013
- Workshop IV: Energy Conservation and Waste Heat Recovery. November 18 - 22, 2013
- Culminating Workshop at Lake Arrowhead (by invitation only). December 8 - 13, 2013

Participation

This program will bring together researchers from mathematics, physics, materials science, engineering, chemistry, biology, computer sciences, and other sciences with the goal to understand the mathematical structure of continuum models governing material properties as well as the electronic, atomic, and molecular structure of such new materials.

Full and partial support for long-term participants is available. We are especially interested in applicants who intend to participate in the entire program, but will consider applications for shorter periods. Funding is available to participants at all academic levels, though recent PhDs, 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/mse2013

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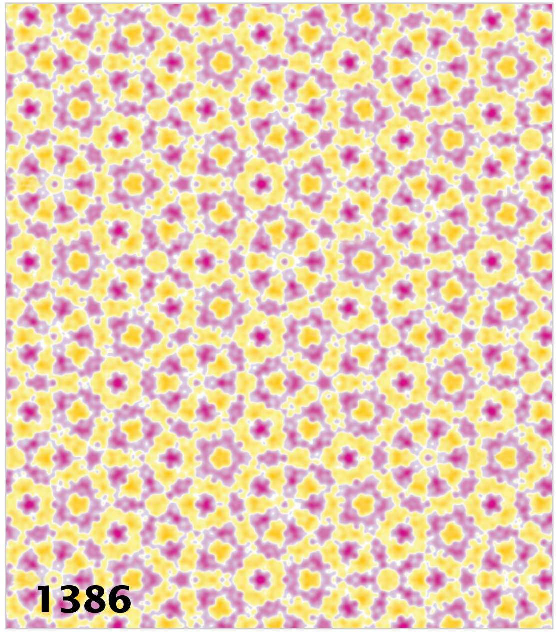

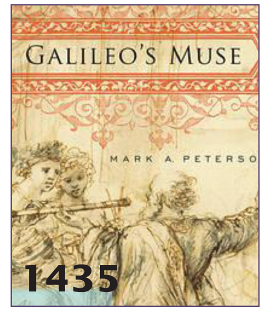

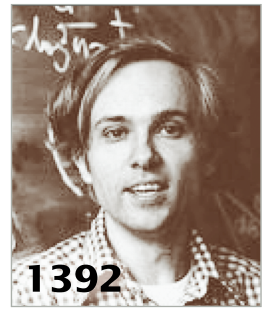

The month of November provides an eclectic offering. We have an article about a college professor returning to teach in high school. There is a piece about the method of Stein in statistical analysis. And an offering about hidden symmetries. Finally, we have a memorial for Fields Medalist Daniel Quillen.

—*Steven G. Krantz, Editor*

Features

Communications

Commentary

Notices
of the American Mathematical Society

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Departments

Improving the Refereeing Process: A Simple Proposal

We've all experienced the sinking feeling of opening a journal's reply to our paper submission only to see a rejection. Many, perhaps most, of us have had the misfortune to experience this in its most unpleasant and least defensible form: when the reply comes six months to a year or more after the submission and the referee report is so perfunctory it's clear that no effort was made to read past the introduction. I've certainly been through this a number of times myself, with twists ranging from the comic (as when a referee stated that he or she had mistaken the paper in question for a different one) to the tragic (as when some referees have clearly fundamentally misunderstood the main results). I've heard even more absurd and frustrating stories from friends. It's hard not to suspect that in some cases, referees take a negative report as the path of least resistance to avoid the hard work of a thorough refereeing job. In theory, an editor may recognize a shoddy report and seek out a better one, but in practice this rarely happens.

Some journals have taken an important step in the right direction by soliciting quick expert opinions prior to sending out a paper to referee, but more could be done and without very much difficulty. My simple proposal is to completely separate out the evaluation of the quality of the results and techniques—which can usually be carried out quite quickly and for the vast majority of papers is the sole factor determining ultimate acceptance or rejection—from the more painstaking process of attempting to verify correctness. Thus, a journal would first solicit one or more quick expert opinions on a paper and then make a binding decision on whether the paper is good enough to accept, assuming the mathematics is correct. Only in the case of a positive decision would the paper be sent out for a thorough refereeing for correctness.

Evidently, the great advantage of this system is that in principle rejections would always occur quickly, except in rare cases of unsalvageable mathematical errors. Also appealing is that it would be relatively easy to implement. Although it would create a modest amount of additional work for journals not already soliciting expert opinions, the benefits could be substantial not only to authors but to journals as well. As with the current expert opinion system, editors would be free to select more prominent and senior mathematicians for the evaluation of the importance of a paper while choosing younger mathematicians with more time for careful reading to evaluate correctness. One could easily imagine that the first journals to advertise the adoption of this system would see an increase in the quality of papers submitted, and once the system is adopted more widely, the average delay between the public posting of a paper and its publication would decrease, counteracting to some extent the present march towards irrelevance of published versions of papers.

Switching to this system would also open the door to further experimentation. For instance, the second referee would not have to be anonymous, since he or she would not be evaluating the quality of the paper. This would allow real credit for improvements due to the referee (in contrast to the currently ubiquitous thanking of the "anonymous referee") and, depending on how it was implemented, could put more pressure on referees not to simply rubber-stamp the paper.

Despite the present rapid pace of change in mathematical publishing, I believe that the peer-review process continues to play an important role in our profession. Unfortunately, in its present incarnation, it also causes a lot of collateral damage, much of it unnecessary. While the above proposal is no panacea, it offers a practical approach to addressing one of the most serious problems with the process. I hope that editorial boards will seriously consider adopting it.

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Letters to the Editor

The Standards 2.0

I did a double take when I read the second sentence of Solomon Garfunkel's "What's a Math Educator to Do?" (*Notices*, August 2012, p. 909): "I truly think that the Common Core State Standards for Mathematics (CCSSM) are a disaster."

As I read on, it turns out that he "was actually on the writing team for CCSSM," will retrain teachers, will "be involved with the implementation of CCSSM," "will work with assessment consortia," "will sit on advisory boards for curriculum projects," etc.

Between 1991 and 2001, I attended various open houses at my local public school system. Every nauseating mathematics doorstop was ballyhooed as "meeting the Standards." Therefore, I am appalled by Garfunkel's clam concerning "the 1989 Standards of the National Council of Teachers of Mathematics (NCTM), which were never given a fair chance to succeed." At a recent conference, I heard a similar lame excuse from someone who has been a leading promoter of the Standards since 1989.

It is not at all surprising that the latest promotion in mathematics education is being peddled by many of the same people who are responsible for the Standards and "reform math" disaster of the past twenty-three years. The hierarchy of the AMS must speak up and expose those who continue to play such key roles in the continuing pseudo-education of American students.

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(Received July 28, 2012)

Standards for Publishing Errata

At a recent mathematical conference I had several conversations with other researchers on the uncomfortable topic of publishing errata for math articles where proofs of some of the main results turned out to be incomplete or incorrect. I was surprised when several senior mathematicians in my area expressed the opinion that publishing an erratum in the above circumstances should not be regarded as mandatory and that acknowledging the mistake, in private communications or at one's webpage, may be sufficient. I had always thought that publishing an erratum, if a published proof of your significant result falls through, is a basic tenet of professional ethics for a research mathematician. The AMS ethical guidelines, adopted by the AMS Council in 2005, say as much. While the number of published mathematical papers, and presumably the number of serious errors in them, has been rapidly increasing in recent years, the number of published errata, particularly in pure mathematics, has not necessarily kept pace. At the same time, the tolerance among the mathematical community for allowing incorrect published proofs to remain standing without published errata or corrigenda appears to have been quietly increasing. After several MathSciNet searches, I observed that applied math and physics journals were more apt than pure math journals to publish errata, and that AMS journals have a fairly problematic record here. From 2000 to 2011, *Communications in Mathematical Physics* published 2778 articles and 41 errata. For the same period *Transactions of the AMS* published 2966 articles and 12 errata, and *Proceedings of the AMS* published 5688 articles and 27 errata. By comparison, *Inventiones Mathematicae* published 817 articles and 19 errata. On the other hand, the *Journal of the London Mathematical Society* had even more startling statistics: 1191 articles and only 2 errata. I am not sure what exactly to make of this data. Nevertheless, I am certain that mathematical papers are refereed less carefully these days than in the past and that, with the increasing pace of the number of papers published annually, the number of serious errors in them is increasing fast as well. It is imperative for mathematics as a profession to set higher and tougher standards, mandating publishing errata or corrigenda for significant results whose proofs turn out to fall through or to be substantially incomplete. The AMS should lead the way here, starting with its own journals.

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Not a Fond Farewell

In response to the adoption of a fellows program, I am letting my membership in the AMS lapse, as I do not wish to be a member of an organization that is not egalitarian. The program will politicize the AMS and have ramifications for hiring, promotion, and tenure. It is only a matter of time before cries of discrimination arise, and fellows are anointed solely to achieve diversity. Adoption of this program is the most foolish thing the AMS has done since I have been a member.

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AMS Fellows

I am declining the invitation to be an AMS Fellow, and I urge others to do the same. The many harmful effects of this type of program were well explained in the August 2006 *Notices* by AMS past president David Eisenbud, who wrote, "A Fellows program goes against one of the things that makes mathematics special and wonderful: its uniquely egalitarian culture."

—*Neal Koblitz*
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Forbidden Symmetries

Frank A. Farris

The crystallographic restriction, as it applies to patterns in the plane, tells us that a pattern invariant under two linearly independent isometries cannot have 5-fold symmetry. And yet the pattern in Figure 1 seems to have translational symmetry in two directions as well as rotational symmetry through 72°. To see what I mean, start with the wheel shape at the point labeled A and notice translational symmetries along vectors $\overrightarrow{AB}$ and $\overrightarrow{AC}$; then rotate the image 72° about A, so that B goes to C, and see that the image is unchanged, apparently in violation of the crystallographic restriction. How can this be?

A moment's thought can break the illusion: If the pattern really enjoyed translational symmetry along vector $\overrightarrow{AB}$, then we could rotate 72° clockwise about B and move A to C. Alas, angle $\angle ABC$ is an unfortunate 54°, so B is not truly a translate of A.

The purpose of this paper is to show that an effort to construct functions known not to exist may on occasion produce interesting frauds. Our method produces a family of Harald Bohr's *quasiperiodic functions*, which may well remind readers of the quasicrystals that have been much in the news since Daniel Shechtman won the Nobel Prize in Chemistry in 2011 [1].

The term *quasicrystal* has an interesting history, as explained by Senechal in the *Notices* [6]. Diffraction patterns found by Shechtman in 1982 displayed 5-fold symmetry and so fell outside the mathematical categories commonly accepted as encompassing all possible crystalline structures. Our quasiperiodic functions are a different sort of object altogether. Unlike the structures studied by crystallographers, which are idealized as sets of isolated points in space, these are smooth *functions* that have honest 5-fold symmetry about a single point and come so close to having translational symmetry that they can easily fool the eye, provided we select a suitable translation.

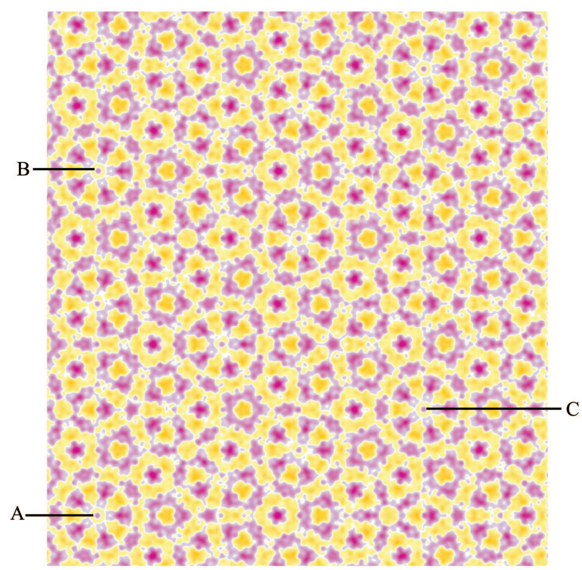

Figure 1. Wallpaper with 5-fold symmetry?

The techniques developed to create these functions may offer more interest beyond creating fraudulent images such as Figure 1. We show how

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to construct functions with 3-fold symmetry and how the technique breaks down when we try to change 3 to 5.

Preliminaries

By *wallpaper group* we mean a group G of Euclidean isometries of the real plane whose translational subgroup is a lattice generated by two linearly independent translations. As is well known, there are seventeen isomorphism classes of such groups. Also well known is the fact that if ρ is a rotation in one of these groups, then its order is 2, 3, 4, or 6.

Unlike many discussions of patterns in the plane which refer to subsets, called *motifs*, being repeated without overlap [4, p. 204], we use analysis to develop the concept of pattern. For us, a pattern is given by a *wallpaper function*, which is a real- (or perhaps complex-) valued function on the real plane that is invariant under the action of one of the wallpaper groups [2]. In symbols, we require that

$$f(g\mathbf{x}) = f(\mathbf{x}) \quad \text{for every} \quad \mathbf{x} \in \mathbb{R}^2, \; g \in G.$$

For any given group G, it is easy to construct such functions by superimposing plane waves invariant with respect to the lattice of translations in the group. My paper "Wallpaper functions" [2] explains the construction and also covers functions with color-reversing symmetries. For wallpaper functions with 3-fold symmetry, an alternate method is possible, one that readers familiar with group representations may recognize. We present this method and try to generalize it to produce functions with 5-fold symmetry. In the generalization, we can see exactly why Figure 1 fails to enjoy honest translational symmetry.

Constructing Patterns with 3-fold Symmetry

To construct functions on the plane with 3-fold symmetry, we start with an unlikely object: cyclic permutation of *three* variables, considered as a linear transformation of $\mathbb{R}^3$. After all, this permutation, which we will call P, does have order 3. If f is any function of three variables, then $f(x,y,z)+f(z,x,y)+f(y,z,x)$ is a function invariant under P.

Since we seek periodic functions, let us suppose that the function $f(x,y,z)$ is periodic with respect to the integer lattice in $\mathbb{R}^3$. Let us limit ourselves to constructing continuously differentiable functions. Then we may assume that f is represented as the sum of its Fourier series in three variables:

$$f(x,y,z) = \sum_{\mathbf{n}\in\mathbb{Z}^3} a_{\mathbf{n}} e^{2\pi i \mathbf{n}\cdot\mathbf{x}}.$$

For 3-fold symmetry, we may either take such an f and average it over cyclic permutation of variables or require that

$$a_{\mathbf{n}} = a_{\mathbf{n}P} = a_{\mathbf{n}P^2},$$

since these coefficients will become equal after averaging. (Here, we think of the matrix P as acting on row vectors $\mathbf{n}$, the adjoint action.)

It remains to find planar functions somewhere in this 3-dimensional setup. The eigenspaces of the linear transformation P are easily found to be the line generated by $[1,1,1]$ and a plane Π, with basis $\mathbf{V}_1 = [1,-1,0]$ and $\mathbf{V}_2 = [0,1,-1]$, on which P acts as rotation through an angle $2\pi/3$.

If we restrict f to the plane Π, the resulting function has translational invariance with respect to the integer vectors $\mathbf{V}_1$ and $\mathbf{V}_2$, as well as rotational symmetry through an angle of $2\pi/3$. Of course, f is necessarily invariant with respect to all compositions of these symmetries and so is a wallpaper function with group at least as large as the one generated by the rotation and one translation. (Translation along $\mathbf{V}_2$ can be written by conjugating the other translation by the rotation.) We call this group $p3$, preferring the notation of the International Union of Crystallography to Conway's orbifold notation.

We can easily construct wallpaper functions with groups that contain $p3$ as a subgroup by including special groupings of terms in the Fourier expansion of the function of three variables before we restrict. To explain this in some detail, we begin with packets of waves invariant under 3-fold rotation:

$$W_{\mathbf{n}}(\mathbf{x}) = \frac{1}{3}\left(e^{2\pi i\mathbf{n}\cdot\mathbf{x}} + e^{2\pi i\mathbf{n}\cdot P\mathbf{x}} + e^{2\pi i\mathbf{n}\cdot P^2\mathbf{x}}\right),$$

where we divide by three simply so that $W_{\mathbf{n}}(0) = 1$. Notice that when restricted to the plane Π,

$$W_{\mathbf{n}+(j,j,j)} = W_{\mathbf{n}} \text{ for } j \in \mathbb{N}.$$

Setting $\mathbf{n} = (n_1, n_2, n_3)$ and representing a typical point in Π as $X\mathbf{V}_1 + Y\mathbf{V}_2$, we write these wave packets in the form

$$W_{n,m}(X,Y) = \frac{1}{3}\left(e^{2\pi i(nX+mY)} + e^{2\pi i(mX-(n+m)Y)} + e^{2\pi i(-(n+m)X+nY)}\right),$$

where

$$n = n_1 - n_2 \text{ and } m = n_2 - n_3.$$

If we wish to choose n and m first and find a vector $\mathbf{n}$ that gives rise to those frequencies, one choice is $(n+m, m, 0)$.

This is why we claim that every (sufficiently smooth) wallpaper function on the plane with 3-fold rotational symmetry can be exhibited as the restriction of a function of three variables that is periodic with respect to the integer lattice and invariant under cyclic permutation of variables: The functions $W_{n,m}(X,Y)$ form a basis for functions with the desired symmetry in the plane, and every $W_{n,m}$ is the restriction of some $W_{\mathbf{n}}$. We write

$$f(X,Y) = \sum_{n,m} a_{n,m} W_{n,m}(X,Y) \tag{1}$$

for the typical wallpaper function—a superposition of wallpaper waves.

To continue the discussion of functions with additional symmetries, we omit some messy details and present the reader with the fact that the map

$$\sigma_c(X,Y) = (Y,X)$$

is a mirror reflection in Π, so that any sum of the form (1) where

$$a_{n,m} = a_{m,n}$$

will represent a function with mirror symmetry. Every function of the form

$$f(X,Y) = \sum_{n,m} a_{n,m}(W_{n,m}(X,Y) + W_{m,n}(X,Y))$$

is invariant under the group p31m (or 3*3 for orbifold enthusiasts).

It is amusing to choose coefficients to create pleasing functions. One example of a function invariant under p31m is shown in Figure 2.

It is likewise amusing to work out recipes to create functions invariant under the groups p3m1, p6, and p6m, but that information appears elsewhere [2], along with the details about various ways to use color to depict a complex-valued function in the plane, so we move on to 5-fold symmetry.

Before we do, note this crucial fact about the construction: We were able to find a basis for Π consisting of vectors with integer coordinates. This is the only reason we could claim that the restricted function is periodic with respect to a lattice within Π, given only that it is periodic with respect to the integer lattice in $\mathbb{R}^3$.

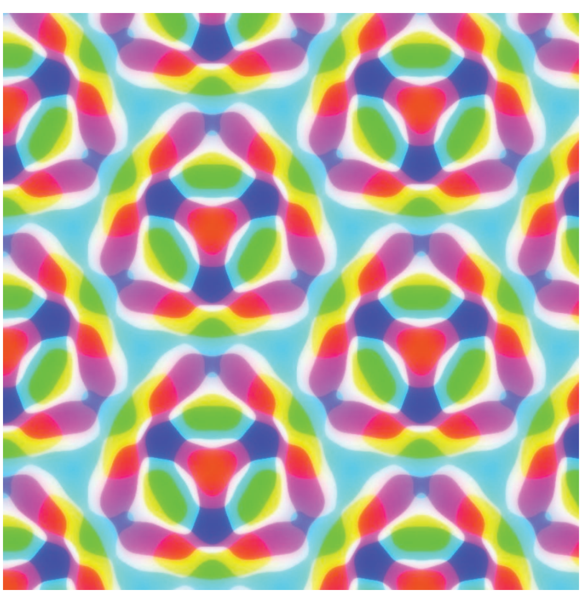

Figure 2. A function with symmetry group p31m.

What Happens If We Use 5 Variables?

The same construction can be attempted in $\mathbb{R}^5$. Let us review why we do not expect to create functions with 5-fold symmetry that are also periodic with respect to a lattice. The reason to include this well-known explanation is that it suggests something to look for in the images.

The Crystallographic Restriction

We prove a special case of the crystallographic restriction, showing that 5-fold rotations are never present in wallpaper groups: Suppose a wallpaper group G contains a translation T and a rotation R through $2\pi/5$ radians. In any wallpaper group, one may always find a shortest translation, so suppose further that T is a shortest translation in G. It is easy to check that $U := RTR^{-1}$ and $V := R^{-1}TR$ are translations along vectors at angles of $\pm 2\pi/5$ radians from the direction of T, as shown in Figure 3. If T translates the center of rotation O to the point A, then the composite translation UV translates O to X, producing a shorter translation and contradicting our assumptions. Therefore, no wallpaper group contains a rotation of order 5.

It is easy to compute that the ratio $\overrightarrow{OA}/\overrightarrow{OX}$ is the golden ratio, $(1+\sqrt{5})/2$, which we denote ϕ. The reader may enjoy looking back at Figure 1, which seems to be invariant under a translation T and a rotation R through $2\pi/5$ radians. Where is the shorter translation that our computations have guaranteed?

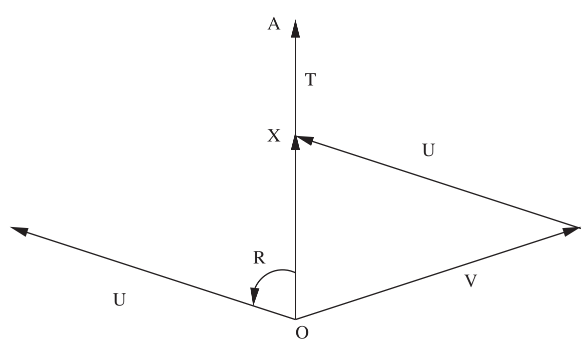

Figure 3. A translation and a rotation through 72° create a shorter translation: The composition of $V := R^{-1}TR$ with $U := RTR^{-1}$ produces a translation that is shorter than T by a factor of $1/\phi$.

Wallpaper with 5-fold Symmetry?

Let us imitate the procedure we used for 3-fold symmetry. Again we call P the linear transformation defined by cyclic permutation of the variables: $P(x, y, z, u, v) = (v, x, y, z, u)$.

Likewise, we take f to be any function periodic with respect to the integer lattice in $\mathbb{R}^5$ and symmetric under cyclic permutation. An easy first example, which we will carry through the remainder of this section, is

$$f(x, y, z, u, v) = \sin(2\pi x) + \sin(2\pi y) + \sin(2\pi z) + \sin(2\pi u) + \sin(2\pi v).$$

The eigenspaces of P are one line spanned by $[1, 1, 1, 1, 1]$ and two planes, with P acting as rotation through $2\pi/5$ in one plane and $4\pi/5$ in the other. We select the first of these planes to call Π. One basis for Π is

$$\mathbf{E}_1 = [1, \cos(2\pi//5), \cos(4\pi/5), \cos(6\pi/5), \cos(8\pi/5)],$$
$$\mathbf{E}_2 = [0, \sin(2\pi/5), \sin(4\pi/5), \sin(6\pi/5), \sin(8\pi/5)],$$

In our construction of functions with 3-fold symmetry we easily found an eigenbasis with integer entries. Some reorganization of $\mathbf{E}_1$ and $\mathbf{E}_2$ gives the basis

$$\mathbf{V}_1 = [\frac{1}{\phi}, \frac{1}{\phi^2}, -\frac{1}{\phi^2}, -\frac{1}{\phi}, 0],$$

$$\mathbf{V}_2 = [0, \frac{1}{\phi}, \frac{1}{\phi^2}, -\frac{1}{\phi^2}, -\frac{1}{\phi}] = P\mathbf{V}_1,$$

where ϕ is the golden ratio.

We can see that there is no way to obtain integer entries from these: If we clear a denominator of ϕ^2, we create a factor of ϕ in another entry. In fact, this plane is *irrational*, in the sense that it contains no rational vectors at all.

This throws a fly into the ointment if we are trying to construct wallpaper functions with 5-fold symmetry. However, it leads us to interesting pictures. Let us start with a function invariant under P and defined by a Fourier series relative to the integer lattice in $\mathbb{R}^5$. Then let us restrict f to Π by the equation

$$F(s, t) = f(s\mathbf{V}_1 + t\mathbf{V}_2).$$

When we do this with our example of the cyclic sum of sines, we obtain the function pictured in Figure 4. The origin of Π, near the lower left of the picture, is, in fact, a center of 5-fold symmetry. Toward the top there seems to be a translated appearance of the same pattern, with what looks like another 5-center. Another appears on a ray through the origin 72° from the vertical. Divide either of these apparent translation vectors by ϕ and notice that there is, well, not translational symmetry, but translational ballpark nearness of the pattern. Divide again.

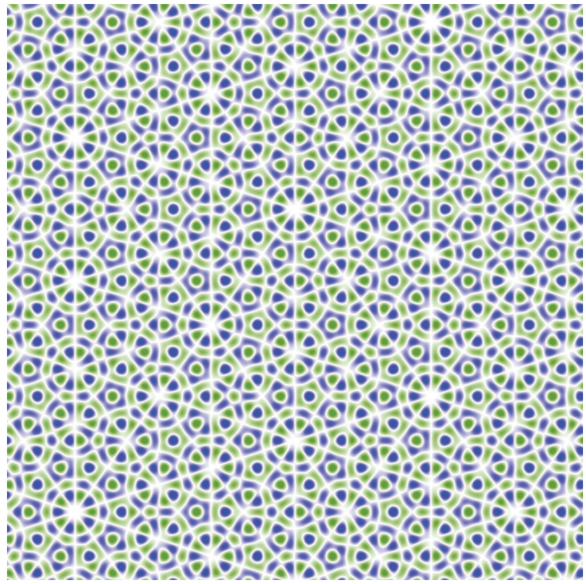

Figure 4. A cyclic sum of sine waves, restricted to the plane Π.

To move in the other direction, we recompute the image for the translated function $f((s+89)\mathbf{V}_1 + t\mathbf{V}_2)$. It looks exactly the same as Figure 4! We know that this function cannot have translational symmetry, but something interesting is going on.

Perhaps you have already guessed what, having recognized the number 89. Applying the Binet formula for F_n, the nth Fibonacci number,

$$F_n = \frac{\phi^n - (-\phi)^{-n}}{\sqrt{5}},$$

we find that, although there are no integer vectors in the plane Π, there are integer vectors arbitrarily close:

$$F_n\mathbf{V}_1 = [F_{n-1}, F_{n-2}, -F_{n-2}, -F_{n-1}, 0] + (-\phi)^{-n}[-1, 1, -1, 1, 0],$$

and likewise for Fibonacci multiples of $\mathbf{V}_2$. From this, it is an easy estimate to find that

$$|F(s + F_n, t) - F(s, t)| < 5/\phi^n.$$

Although this exemplary function f cannot have any translational symmetries (we know this from the crystallographic restriction), it does have what we will call *quasisymmetries*. As with Bohr's almost-periodic functions, given any $\epsilon > 0$, we can find a translational distance T so that

$$|F(s + T, t) - F(s, t)| < \epsilon.$$

Conclusion

The example is only one in a large space of functions with the same symmetry, or rather quasisymmetry. Just as in our construction of functions with 3-fold symmetry, we can start with any cyclically invariant waves in 5-space and

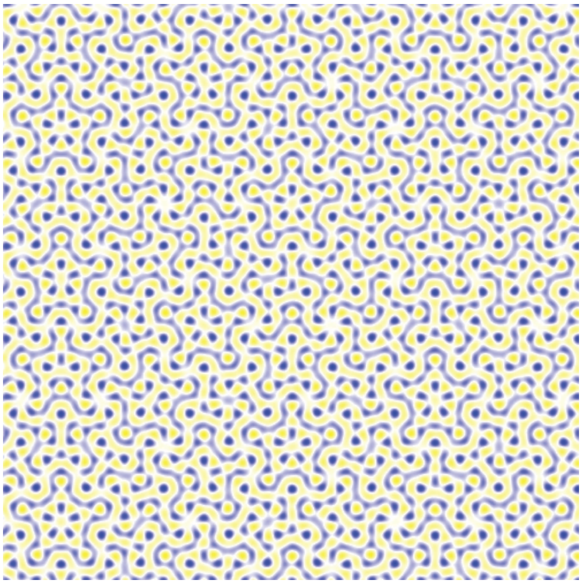

Figure 5. An unretouched depiction of our effort to create 5-fold symmetry.

restrict them to the plane Π. There are limited possibilities for mirror symmetry, though we will mention that the example that arose from the sine function had a mirror color-reversing symmetry. Superimposing only cosine waves does create functions with symmetry about five mirror axes, at least at one point. The opening example enjoyed this extra symmetry.

Though we have not violated the crystallographic restriction, we have found an interesting family of functions. They invite our eye to wander and enjoy the near-repeats. As for the attractive fraud that opened this paper: A bit of Photoshopping made it look rather more symmetrical than it is. Figure 5 gives an unaltered view of the quasisymmetry.

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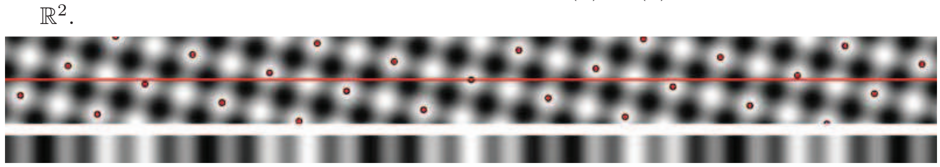
About the Cover

Irrational Symmetry

The cover image was produced by Frank Farris, and is a modification of Figure 4 in his article in this issue.

It records the values (through coloring and shading) of a fairly simple periodic function (specified in that article), restricted to one of the eigenplanes of the cyclic permutation in $\mathbb{R}^5$. What's important here, as he says in the article, is that although crystalline 5-fold symmetry is impossible, it can be very closely approximated. The basic idea behind what one sees is already apparent in two dimensions—the figure below shows in a similar way the restriction of $\cos(x)\cos(y)$ to an irrational line in $\mathbb{R}^2$.



But the details of what happens in Farris' figure are nonetheless striking, perhaps even hypnotic, and what one sees is certainly more striking in two dimensions than in one. Mathematically, the effect is due to lattice points in $\mathbb{Z}^5$ that are near to the plane, and the extraordinary accuracy with which patterns are repeated is presumably due to the accuracy with which the golden ratio is tightly approximated by rational numbers. And perhaps also something intrinsic to human visual perception.

We thank Frank Farris for the time and effort spent on this.

—*Bill Casselman*
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Daniel Quillen

Eric Friedlander and Daniel Grayson, Coordinating Editors

Daniel Quillen, 1940–2011, Fields Medalist, transformed many aspects of algebra, geometry, and topology. Especially in a succession of remarkable papers during the ten-year period of 1967–1977, Quillen created astonishing mathematics which continues to inspire current research in many fields. Quillen's mathematical exposition serves as the ultimate model of clarity. Despite his brilliance, those who knew Quillen were regularly impressed by his generosity and modesty. It has been our privilege to have been mentored by Quillen and to study his remarkable achievements. We feel a deep personal loss at his passing.

In this memorial article we assemble twelve contributions from Quillen's colleagues, collaborators, students, and family. Graeme Segal's contribution is a broad mathematical biography of Quillen which emphasizes the scope and breadth of his work. Hyman Bass surveys Quillen's stunning contributions to algebraic K-theory. Quillen's collaborators Joachim Cuntz and Jean-Louis Loday discuss their work with Quillen on cyclic homology. Michael Atiyah and Ulrike Tillmann, colleagues at Oxford, and Barry Mazur, of Harvard, offer their remembrances. Dennis Sullivan and Andrew Ranicki recall their early mathematical interactions with Quillen. Ken Brown and Jeanne Duflot reflect upon their experiences as students of Quillen. The final contribution, from Quillen's wife and the mother of their six children, Jean Quillen, gives a glimpse of the shy family man who created such beautiful mathematics.

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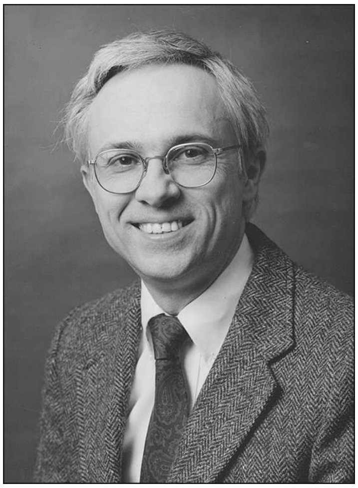

Photo courtesy of Cypora Cohen.

Daniel Quillen.

Graeme Segal

Daniel Quillen, who died on April 30, 2011, at the age of seventy, was among the most creative and influential mathematicians of his time, transforming whole areas of mathematics. He solved a number of famous and important problems, but his most valuable contribution came less from that than from finding new ways of looking at the central questions of mathematics and opening paths into previously inaccessible terrain.

He was born in Orange, New Jersey, the elder of two brothers. His father, Charles Quillen, was a chemical engineer who became a teacher in a vocational high school, and his mother, Emma (née Gray), was a secretary. His mother, in particular, was very ambitious for her sons and sought out

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scholarships for Dan which carried him first to Newark Academy, an excellent private secondary school, and then (a year before finishing high school) to Harvard, where after his undergraduate degree he became a graduate student working under Raoul Bott. His thesis was on overdetermined systems of linear partial differential equations. Immediately on completing his Ph.D. in 1964, he obtained a post at MIT, where he stayed until he moved to Oxford (though with a number of years away on leave, at the IHES, and in Princeton, Bonn, and Oxford).

He said that Bott—a large, outgoing man universally beloved for his warmth and personal magnetism, outwardly quite the opposite of his shy and reticent student—was a crucial model for him, showing him that one did not have to be quick to be an outstanding mathematician. Unlike Bott, who made a performance of having everything explained to him many times over, Quillen did not seem at all slow to others, yet he saw himself as someone who had to think things out very slowly and carefully from first principles and had to work hard for every scrap of progress he made. He was truly modest about his abilities—very charmingly so—though at the same time ambitious and driven. Bott was a universal mathematician, who made contributions to many different areas of the subject while always preserving the perspective of a geometer, and Quillen too never confined himself to a "field". His most famous achievements were in algebra, but he somehow came at algebra from the outside. He was interested in almost all of mathematics and in a lot of physics too: when his eldest daughter was studying physics at Harvard, he carefully worked through the problem sheets she was given, and twenty years later he was doing the same when his youngest daughter was studying electrical engineering at Imperial College. It was a characteristic of his mathematics that he drew in ideas from very diverse areas to use for his own purposes. Throughout his life he kept a beautifully written record of the mathematical thoughts he had each day,[1] and they form an extraordinary archive, covering a huge range of topics, often his own reworkings of papers he had read or lectures he had attended. One finds, for instance, that in 1972, in the middle of the section where he was working out his treatment of algebraic K-theory for categories with exact sequences, there is a long digression entitled "Education in statistical mechanics", which begins with a conventional account of ideal gases and Carnot cycles that one might find in an undergraduate physics course, and then moves through a more mathematical discussion of entropy in statistical mechanics into considering how one can perturb the Hamiltonian or the symplectic structure on the product of a large number of copies of a symplectic manifold. It ends, mystifyingly, "Possible idea to use: entropy and how it arises from the gamma replacement for factorials."

The second great mathematical influence on Quillen—as on many others of his generation—was the towering figure of Alexander Grothendieck. Grothendieck is famous for his mystical conviction that a mathematical problem will solve itself when, by sufficient humble attentiveness, one has found exactly its right context and formulation. However that may be, he opened up one of the most magical panoramas of modern mathematics, connecting number theory, algebra, and geometry. Grothendieck's influence is most evident in Quillen's first lastingly famous work, his Springer Lecture Notes volume *Homotopical Algebra*, published in 1967, on a completely different subject from his thesis.

Its historical context was the development over the previous few decades of the new field of "homological algebra": the art of assigning homotopy types—or, initially, homology groups—to many algebraic and combinatorial structures such as groups and algebras which at first sight have nothing space-like about them. Grothendieck's special contribution to this field had been the invention (with his student Verdier) of the *derived category* in which any given abelian category—such as the modules for a given ring—can be embedded. The derived category is to the abelian category what the homotopy category is to the category of topological spaces. More strikingly, Grothendieck had shown how to associate a homotopy type to an arbitrary commutative ring, and to an algebraic variety over any field, in a way which promised to prove Weil's conjectures (made in 1949) relating the number of points of algebraic varieties defined over finite fields to the topology of the corresponding varieties over the complex numbers. Quillen had made himself a master of the ideas of the Grothendieck school, but at the same time he had immersed himself in a different mathematical tradition, that of the MIT algebraic topologists, especially Daniel Kan, who was his third great influence. (They shared a love of early rising, and were often talking at MIT long before the rest of the world was awake.) Kan was the apostle of simplicial methods: he had proved that the homotopy theory of topological spaces can be studied by entirely combinatorial means. The homotopy category is obtained from the category of topological spaces by formally

[1] *Contradicting what he often said about his own slowness, he said that he needed to write these long careful accounts to slow himself down, as otherwise his thoughts rushed headlong onwards and ended in chaos and confusion.*

Photo from George Lusztig, used with permission.

From left: George Lusztig, Daniel Quillen, Graeme Segal, and Michael Atiyah at the Institute for Advanced Study in Princeton, 1970.

inverting maps which are homotopy equivalences, and Quillen realized that Kan had proved that the *same* category is obtained by inverting a class of maps in the category of simplicial sets. He asked himself when it makes sense to invert a class of morphisms in an arbitrary category and call the result a homotopy category. He saw that the key lay in the concepts of fibration and cofibration, the traditional tools of algebraic topology, and that these were the right context for the projective and injective resolutions of homological algebra—an injective module, for example, is the analogue of a simplicial set obeying the Kan condition. His book went on to develop a very complete abstract theory of homotopy. At the time it attracted little attention except from a small band of enthusiasts, but it proved very prescient; thirty years later the theory was being widely used, and it is central on the mathematical stage today. The book was severely abstract, with hardly any examples and no applications, but Quillen immediately went on to apply the ideas to develop a cohomology theory for commutative rings—now called "André-Quillen cohomology"—and the associated theory of the cotangent complex and, after that, to show that the rational homotopy category can be modeled by differential graded Lie algebras, or, equivalently, by commutative differential graded algebras.

None of his subsequent works have the same unmistakable Grothendieck flavor of this first book. Both Grothendieck and Quillen sought for what was absolutely fundamental in a problem, but where Grothendieck found the essence in generality, Quillen's guiding conviction was that to understand a mathematical phenomenon one must seek out its very simplest concrete manifestation. He felt he was not good with words, but his mathematical writings, produced by long agonized struggles to devise an account that others would understand, are models of lucid, accurate, concise prose, which, as Michael Atiyah has pointed out, are more reminiscent of Serre than of Grothendieck.

He spent the year 1968–1969 as a Sloan Fellow at the IHES near Paris, where Grothendieck was based. The following year, spent at the Institute for Advanced Study in Princeton, was the most fertile of his life, and he produced a torrent of new work. Perhaps the most exciting development at the time was a proof of the Adams conjecture, which identifies—in terms of K-theory and its Adams operations—the direct summand in the stable homotopy groups of spheres which comes from the orthogonal groups. Quillen had already given an outline proof of this three years earlier, showing how it follows from the expected properties of Grothendieck's étale homotopy theory for algebraic varieties in characteristic p.[2] Meanwhile, however, he had been carefully studying the work of the algebraic topologists centered in Chicago, who had used ideas of infinite loop space theory to calculate the homology of many important classifying spaces. He now realized that the crucial idea of his first proof amounted to saying that the classifying spaces of the discrete group $GL_n(\bar{\mathbb{F}}_p)$ and of the Lie group $GL_n(\mathbb{C})$ have the same homology away from the prime p, and that this could be proved directly. (Here $\bar{\mathbb{F}}_p$ denotes the algebraic closure of the field with p elements.) This led straight to his development of algebraic K-theory, which is the achievement he is now most remembered for; but before coming to that I shall mention a few other things.

First, the Adams conjecture was almost simultaneously proved by Dennis Sullivan, also using Grothendieck's theory, but in a different way. While Quillen's proof led to algebraic K-theory, Sullivan's was part of a quite different program, his determination of the structure of piecewise linear and topological manifolds. This was just one of several places where Quillen's work intersected with Sullivan's though they were proceeding in different directions. Another was their independent development of rational homotopy theory, where Sullivan was motivated by explicit questions about the groups of homotopy equivalences of manifolds. Ib Madsen has remarked on the strange quirk of mathematical history that, a few years later, Becker and Gottlieb found a very much more elementary proof of the Adams conjecture which did not use Grothendieck's theory: if this had happened earlier, one can wonder when some active areas of current mathematics would have been invented.

[2] *This sketch proof was made complete a few years later in Friedlander's MIT thesis.*

At the ICM in Nice in 1970 Quillen described the theme of his previous year's work as the cohomology of finite groups. Besides the Adams conjecture and algebraic K-theory, another fertile line of development came out of this. Quillen had shown that the mod p cohomology of any compact group is controlled by the lattice of its elementary p-subgroups, proving, among other things, the Atiyah-Swan conjecture that the Krull dimension of the mod p cohomology ring is the maximal rank of an elementary p-subgroup and calculating for the first time the cohomology rings of the spin groups. He was interested in using these ideas to obtain significant results in finite group theory, but quite soon he left the field to others.

Another achievement of this golden period concerned the complex cobordism ring and its relation to the theory of formal groups. This idea is the basis of most recent work in stable homotopy theory, beginning with the determination by Hopkins of the primes of the stable homotopy category and the "chromatic" picture of the homotopy groups of spheres. Milnor's calculation of the complex cobordism ring in 1960 by means of the Adams spectral sequence had been one of the triumphs of algebraic topology. Quillen had been thinking about Grothendieck's theory of "motives" as a universal cohomology theory in algebraic geometry and also about the use Grothendieck had made of bundles of projective spaces in his earlier work on Chern classes and the Riemann-Roch theorem. He saw that complex cobordism had a similar universal role among those cohomology theories for smooth manifolds in which vector bundles have Chern classes, and that the fundamental invariant of such a theory is the formal group law which describes how the first Chern class of a line bundle behaves under the tensor product. He made the brilliant observation that the complex cobordism ring is the base of the universal formal group, and he succeeded in devising a completely new calculation of it, not using the Adams spectral sequence, but appealing instead to the fundamental properties of the geometric power operations on manifolds. This work is yet another mélange of Grothendieck-style ideas with more concrete and traditional algebraic topology. After his one amazing paper on this subject he seems never to have returned to the area.

I shall not say much about Quillen's refoundation of algebraic K-theory here, as so much has been written about it elsewhere. As he explained it in 1969–1970, one key starting point was the calculation of the homology of $BGL_\infty(\overline{\mathbb{F}}_p)$, and another was when he noticed that the known Pontrjagin ring of the union of the classifying spaces of the symmetric groups essentially coincided with the also-known Pontrjagin ring of $\Omega^\infty S^\infty$, the infinite loop space of the infinite sphere. This led him to the idea that from a category with a suitable operation of "sum"—such as the category of finite sets under disjoint union, or of modules over a ring under the direct sum—one can obtain a cohomology theory if, instead of forming the Grothendieck group from the semigroup of isomorphism classes, one constructs in the homotopy category the group completion of the topological semigroup which is the *space* of the category. The famous "plus construction", which he used in his 1970 ICM talk, is a nice way to realize the group completion concretely; it came from a suggestion of Sullivan, but I do not think it was the basic idea. Throughout his year in Princeton, Quillen was making lightning progress understanding the homotopy theory of categories, which he had not much thought about before. He realized that he must find a homotopy version of the more general construction of Grothendieck groups in which the relations come from exact sequences rather than just from direct sums, and eventually he settled on the "Q-construction" as his preferred method of defining the space. The culmination of this work was the definitive treatment he wrote for the 1972 Seattle conference on algebraic K-theory. He published only one paper on algebraic K-theory after that: his proof in 1976 of Serre's conjecture that projective modules over polynomial rings are free. This came from reflecting deeply on what was already known about the question—especially the work of Horrocks—and seeing that, when brewed lovingly in the way Grothendieck advocated for opening nuts, the result fell out.

By 1978, when he was awarded a Fields Medal, Quillen's interests had shifted back towards global geometry and analysis. His notebooks of the years 1976–1977 are mainly concerned with analysis: Sturm-Liouville theory for ordinary differential equations, scattering and inverse scattering theory in one dimension, statistical mechanics, the theory of electric transmission lines, quantum and quantum field theoretical aspects of the same questions, and also orthogonal polynomials, Jacobi matrices, and the de Branges theory of Hilbert spaces of entire functions. He gave a wonderful graduate course on these topics at MIT in 1977. He published nothing of this, however. He felt, I suppose, that he hadn't obtained any decisively new results. Nevertheless, I think one can say that a single circle of ideas connected with global analysis and index theory—an area extending to quantum field theory at one end, and at the other end to algebraic K-theory through Connes's treatment of index theory by cyclic homology—held his interest in many different guises ever after. The very last graduate course he gave in Oxford (in the year 2000, I think) was on scattering theory for the discretized Dirac equation in two dimensions.

Early in 1982 he decided that Oxford was the place he wanted to be, attracted to it especially by the presence of Michael Atiyah. He spent the year 1982–1983 on leave there, and in 1985 he moved permanently from MIT to Oxford as Waynflete Professor. (The joke surged irresistibly around the mathematical world of a dean at MIT rushing to Dan with an offer to halve his salary.)

In the 1980s he made at the very least three outstanding contributions which will shape mathematics for a long time: the invention of the "determinant line" of an elliptic partial differential operator as a tool in index theory, the concept of a "superconnection" in differential geometry and analysis, and the Loday-Quillen theorem relating cyclic homology to algebraic K-theory.

The first of these came from thinking about the relation of index theory to anomalies in quantum field theory. Determinant lines were a familiar idea in algebraic geometry, and defining regularized determinants by means of zeta functions was standard in quantum field theory and had been studied by mathematicians such as Ray and Singer. Nevertheless, the simple idea that any Fredholm operator has a determinant line in which its determinant lies and that the role of the zeta function is to "trivialize" the determinant line (i.e., identify it with the complex numbers) brought a new perspective to the subject.

"Superconnections" came from thinking about the index theorem for families of elliptic operators and also about Witten's ideas on supersymmetry in quantum theory. When one has a bundle whose fibers are compact Riemannian manifolds, there is a virtual vector bundle on the base which is the fiberwise index of the Dirac operators on each fiber. The index theorem for families gives a formula for the Chern character of this virtual vector bundle. Quillen's idea was to combine the formula expressing the index of a single Dirac operator D as the supertrace of the heat kernel $\exp D^2$ with the identical-looking definition of the Chern character form of a connection in a finite-dimensional vector bundle as the fiberwise supertrace of $\exp D^2$, where now D denotes the covariant derivative of the connection, whose curvature D^2 is a matrix-valued 2-form. He aimed to prove the index theorem for families by applying this to the infinite-dimensional vector bundle formed by the spinor fields along the fibers, defining a superconnection D, with $\exp D^2$ of trace class, by adding the fiberwise Dirac operator to the natural horizontal transport of spinor fields. Superconnections are now very widely used but, after the first short paper in which he gave the

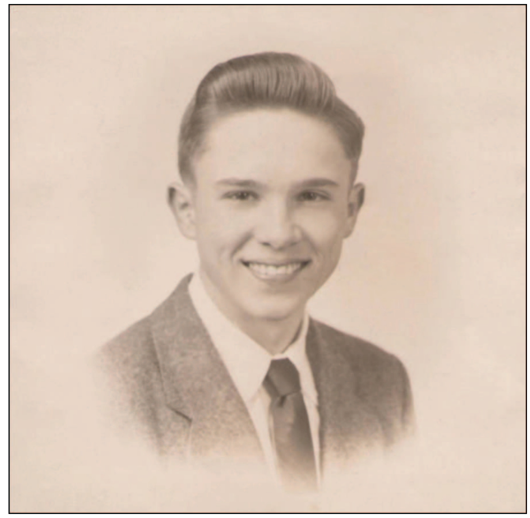

Photo courtesy of Cypora Cohen.

Quillen's Harvard college application photo.

definition and announced his project, Quillen himself did not return to the index theorem for families, as Bismut published a proof of it the following year along Quillen's lines. Only two of his subsequent papers involved superconnections. One of them (joint with his student Mathai) was extremely influential, though it dealt only with finite-dimensional bundles. It gave a beautiful account of the Thom class of a vector bundle in the language of supersymmetric quantum theory and has provided a basic tool in geometrical treatments of supersymmetric gauge theories.

The last phase of Quillen's work was mostly concerned with cyclic homology. He was attracted to this from several directions. On one side, cyclic cocycles had been invented as a tool in index theory, and the Connes "S-operator" is undoubtedly but mysteriously connected with Bott periodicity, whose role in general algebraic K-theory Quillen had constantly tried to understand. More straightforwardly, cyclic homology is the natural home of the Chern character for the algebraic K-theory of a general ring. Yet again, it seemed that cyclic theory ought somehow to fit into the framework of homotopical algebra of Quillen's first book. Connes was a virtuoso in developing cyclic cohomology by means of explicit cochain formulae, but to someone of Quillen's background it was axiomatic that these formulae should not be the basis of the theory. In trying to find the "right" account of the subject, he employed a variety of techniques, pursuing especially the algebraic behavior of the differential forms on Grassmannians when pulled back by the Bott map. One notable success has already been mentioned, his proof of a conjecture of Loday which, roughly, asserts that cyclic homology is to the Lie algebras of the general linear groups exactly what algebraic K-theory is to the general linear groups themselves.[3] In a paper written in 1989, dedicated to Grothendieck on his sixtieth birthday, he succeeded in giving a conceptual definition of cyclic homology but still wrote that "a true Grothendieck understanding of cyclic homology remains a goal for the future." He continued to make important contributions to the subject throughout the 1990s, mostly jointly with Cuntz, but I am far from expert on this phase of his work, and refer the reader to Cuntz's account. Nevertheless, on the whole I think he felt that, in T. S. Eliot's words, the end of all his exploring of Connes's work had been to arrive at where he started and know the place for the first time.

Outside mathematics his great love was music, especially the music of Bach. He always said that he met his wife, Jean, whom he married before he was twenty-one, when he was playing the triangle—and she the viola—in the Harvard orchestra. (She, however, says that he was the orchestra's librarian and occasional reserve trumpeter.) The triangle seems just the right instrument to go with his minimalist approach to mathematics. He delighted in "figuring out" things about how music worked and in devising tiny compositions of twenty or thirty bars, but he was far too driven mathematically to let himself spend much time on music. He and Jean had two children before he completed his Ph.D. and went on to have six altogether. His family was his whole life apart from mathematics, and, tongue-tied as he was, he never needed much encouragement from those he knew well to talk about his children's adventures and misadventures. Although his hair turned white in his twenties, he never lost the look or the manner of a teenager.

The last decade of his life was tragically blighted by steadily encroaching dementia. He is survived by his wife, his six children, twenty grandchildren, and one great-grandchild.

Michael Atiyah

I first met Dan during my visits to Harvard, when he was a student of Raoul Bott. I remember an excitable young man bubbling with ideas and enthusiasm which Raoul was happy to encourage. Many years later Dan became a senior colleague of mine at Oxford. By this time he was a mature mathematician with his own very individual style. He was a great admirer of Serre and later Grothendieck, and his research reflected the influence of both. Clarity and elegance were derived from Serre, but his universalist functorial approach was that of Grothendieck.

Dan was a solitary and deep thinker who spent years trying to get to the roots of a problem, and in this he was remarkably, if not invariably, successful. His interests were broad and his important contributions were characterized by their essential simplicity and inevitability. I am still impressed by his beautiful use of formal groups in cobordism theory, where elegant algebra is brought to bear so fruitfully on geometry.

His style did not lend itself to collaboration, but his influence was extensive. As a person he was quiet and modest, with none of the brashness that sometimes accompanies mathematical brilliance. But beneath the quiet exterior there was still the sparkle that I saw in the young student. Although he was dedicated to mathematics, this was balanced by his commitment to his family and to music.

Hyman Bass

Dan Quillen and I worked in the same physical space on only two occasions, both of them in settings that were pleasantly garden-like, but filled with intellectual ferment. One was the 1968–1969 year we both spent at the Institut des Hautes Études Scientifiques, attending Grothendieck's seminars, as well as Serre's course at the Collège de France. The other was a two-week conference on algebraic K-theory at the Battelle Memorial Institute in Seattle, in the summer of 1972.

During the year in Paris, Quillen presented his typical personal characteristics: a gentle good nature, modesty, a casual and boyish appearance unaltered by his prematurely graying hair, and his already ample family life. In that brilliant, and often flamboyant, mathematical milieu, Quillen seemed to listen more than he spoke, and he spoke only when he had something substantial to say. His later work showed him to be a deep listener.

At the Battelle Conference, in contrast, Quillen was center stage. This conference was a watershed event in the history of algebraic K-theory, owing primarily to Quillen's performance. In what follows I recall the context and atmosphere of that event and the paradigm-changing results and ways of thinking that Quillen brought to it, work for which he was awarded a Fields Medal in 1978.

The seed of K-theory was Grothendieck's introduction of his group $K(X)$ to formulate his generalized Riemann-Roch theorem for algebraic

[3] *This theorem was proved independently and roughly simultaneously by Tsygan.*

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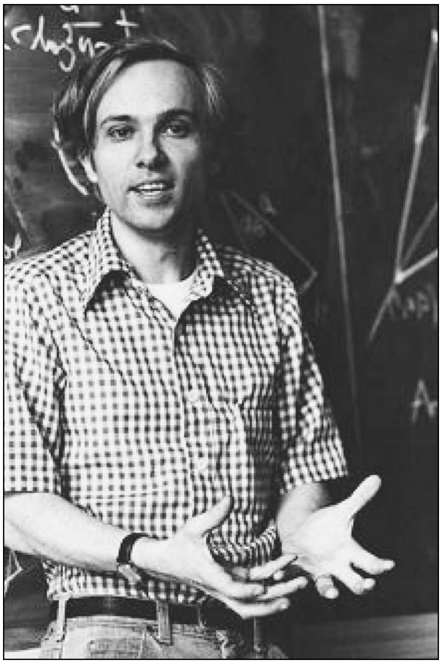
Photo courtesy of Cypora Cohen.

Quillen lecturing.

varieties X [4]. This inspired Atiyah and Hirzebruch to create topological K-theory, taking X to be a topological space and making $K(X)$ the degree zero term, $K^0(X)$, of a generalized cohomology theory with groups $K^n(X)$ $(n \geq 0)$ [1].

When X is an affine scheme, $X = \mathrm{Spec}(A)$, the algebraic vector bundles from which Grothendieck formed $K(X)$ correspond to finitely generated projective A-modules (Serre [11]), and the same applies to topological $K(X)$ when X is compact Hausdorff and $A = C(X)$ is the ring of continuous functions (Swan [12]). This suggested introducing the Grothendieck group[4] $K_0(A)$ of finitely generated projective A-modules, a definition sensible for *any* ring A (not necessarily commutative). This extra algebraic (and nongeometric) generality was not frivolous, since topologists had identified obstructions to problems in homotopy theory that reside in groups K_0 of the integral group ring, $\mathbb{Z}\pi$ of some fundamental group π (see Wall [13]).

It was natural then to seek some algebraic analogue of topological K-theory, composed of groups $K_n(A)$ $(n \geq 0)$. There was no obvious way to do this, but somewhat ad hoc methods succeeded in making the first two steps. First came the definition (Bass and Schanuel [3]) of $K_1(A) = GL(A)/E(A)$, where $GL(A)$ is the infinite general linear group and $E(A)$ is its commutator subgroup, known to be generated by the elementary matrices in $GL(A)$ (Whitehead [14]). Considerations recommending this definition of K_1 included natural functorial relations with K_0, and connections again with topology, where Whitehead torsion invariants in simple homotopy theory reside in groups of the form $Wh(\pi) = K_1(Z\pi)/(\pm\pi)$ [14].

When A is the ring of integers in a number field, K_0 is related to the ideal class group, K_1 to the group of units, and relative K_1 groups hold the answer to the classical congruence subgroup problem for $SL_n(A)$ $(n \geq 3)$ (see [2]).

[4] *The switch to subscript is because of the contravariance between X and A.*

The second step was the definition (Milnor [6]) of $K_2(A) = H_2(E(A), \mathbb{Z})$, the kernel of the universal central extension $St(A) \twoheadrightarrow E(A)$, where the "Steinberg group" $St(A)$ is presented by elementary generators and relations. Again, this had good functorial properties, and calculations for number fields showed deep relations with explicit reciprocity laws. Also, Hatcher ([5]) found topological connections of K_2 to problems in pseudoisotopy.

So while these algebraic K_0, K_1, and K_2 were only the first steps of a still unknown general theory, they already exhibited sufficiently interesting connections with algebraic topology, algebraic geometry, and number theory, as well as unmentioned connections with operator algebras, so that the quest for a full-blown algebraic K-theory seemed like a promising investment. In fact several people (Gersten, Karoubi-Villamayor, Swan, Volodin) produced candidates for higher algebraic K-functors. However their nature and the relations among them were not completely understood, and there were no extensive calculations of them for any ring A.

So this was the state of algebraic K-theory around 1970: a theory still in a fragmentary state of hypothetical development but already yielding several interesting applications that drew potential clients from diverse parts of mathematics. This led me to assemble this motley group of developers and consumers to seek some possible convergence. A two-week conference was convened on the pleasant campus of the Battelle Memorial Institute in Seattle. The seventy participants included Spencer Bloch, Armand Borel, Steve Gersten, Alex Heller, Max Karoubi, Steve Lichtenbaum, Jean-Louis Loday, Pavaman Murthy, Dan Quillen, Andrew Ranicki, Graeme Segal, Jim Stasheff, Dick Swan, John Tate, Friedhelm Waldhausen, and Terry Wall. As I wrote in the Introduction to the conference proceedings [BC],

> "…a large number of mathematicians with quite different motivations and technical backgrounds had become interested in aspects of algebraic K-theory. It was not altogether apparent whether the assembling of these efforts under one rubric was little more than an accident of nomenclature. In any case it seemed desirable to gather these mathematicians, some of whom had no other occasion for serious technical contact, in a congenial and relaxed setting and to leave much of what would ensue to mathematical and human chemistry."

The experiment was, I think, a dramatic success, beyond all expectations. It would not be unreasonable to call it the "Woodstock" of algebraic K-theory, and the superstar performer was undeniably Daniel Quillen. He came with two successful constructions of higher algebraic K-theory, the "+-construction", achieved prior to the Battelle Conference, and the "Q-construction", unveiled at the conference itself.

The +-construction defined

$$K_n^+(A) = \pi_n(BGL(A)^+) \qquad n \geq 1,$$

where $BGL(A)^+$ is a modification of the classifying space $BGL(A)$, sharing the same homology and having fundamental group

$$K_1(A) = GL(A)/E(A).$$

Quillen checked further that

$$\pi_2(BGL(A)^+) = K_2(A),$$

thus providing one main motivation for this definition. The other motivation was that, in the case of finite fields, Quillen had shown that the homotopy of $BGL(Fq)^+$ coincides with that of the homotopy fiber of

$$\Psi^q - Id : BU \to BU,$$

which arose in Quillen's proof of the Adams conjecture [7]. The latter thus provided a complete calculation of the K-theory of finite fields.

While the +-construction provided a major advance, it suffered from two related limitations. First, it did not directly account for $K_0(A)$. Second, and more importantly, it did not bring with it the basic computational tools that had proved effective with the lower K_n's ($n = 0, 1, 2$). To overcome this, one needed a definition of $K_n^Q(C)$ ($n \geq 0$) for additive categories C with exact sequences, in the spirit of Grothendieck's original definition. (For a ring A, to get $K_n^Q(A)$, one would take C to be the category of finitely generated projective A-modules.) This was accomplished by the "Q-construction", which defined $K_n^Q(C) = \pi_{n+1}(BQC)$, where BQC is the classifying space (defined for any category) of a new category QC (the Q-construction) invented by Quillen. This definition was validated by a spectacular cascade of theorems and foundational methods:

- *Consistency*: $K_n^Q(A) = K_n(A)$ for $n = 0, 1, 2$, and $K_n^Q(A) = K_n^+(A)$ for $n \geq 1$. Hence one defines $K_n(A)$ to be $K_n^Q(A)$ for all $n \geq 0$.
- *Resolution*: If $C' \subseteq C$ and every object has a finite C'-resolution, then $K_n(C') \to K_n(C)$ is an isomorphism.
- *Dévissage*: If $C' \subseteq C$ and every object has a finite filtration with subquotients in C', then $K_n(C') \to K_n(C)$ is an isomorphism.
- *Localization*: If C is an abelian category and C' is a Serre subcategory, then there is a localization exact sequence relating $K_n(C)$, $K_n(C')$, and $K_n(C/C')$.
- *Homotopy invariance*: If A is noetherian, then $K_n'(A[t]) = K_n'(A)$, where $K_n'(A)$ is the K-theory of the category of finitely generated A-modules (which agrees with $K_n(A)$ for A regular, by the Resolution Theorem).
- *Fundamental Theorem*: There is a natural exact sequence, $0 \to K_n(A) \to K_n(A[t]) \oplus K_n(A[t^{-1}]) \to K_n(A[t;t^{-1}]) \to K_{n-1}(A) \to 0$.
- *Algebraic geometry*: A host of theorems applying to the K-theory of schemes, including calculations, and relations to the Chow ring.

All of this, and more, was accomplished essentially from scratch, in sixty-three double-spaced pages [8]. It is a stunning composition of concepts, techniques, and applications that one would normally expect from the work of many mathematicians over a decade or more. It brought algebraic K-theory from gestation to young adulthood in one awesome leap, and there was more. In one lecture Quillen provided a complete proof, with elegant new methods, of the finite generation of the K-groups of rings of algebraic integers [9]. Later Quillen, in a display of technical virtuosity, proved Serre's so-called "Conjecture" that projective modules over polynomial algebras are free [10].

Individual mathematicians are often characterized as either theory builders or problem solvers. Quillen was a virtuoso in both modes. Like Grothendieck, he was disposed to solve concrete problems not head on, but by finding and mobilizing just the right general concepts, to make arguments flow with almost a mathematical inevitability. But if Grothendieck's style was perhaps Wagnerian, Quillen's was closer to Mozart. He was personally modest, but amiable, and he was a magnificent expositor, kind and edifying to his audience, leaving nothing superfluous, nothing one would want to change, but much from which one continues to learn. It was a personal pleasure and privilege to witness him in action.

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Ken Brown

I had the privilege of being Dan's first official Ph.D. student, although Eric Friedlander preceded me as Dan's unofficial student. In the late summer of 1970, Eric and I were talking in the MIT lounge when Dan walked in, having recently returned from two years abroad. Eric called him over and said, "Hey, Dan, I've got a student for you." Dan asked me what I was interested in, and I nervously told him some things I had been thinking about and what I hoped to prove. He let me down as gently as he could, saying, "That's a good idea; unfortunately it's been done already. But I've got a problem that you might like."

He then gave me a spontaneous one-hour lecture on the higher algebraic K-theory that he had been developing. By that point he had defined the K-groups via the "plus construction", and he had computed them for finite fields. But he hadn't been able to prove the basic theorems about them that he was sure should be true (various isomorphisms, long exact sequences, etc.). His idea was that there should be an alternative definition of the K-groups as a very fancy kind of sheaf cohomology, and the theorems would follow easily. My task, if I chose to accept it, was to develop that sheaf cohomology theory.

I worked on this for a couple of months and then went to Dan's office to tell him I had an idea. I started by telling him I had been reading his Springer Lecture Notes *Homotopical Algebra*. He smiled and said, "Why are you reading *that*? I should never have written it. I was trying to be like Grothendieck, and I couldn't pull it off." [I think history has proven him wrong.] But he listened carefully as I told him how I thought homotopical algebra might lead to a solution to the problem he had proposed. He was very encouraging in spite of his initial skepticism, and he gave me a wealth of ideas as to how I could continue my work.

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Three Oxford Fields Medalists: Michael Atiyah, Simon Donaldson, and Quillen.

Those first two meetings with Dan were typical. He was always generous with his time, and he always freely shared his ideas, even if not fully developed, about his work in progress. He also very openly talked about his perceived weaknesses. In my talks with him I got many spontaneous lectures on a variety of subjects that he thought I should know about.

I only saw Dan a handful of times after getting my degree in 1971 and leaving MIT. But, whenever I did get back, he would invite me to spend a day at his house, where he would tell me about his current work and show me his private handwritten notes. He would also feed me lunch and openly wonder how I could possibly eat a sandwich without a glass of milk. His devotion to his family was always evident during these lunches.

Dan Quillen was everything I could possibly have hoped for in a thesis advisor and mentor. It is impossible to express in a few words how much he did for me. Although we lost touch with one another in later years, I will always look back with fondness on the time I spent with him early in my career.

Joachim Cuntz

I first met Dan at a conference (I believe it was in 1988). At that time, following his first paper with Jean-Louis Loday, he had already written several papers exploring different approaches to cyclic homology and different descriptions of cyclic cocycles. On the other hand, in a paper with Alain Connes, I had at that time studied

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a description of cyclic cocycles on the basis of (even or odd) traces on certain universal algebras constructed from a given algebra A. It became clear that we were working on similar questions. I also immediately found Dan congenial and I like to think that this feeling was reciprocal. Dan was a very nice person and definitely not spoiled by his fame. In the beginning of 1989 I wrote a letter to him describing some considerations about connections between our work and possible ways to proceed from there. He wrote back saying that he had made progress in the same direction and suggested pooling our efforts. I felt of course honored by that proposal. Nevertheless, some time passed before we really started making progress and exchanging more letters (email of course already existed and we used it too, but still we adopted to some extent the old-fashioned method—also partly because at that time, unlike Dan, I was not fluent with TeX). Then we also exchanged visits. Dan came to Heidelberg several times and I went to Oxford several times (on which occasions Dan, together with his wife Jean, proved to be an excellent host). At that time, Dan was also strongly interested in C^*-algebras. From time to time he would ask me a technical question about C^*-algebras.

On one occasion when Dan visited Heidelberg, we went on a bicycle tour through the Neckar Valley. Originally we had planned to go for a distance of forty-five kilometers along the river and to take a train back. But when we arrived at the train station in Zwingenberg, it was still relatively early, and when I asked Dan, he agreed that we could still continue by bike a little bit. The same procedure repeated itself at the following station and so on, so that, in the end, we had gone back by bike the entire way to Heidelberg. At that point, we had done nearly 100 kilometers by bike. For an inexperienced cyclist this was quite a feat. But I remember that Dan was really tired and could hardly move the next day. Another time, he impressed me by playing (very well!) on my piano pieces in the style of Haydn and Mozart or other composers, which he had created himself and which really conveyed the spirit of those composers. It seems to me that this was another example for his wonderful sense of structures (this time within music).

In the beginning of our collaboration, I contributed mainly computations and some more pedestrian considerations. I was surprised how, in his hands, these developed into a big and powerful machinery. For instance, I had in my computations come across and used a natural projection operator on the cyclic bicomplex. Not much later, Dan sent me several chapters containing a striking and fundamental interpretation of this operator as the projection onto the generalized eigenspace of the Karoubi operator for the eigenvalue 1. Dan had an amazing gift in recognizing structures in formulas and computations. Thus he also embedded our computations into the powerful formalism of using quasifree extensions of a given algebra. I remember that he was quite modest about this achievement. He told me, "This result is only due to my training which made this way of thinking about the situation unavoidable for me." Finally, after nearly five years, in the paper "Cyclic homology and nonsingularity" (*J. Amer. Math. Soc.*, 1995) we had reached the culmination of the first phase of our collaboration. This paper contains a new description of cyclic homology, of cohomology, and of the bivariant theory (which has since become a basis for cyclic theories for algebras with additional structures, such as the entire and local theories or the equivariant theory) and gives a satisfactory unifying treatment for all the ideas which had started our collaboration. Also, we had two other long papers that developed the general framework underlying the construction. I think that, at that point, we both considered this as being the successful end of our collaboration (and in fact I think we were both, but especially Dan, a little bit relieved, because the project had developed into something much bigger and more time consuming than we had originally planned). However, not very much later, we realized that the universal extension algebra JA, associated with an algebra A, which plays a basic role in our approach, has another important feature. While not being H-unital in the sense of Wodzicki, it has a property (we called it approximately H-unital) which makes it amenable to an argument in the spirit of Wodzicki to show that it satisfies excision in periodic cyclic cohomology. The excision problem in periodic cyclic theory had been on my mind for many years. Shortly after, we realized that this property is in fact shared by any ideal in a quasifree algebra. This observation then led directly to a proof of excision in periodic cyclic cohomology in the general case. When these ideas came up, Dan immediately came to Heidelberg to discuss the details. Our collaboration was thus revived and continued until we had worked out the complete proof for excision in periodic cyclic theory (homology, cohomology, and bivariant); cf. "Excision in bivariant periodic cyclic cohomology", *Invent. Math.* **127** (1997). Altogether we have four joint papers and two joint announcements. I feel strongly in Dan Quillen's debt.

Photo by Olli Lehto, used with permission.

Quillen at the Fields Medal award ceremony, Helsinki, 1978, with Pierre Deligne, Charles Fefferman, and Rolf Nevanlinna, who awarded the medals to the three.

Jeanne Duflot

Entering MIT as a new graduate student, and indeed entering the high-powered world of East Coast academics, was daunting to me, a diffident Texan to whom someone with a heavy Boston accent not only seemed to be speaking a foreign language but who also seemed to think I was. In a happy change of fortune, one of my professors in my first year at MIT was Daniel Quillen. That year, he was teaching the first-year graduate course in algebra, and at that particular moment in time, with that particular professor, this meant the first semester was an illuminating series of lectures on homological algebra and sheaf theory; the second semester was a complete course on commutative algebra. I was also taking a course on algebraic topology, and the resulting juxtaposition of inspirations, as well as my starry-eyed appreciation of the unparalleled lucidity of Professor Quillen's lectures, emboldened me to ask him to be my dissertation advisor, to which he kindly consented, after I had explained my naive hope of doing research in algebraic topology and commutative algebra simultaneously. I was, of course, completely unaware that he had done groundbreaking work uniting these fields; cf. the series "The spectrum of an equivariant cohomology ring, I, II", *Ann. of Math.* **94** (1971), no. 3.

Having him as an advisor was wonderful, mostly because of the remarkable clarity of his explanations and reasonings when he talked to me about mathematics. By clarity, I don't mean that I understood everything he told me immediately, far from it, but I intend rather a quality of clearing obscurities and lighting up new ways of thinking. After leaving MIT with my Ph.D., I continued to work in the application of concepts from commutative algebra applied to equivariant cohomology for a few years, then moved on to other diversions. However, I've recently come back to thinking about that topic, even passing on my comparatively meager expertise therein while directing the recent Ph.D. of one of my students. Quillen's mathematical lessons and remarks of thirty years ago at MIT, as well as the remembrance of the quality of his mentorship as an advisor, were then with me.

He was devoted to his family; one child was born during my time at MIT, and I remember him apologizing for grogginess more than once, due to late nights up with the baby—an affliction that at the time I could not even imagine, but now I laugh at the recollection, having had first-hand experience. He was a teetotaler, and he won the Fields Medal while I was his student; I was awestruck and could barely speak to him at our first meeting after I found out about this and was floored when he offered me a bottle of champagne that had been given to him by a congratulatory colleague, explaining that he did not drink alcoholic beverages. I gratefully accepted it and drank it with some fellow students. I think it was quite good champagne, but I was not an expert. He did seem to favor wearing a particular plaid shirt a lot, and indeed, when I read over Graeme Segal's obituary for Professor Quillen in *The Guardian*, I noticed with both sadness and a smile that in the accompanying picture he was wearing exactly that plaid shirt and looked exactly the way I remember him.

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Jean-Louis Loday

I was fortunate to begin my mathematical career in the early seventies when Quillen opened up the book of algebraic K-theory. As a result, I could participate in the development of higher K-theory and meet Quillen on several occasions. Then, later on, I had the opportunity to lecture at Oxford (UK) with Quillen present in the audience. A few weeks later I received a friendly letter from him telling me how to finish the work that I had begun. It started a fruitful collaboration on cyclic homology, and thus Quillen played a major role in my mathematical life. But there is more. When I wrote my master's thesis in Paris under the supervision of Jean-Louis Verdier, I had to deal with the van Kampen theorem. It turns out that the question was strongly related to the first published paper of Quillen [1]. This concise three-page paper is a jewel. It has the characteristics of a French theater piece by Corneille or Racine: one notion, one result, one argument. Here, the notion

The late Jean-Louis Loday was professor of mathematics at the Institut de Recherche Mathématique Avancée.

is *simplicial group*; the result is *any bisimplicial group gives rise to a homotopy spectral sequence abutting to the same object*; the argument is *look at the diagonal simplicial group*.

Since I mentioned the first paper of Quillen, I will also comment on one of his last ones [2], published thirty years later. Since our collaboration on cyclic homology, Quillen had the idea that nonunital associative algebras should have specific homology and homotopy invariants. The classical way to handle nonunital algebras was to add a unit formally, a trick that he found too naive to be useful. We did get some results for Hochschild and cyclic homology, but his aim was to produce K-theoretic invariants. To understand the task at hand, it suffices to recall that K_1 is a generalization of the determinant and that the determinant of an invertible matrix lives in the group of units of the ring. But without a unital element (i.e., 1) there are no units. In fact Quillen did not begin with K_1, but with K_0, and this is precisely the subject of this last paper [2]. The subject is now an orphan.

During the period between these two papers Quillen produced an immense body of work, about which you may read in other contributions, as well as in the small tribute that you can find on my homepage: `http://www-irma.u-strasbg.fr/~loday/DanQuillen-par-JLL.pdf`

Quillen influenced my mathematical life deeply. It has been a tremendous opportunity to read his papers, to hear him speak, and to collaborate with him.

Thanks, Dan!

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Barry Mazur

I feel grateful to Dan for this gift of his: in each of the areas of mathematics in which he worked, his vision always had the marvelous consequence of "opening" the subject if it were brand new and of "opening up" the subject if it had a previous tradition; the mathematics became all the fresher, all the larger, all the more vibrant, and yet all the more unified, once he got to it. This is true, for example, of algebraic K-theory, of course, of his work on the "Quillen determinant", and of his striking "harnessing" of the power of complex cobordism theory by making that celebrated connection to formal groups. I'm, of course, not alone in feeling this gratitude.

Andrew Ranicki

The name of Quillen featured already in the very first topology seminar I attended as a graduate student in Cambridge in 1970. It was given by Frank Adams, who talked about the then-recent work of Quillen and Dennis Sullivan on the solution of the Adams conjecture. Frank spoke about both Dan and Dennis with an unusual amount of respect!

I actually met both Quillen and Sullivan at the same time, when I spent a year at IHES, 1973–1974. Sullivan's interest in surgery theory was naturally greater than Quillen's. Both Dan and his wife, Jean, were kind to me, and I was a frequent visitor at Pavillon 8 of the Residence de l'Ormaille. Although I did not talk to Dan all that much about mathematics, there were plenty of other topics, and I was always impressed by his seriousness of purpose and independence of mind, allied with a winning personal modesty. Soon after Dan moved to Oxford in 1984 I invited him and his family to visit us in Edinburgh. I asked him if MIT had proposed to match his Oxford offer. He answered that to do this they would have had to cut his MIT salary by two-thirds!

On my occasional visits to Oxford I would always call on the Quillens, who were as kind to me as they had been at IHES. There was in fact one occasion when Dan and I did talk about mathematics, Over dinner I mentioned that I had worked out a formula for the projective class of a finitely dominated chain complex. He asked me to come to his office the next day and explain it to him in detail—it turned out that he needed just such a formula for his work on K_0 of nonunital rings. I was most flattered! But I should have spent much more time talking to Dan about his mathematics. Too late now.

Dennis Sullivan

My interactions with Dan Quillen were concentrated in the late sixties and early seventies in Princeton, Cambridge, and Paris.

In our mathematical encounters the more naive geometric tradition of Princeton topology and the more sophisticated algebraic tradition of Cambridge topology and geometry informed one another. Here are three examples.

(i) Together we pondered the conflict between Steenrod's cellular approximations to the main

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diagonals in products of a cell complex with itself leading to cohomology operations beyond cup product and the Cartan-de Rham differential algebra of smooth forms which is graded commutative and associative.

(ii) Quillen explained to me one day at MIT how the structure of a nilpotent group is built from the abelianization as extensions of quotients of functors applied to it. Quillen's insight was of great utility to me in understanding the algebraic groups that arise in rational homotopy theory. The clarity of his insight was remarkable.

(iii) One day in Princeton I showed Dan an elementary pictorial argument that attaches two and three cells to a space with zero first homology to go on to kill the fundamental group without changing the homology. The discussion arose when he showed me his beautiful computations of the cohomology of $GL\,[n$, finite field]. Quillen made use of this device in the early stages of his constructions of algebraic K-theory.

Our later interactions near Paris at IHES were more about kids and family in the Residence d'Ormaille.

One memory that seems to fit with everything was of a large smooth wooden table situated without chairs in the middle of the main room of Pavillon 8 in the Residence d'Ormaille. On the table hundreds of little shapes were deployed into a dozen or so neat little battalions surrounding a coherent structure emerging in the middle. Dan and a couple of kids and anyone else who might be around were hovering around the table, peering intently at these patterns, muttering softly and hoping to experience the exquisite pleasure of fitting in new parts to the emerging structure. It was serious business with good karma.

Ulrike Tillmann

In 1988, as a visiting graduate student at Oxford, I attended a course on cyclic cohomology. It seemed lectures had never been as clear before: new mathematics was created in front of our eyes, and even to a novice like me it all seemed logical and natural. The lecturer, white haired, in jeans and hand-knitted jumpers frayed at the edges, was Dan Quillen, Waynflete Professor of Pure Mathematics.

One of the first research papers that I had read was the one for which Dan had received the Fields Medal in 1978 as the chief architect of algebraic K-theory. I had also studied his papers on group cohomology though I was still unaware of his landmark contributions in homotopy theory. Most of

Quillen lecturing at the University of Florida, April 2000.

this work had been done at MIT. But having visited Michael Atiyah and Graeme Segal in Oxford for a year, in 1985 Dan accepted the Waynflete chair that had been vacated a year before by Graham Higman. At first Dan worked on questions motivated by quantum physics, superconnections in particular. Later on he concentrated on the development of cyclic cohomology, and the lectures that I attended were followed by many more on the topic.

I was told that Dan's work in the subject started when Jean-Louis Loday gave a seminar in Oxford in the early 1980s. Dan was intrigued by the questions it left unanswered, and as a result he and Loday wrote a paper interpreting cyclic cohomology as an infinitesimal version of K-theory. While working on my thesis problem to prove a version of the Novikov conjecture, this was one of a handful of papers that I kept referring back to for information and inspiration.

In the late 1980s and 1990s, together with Joachim Cuntz from the University of Münster, Dan, in a series of nearly a dozen papers, laid out a purely algebraic, noncommutative theory of differential forms and established their homological properties. These papers were first written as lectures, many of which I attended, then back in Oxford as a young member of the faculty. My own work had moved on to different topics, but it was always fascinating and educational to watch a master.

For many years until his retirement in 2006, Dan had been an editor of the Oxford-based journal *Topology*, a leading journal in the field since its foundation by Michael Atiyah and Ioan James in 1962 and until the resignation of its editors and the founding of the new *Journal of Topology* in 2007. Dan also had been part of the LMS-supported regional K-Theory Days for nearly ten years. These had been initiated by his only Oxford DPhil student, Jacek Brodzki. In 2001, there

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was a short conference in honor of Dan's sixtieth birthday, and in 2006, a special *K*-Theory Day marked his sixty-fifth birthday and retirement. Two years later, he and his wife Jean moved to Florida.

Jean was of course the one who had knitted Dan's jumpers. They had met as undergraduates majoring in mathematics at Harvard and have six children with many more grandchildren. The move across the Atlantic from MIT to Oxford was no doubt eased by the fact that as a professional violist and violin teacher Jean found Oxford very amenable and full of opportunities.

Jean Quillen

Dan was born on June 22, 1940, in Orange, New Jersey. From an early age his intellectual abilities and particular approach to the world were apparent. His mother used to enjoy telling how Dan didn't talk as a baby until he surprised everyone by being able to speak full sentences. He spent his high school years at Newark Academy, a private school in New Jersey where he had a full scholarship. His mother was a driving force in his young life, pushing others to recognize his abilities. She discovered that Harvard had a program where promising incoming students were able to start their studies a year early by skipping their last year of high school. She had him apply and I suspect rewrote all his essays (Dan struggled throughout his life with words and writing). At any rate Harvard accepted him to begin in September 1957 when he was only seventeen, whereupon Newark Academy had a problem: whether to give him his diploma or let him go to Harvard without the high school diploma. They awarded him his diploma.

I met Dan the following year when I was a first-year student at Harvard/Radcliffe. For some reason Dan decided to take the first-year chemistry course in his second year. I apparently smiled at him. We were married three years later on June 3, 1961.

We have six children, twenty grandchildren at last count, and one great-grandchild.

I remember Dan as an incredibly motivated and bright young man. Mathematics was his first love from the age of twelve or thirteen when his father gave him a calculus book. He briefly toyed with chess but found it too intense (!) and thereafter a career in mathematics was the only option for him.

Dan and I had many study dates during our undergraduate years; he seemed to absorb his undergraduate mathematics courses like a sponge. He learned and understood all of every course he took. In fact I noticed that he could reproduce by memory nearly every theorem and proof. He also had the talent of being able to identify what was important in a subject. Once when I got behind in a course, he managed to teach me all the important points in only three days. Not only did I get an A on the exam, but I also noticed a misprint in the examination paper!

Although I have little experience of Dan's classroom teaching, I remember what a wonderful teacher he was one-to-one. He never made me feel stupid; he just accepted what I knew and built upon it. This kindness in teaching also extended into other areas of my life. Dan taught me to cook by happily eating the mistakes and by being delighted by dishes that came out well. Once I managed to turn a cake over into the oven. He fended off my tears by cheerfully scooping it up, putting it on a plate, and announcing to the children that we were having an "upside-down-in-the-oven cake".

Dan had three degrees from Harvard: BA (magna cum laude), 1961; MA, 1962; Ph.D., 1964. Dan was awarded his BA with only (!) a magna cum laude because he nearly failed one of his required distribution courses. I remember typing his Ph.D. thesis: Dan in one room producing pages, me in the next room with a hired electric typewriter. What we did with the two babies I cannot imagine! Naturally the thesis was produced about three minutes after it was due. Shortly thereafter he was offered a position at the Massachusetts Institute of Technology.

Dan also spent a number of years at other institutions, mainly because he was interested in working with different mathematicians. He twice took a year sabbatical in France at the IHES in Bures-sur-Yvette. We spent a year at the Institute for Advanced Study in Princeton, a year at the Max Plank Institute in Bonn in Germany, and a year at Oxford University, England. I enjoyed the times abroad. It was a challenge and I learned to speak French, a little German, and British English.

Dan spoke of the year at Princeton as a particularly productive time for him mathematically. It was during our time there that Dan worked on and solved the Adams conjecture. It was also in Princeton where he first came under the influence of Sir Michael Atiyah.

After the year in Princeton we returned to MIT where Dan had been made a full professor. With Dan's support I was able to study music part-time at the New England Conservatory of Music. He arranged his teaching schedule to make it possible. I am so grateful that he gave me that support. That year Dan also started to do most of his research at home, partly to help with the children and partly, I suspect, because nobody could interrupt him at home. We used to close five

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Photo courtesy of Cypora Cohen.

Quillen with daughter, Cypora.

doors between him and my music practice, and woe to any child who left a door open.

It was Dan's relationship with Atiyah that first brought us to Oxford. During the year in Bonn Dan said to me, "I'm in the wrong country." I said, "What country should you be in?" He said he wanted to be in Oxford, partly because he was interested in something that Michael Atiyah was working on. After a year in Oxford we returned to Boston. About six months later Dan was in Oxford giving a talk when Atiyah mentioned that the Waynflete Chair at Magdalen College was opening up and asked if he would consider moving to Oxford permanently. He phoned me. I said, "Yes, please," and that's how we came to Oxford to stay.

Dan worked with and was influenced by many people throughout the years: Grothendieck and Deligne in France in the 1970s and later Loday and Connes. In the early years there were the mathematicians at Harvard and in later years colleagues at MIT and in Germany and England. He often talked to me about those whose work he admired. There was never any jealousy, just admiration for work well done.

Alzheimer's is a cruel disease. The first sign of the disease was Dan's inability to understand mathematics. He was aware of this, and you can imagine his agony. He was such a private person that he never spoke about this. Because of his suffering, in some ways we were prepared to lose him. Although Dan's first love was mathematics, he was also a kind and devoted husband. I will miss him very much and so, I think, will many others.

Adventures in Teaching: A Professor Goes to High School to Learn about Teaching Math

Darryl Yong

During the 2009–2010 academic year I did something unusual for a university mathematician on sabbatical: I taught high school mathematics in a large urban school district. This might not be so strange except that my school does not have a teacher preparation program and only graduates a few students per year who intend to be teachers. Why did I do this? I, like many of you, am deeply concerned about mathematics education and I wanted to see what a typical high school in my city is like. Because I regularly work with high school mathematics teachers, I wanted to experience the life of a high school teacher for myself. I had neither a research project nor an agenda for changing schools or teachers.

I kept a blog during my adventure, but it took some months after that experience before I could begin to process all that had happened. Four lessons emerged from my experience that I hope will give college and university educators a clearer view of what teaching high school mathematics is like.

Before we get to those four lessons, some background information might help. First, you should know that my story is not going to turn out like *Stand and Deliver*, *Dangerous Minds*, or any other inspirational Hollywood movie about a teacher who helped students achieve great things through painful sacrifice and struggle. The Hollywood idealization of a teacher as a martyr who sacrifices her personal life for the sake of her students propagates unrealistic and unhealthy expectations. Teaching is hard, but it shouldn't have to be that hard. This is also not the story of a professor coming down from his ivory tower and becoming outraged by the horrors of how children are taught in schools. I find these narratives unproductive. This article conveys one person's perceptions of the struggles that novice teachers face in one school and discusses what the general public rarely hears about public education.

I applied for teaching positions just like other teachers in my district, though I did not take all of the necessary steps to become credentialed. Visiting Faculty Permits, which were authorized between 2007 and 2013 through California Senate Bill 859 by Senator Jack Scott, gave me a convenient way to teach in the California public school system without a credential.

I was hired at a school that serves about 1,100 students. It is one of three high schools in a working-class neighborhood. Roughly 40 percent of the students at this high school are English language learners, 80 percent qualify for free or reduced meals, 85 percent identify as Hispanic or Latino. In 2009 only 3 percent of students at this school were deemed proficient on the Algebra 1 California Standards Test (CST). That year, I taught Algebra 1, Algebra 2, Geometry, and a math intervention class (an additional period of mathematics for students who are struggling in mathematics). Even though I taught four different classes, I did not teach a full load (six classes at this school). One of my Algebra 1 classes was an inclusion class—half of those students had learning disabilities or some other reason to warrant having an Individualized Education Program (IEP). In that class, all students, with IEPs or without, learned math together.

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In many respects I got what I wanted that year: an authentic experience of teaching in a high-need urban school. I didn't want to teach calculus or teach only "gifted" students. I didn't want to receive any concessions because of my qualifications. My experience was closer to that of a new high school teacher with no prior experience than that of a seasoned educator moving from one institution to another. I had to cut my teeth on many things like a rookie teacher. For example, I had to learn how to avoid taking things that students said or did to me personally. I learned that my students' behaviors in class were often a result of grave personal issues (violence, gangs, fear of deportation, etc.). I made many mistakes that year, but I was also spared many more mistakes because of trusted friends who are or were high school math teachers.

Lesson 1: Schools Are Complex Systems Involving People, Culture, and Policies

The news is full of stories about how our school systems are failing along with accompanying claimed explanations. There is a lot of blame that goes around, even at schools. I have heard some university mathematicians blame high school teachers for the poor preparation of their students. At this high school, I heard teachers blaming elementary school teachers for the poor preparation of their students.

During my short high school teaching experience, I learned that most explanations for why our schools are failing are simplistic and inadequate. For example, consider this frequently cited reason for our underperforming schools: bad teachers. We need to "hold teachers accountable" and "get rid of the bad teachers". I have yet to meet a teacher who willingly wants to be an ineffective instructor—every teacher I know has a desire to do a good job. Of course, I met math teachers at my school who didn't know their subject area as well as they should have. Nevertheless, the idea that we can simply replace "bad teachers" with enthusiastic new ones ignores the reality that years of hard work and experience are required to become an effective teacher. In addition, our schools and districts are not doing enough to help teachers grow in their content knowledge and teaching practice. (See Blog Entry 2 in Lesson 3 section.)

Some place blame on bad school administrators. In my opinion, our high school was poorly run, but our administrators didn't always have the resources to do their job well. Our administration mostly reacted to events and crises instead of implementing sensible practices. There was very little feedback given to us teachers about our teaching. In fact, over the entire year I had an administrator in my classroom observing me for a total of about ninety seconds. I received no meaningful feedback on my teaching. But it's difficult to blame him when you consider how understaffed the school was. Because the school lacked a counselor at the beginning of that school year, the assistant principal had to take on those responsibilities while supervising students during breaks, dealing with disciplinary issues, communicating with parents, and putting out fires.

Some people have asked me whether it was difficult to teach in a school with lots of poor families who didn't care about education. Not only is that stereotype inaccurate, it represents another line of reasoning that is simplistic. During that year I encountered some families who didn't seem to care about their kids' education and many that did. Sometimes when I called a student's home I would get a parent who was involved and would intervene, sometimes not. I encountered one young woman who returned to high school as a senior after having taken some time off to care for her baby. Unfortunately, right at the end of the school year, this woman's mother stopped offering to take care of her baby and she had to quit school. Does that mean her family didn't care about education? I don't think we can tell. I think the best we can say is that each student is a person whose attitudes and capacity for learning is greatly shaped by past and present circumstances.

Simplistic diagnoses are dangerous because they encourage quick fixes. Instead of long-term plans for systemic change, school reform becomes a series of short-lived fads that cause teachers to become jaded by unfulfilled promises of improvement. At my high school, la mode du jour was project-based learning (PBL). All teachers were trained in PBL (oh, how schools love acronyms) and required to design and implement one project for a class that year. The potential benefits of authentic problems that engage students in meaningful thinking and help them to develop useful life skills are great, but the program was not implemented wholeheartedly. When I talked to one of my colleagues at this school a year later, I found out that PBL was no longer being practiced schoolwide. How can we expect to see meaningful improvement when we change from one fad to another every few years? The unfortunate truth is that the work of improving schools is long, arduous, and not at all sexy.

Of all the things that I experienced during that year, the circumstances surrounding my first few weeks of school best illustrate the lesson that schools are complex systems whose components can interact in nonobvious ways to create nonideal learning environments for students. My school district laid off many teachers during the summer of 2009 because of shrinking budgets. Our district has a policy in which displaced (laid-off) teachers are first in line for openings at other schools in the district. This policy is sensible, but because of the size of our district and the large number of teachers that were displaced that summer, it took months before all of these displaced teachers were rehired and my employment papers could be processed. The first day of instruction at my school was September 10, 2009, but I didn't sign my contract with the district until the 17th. I went to school during those first few days of school even though no students were yet assigned to my classes. September 21 was the first day that I had students in my classes and I didn't get access to class rosters until October 1. Here is a blog entry from that chaotic period.

> Blog Entry 1: Sept. 21, 2009 (Monday)
>
> There were 29 students in my third period class today. Hooray! Unfortunately, 30 minutes earlier the assistant principal told me that it was supposed to be an Algebra 1 class and it turned out all the kids were there for Geometry. No problem! I tried not to let my surprise show.
>
> After we got settled, we had a semi-successful discussion on definitions for points, lines, and planes for about 10 minutes. Then I was just about to start an activity involving area and perimeter [when] a teacher came in and took about two thirds of my students to another room. Apparently my class really was supposed to be an Algebra 1 class and these students were going off to Geometry.
>
> After the exodus we regrouped, but just as we were about to restart, another teacher came in with new students who were supposed to be [in] the class. By the time we got settled again, there were about three minutes left of class.
>
> I think the thing that bothers me the most is that these students are being subjected to so much chaos. If my own child was in this situation, I would be a furious parent: not just about the fact that almost two weeks of instruction [had] been lost (so far), but that the behaviors and attitudes of students are adversely affected by starting off school in such a chaotic way. I think I will have to work hard to send a message to my students, when I get them, that we are starting fresh.
>
> I had no students in two other periods and 20 kids show up in my sixth period Algebra 1 class. I'm thrilled and scared all over again.

I had been looking forward to the scary experience of high school all summer, so it was frustrating to have the year start in this way. But it was much worse for my students. They were shuffled from class to class for weeks, never knowing whether they were going to be in a class permanently or not. Would you take your teacher seriously if you were in this situation? Consequently, it was difficult to establish credibility with my students, and little learning took place in these first few weeks.

Who was to blame for the missed opportunities to learn during these first few weeks of school? Students were incredibly rowdy during this time, as one might expect, but I was also too timid as a new teacher. I delayed teaching the mathematical content of my classes until I had steady enrollments, thereby wasting students' time, even those who weren't ultimately going to be in my class. Our administration's disorganized scheduling also contributed to the mess. I'm not sure one could say that parents were at fault in this situation, although if the school were in a more affluent neighborhood, you can be sure that there would have been many more savvy parents who would have demanded that their children be assigned to the right classes. The district too caused part of the problem because of the way in which my contract was processed. It is important to keep in mind that all of these observations are mine alone—from another observer's perspective the situation would appear very different. No wonder we seem to be at a loss for how to fix our ailing schools.

Lesson 2. Student Self-Concept Is the Best Explanatory Variable for Student Success

I have won teaching awards at the institutions where I've worked, but I intentionally held low expectations for my effectiveness as a high school teacher. Even so, I felt depressingly ineffective as a teacher most of that year. While it's not wise to generalize from a single case, my experience shows that having strong content knowledge in one's field is a necessary but insufficient condition for student learning to take place.

In the education research literature there are some econometric studies that attempt to measure how different variables (district spending per student, parents' education level, past academic performance, training of teacher, students' socioeconomic status, etc.) correlate with student achievement. So, which variables matter most?

According to John Hattie, the variable that correlates most strongly with student achievement is student self-concept. This is a very robust finding. His amazing book [2] synthesizes over 800 meta-analytic research papers on education (thereby covering over 15,000 journal articles!) to determine

the variables that most strongly correlate with student achievement.

Self-concept is a person's concept of "self" in a particular domain. The difference between self-esteem and self-concept is that the former is an overall view of oneself, whereas self-concept is domain specific. For example, I see myself as a successful learner of mathematics but a pretty poor painter and basketball player. The vast majority of people in our country have a low math self-concept—many almost see it as a badge of honor to be bad at math.

Incidentally, among all school-related variables (i.e., the variables that schools can directly control) teacher quality seems to have the greatest effect on student performance. However, researchers haven't yet conclusively figured out what makes a teacher more effective, only that they seem to have a very large effect on student learning. According to Eric Hanushek, the highest performing teachers can help students attain the equivalent of an entire year's worth of additional learning compared to the lowest performing teachers [1].

At the beginning of the school year, I gave this task to my students: "Draw a picture of what it looks like when you do mathematics." Their pictures were both enlightening and depressing. See Figure 1.

Self-concept is shaped by prior academic achievement and one's beliefs about who has access to mathematical skill and what it means to be "good" at mathematics. During this year I repeatedly observed that my attempts to make learning engaging (by using fun activities, putting mathematics in contexts that students could relate to, making connections to prior learning) were helpful, but not nearly as helpful as attending to students' self-concepts as learners of mathematics.

If a student's self-concept is based on past academic achievement and future performance correlates strongly with self-concept, how can we break this cycle? I learned that, regardless of how

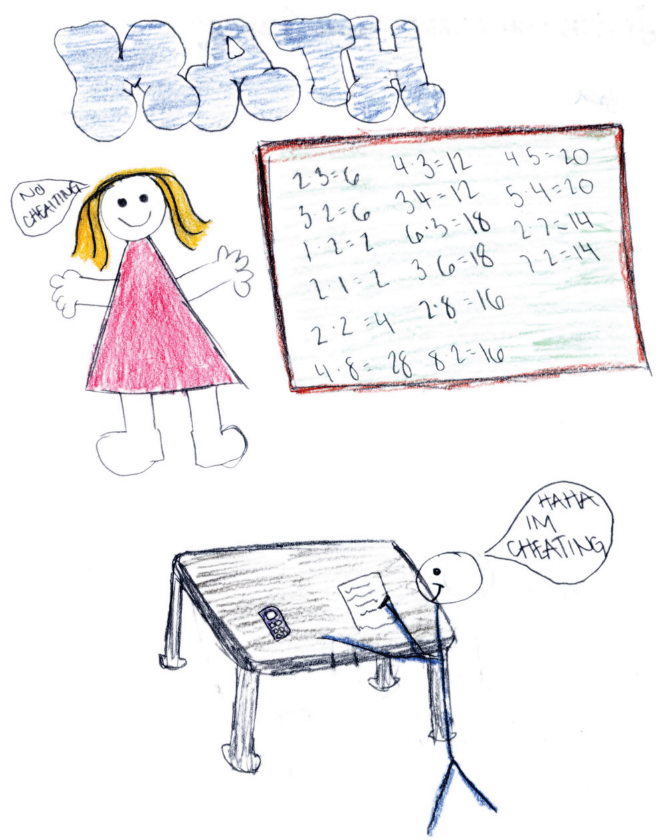

Figure 1.

"tough" some students are or how weak their math skills are, teenagers still love feeling successful when they become good at something or when they figure something out. A sequence of small successes can lead students to develop intrinsic motivation to learn and take risks in a classroom. One way to stage these sequences of successes is through minute, detailed, careful scaffolding of mathematics content.

I found that 95 percent of the cases when one of my students was disruptive or seemed

(a)	$x^2 + 8x + 12$	(g)	$x^2 - 49$
(b)	$x^2 - 4x - 12$	(h)	$a^2 + 2ab + b^2$
(c)	$x^2 + 16x + 39$	(i)	$12x^2 - 23x - 2$
(d)	$3x^2 + 9x$	(j)	$x^2 + 10x - 39$
(e)	$2x^2 + 25x + 12$	(k)	$x^2 + 4x + 4$
(f)	$x^2 + 10x + 24$	(l)	$6x^2 + 5x + 1$

Figure 2.

disinterested in learning were the result of the student not understanding what to do or how to do something. Often this happened because I gave poor instructions or because the mathematical tasks that students confronted grew in complexity too quickly or chaotically. Textbooks can frustrate students when they contain sequences of problems that are randomly ordered instead of being arranged by increasing cognitive demand or according to some pedagogical logic. Being able to sequence mathematical tasks well requires knowledge of the cognitive demand of each task, students' prior knowledge of a topic, what students typically find difficult about a topic, and the potential misconceptions that students can develop.

Here's an example to help illustrate this point. Imagine that you are going to prepare a lesson on factoring quadratic polynomials. This is the first time that students will have seen this topic, and you will present a sequence of worked examples on the board to help them understand it. How would you order these 12 quadratic polynomials in your presentation?

After a recent talk on this subject, I had a conversation with a university professor who was adamant that all of these factoring problems are equally difficult: "You just factor them!" For us mathematicians, the cognitive demand required to factor any of these polynomials is so low that all of them are equally challenging. But these problems aren't as easy for students learning how to factor for the first time; some of these examples are more challenging than others. For example, the monic quadratics in Figure 2 are easier to factor than the nonmonic ones. Also, though (c) has a constant term of 39, which is larger than the 24 in (f), many students find (c) easier to factor because 39 has fewer factors than 24. It also turns out that (k) often confuses students because the fact that $2\times2=2+2$ obscures which 4 corresponds to the addition or product of factors. I found that careful sequencing of problems and mathematical tasks matters a great deal.

Another vivid example of these ideas came about one day when my students were solving linear equations such as $3x-4=8$ and $2x-1=15$. Most students were happily solving equations successfully and independently, but one student was off-task most of the class. I walked by many times to offer encouragement and help on the assignment with no effect. Then finally he revealed why he wasn't working: "I don't want to do this, Mister; it's hard."

In a moment of clarity, I brought over another worksheet on graphing linear equations (see Figure 3), something that we had learned the previous week. "Would you like to work on this instead?" The student replied, "Oh yeah, I'll do that; it's easy." He whipped out that worksheet with no complaints. At that point during the year, students had not yet learned to graph lines using slopes or intercepts; they only knew how to make a table of numbers and plot points. Since the coefficients of x and y in the given line $3x-2y=6$ are not 1, the student had to solve for one variable given the other. He was essentially doing the same task as the rest of the class, but he was much more engaged because his self-concept for graphing was higher than for solving linear equations.

As I began to understand the importance of attending to students' self-concept, I noticed my students becoming more engaged in learning mathematics. I initially spent a great deal of time thinking of fun or creative lessons that would get students excited. These lessons rarely worked because they were often too complicated or inappropriate for my students' mathematical development. Instead, I began to design my lessons and accompanying student work so that (1) all of my students could successfully complete the first problem or task independently, and in which (2) the sequence of problems/tasks matched my students' tolerance for challenge and self-concept. This strategy not only increased student learning but also eliminated most of the discipline issues in my class and relieved the pressure of having to develop whiz-bang "fun" lessons every day.

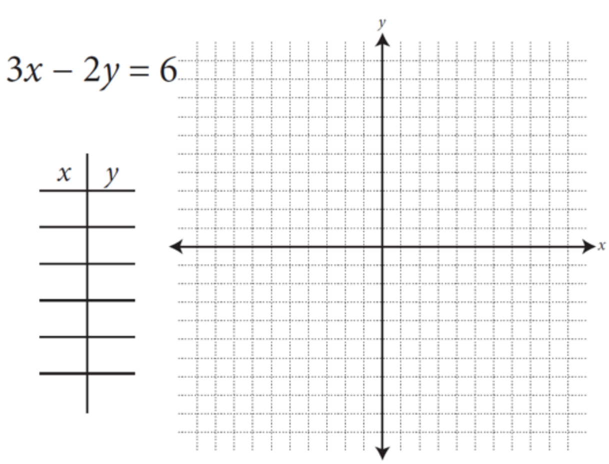

Figure 3.

Lesson 3. Teaching Is a Far Less Respected Profession Than It Should Be

Many parents of school-age children will tell you their kids' teachers are great but that "bad teachers" are part of the reason why the school system as a whole is failing. To me, this is one of many indicators of the level of respect that we afford teachers and teaching as a profession. In my opinion, discussions about teacher compensation just scratch the surface. I believe that the deeper issue is that our society, including some people in the school system, doesn't see teaching as a growth-oriented, intellectually demanding career deserving of our nation's best and brightest individuals.

Teachers receive messages every day about how much they are valued as professionals. The way students and parents talked to teachers at our school, the process of signing in and out of work every day, down to the inconvenience of not being given a key to the school office (where the copier was) were examples of such messages. But the most disturbing messages came from the weekly professional development meetings that all teachers had to attend. Here's an excerpt from a blog post describing one of these meetings.

> Blog Entry 2: Feb. 16, 2010 (Tuesday)
>
> (2:15 pm) The meeting begins with the assistant principal asking us to write for a few minutes in response to one of these three guiding questions:
>
> 1. "What works?" vs. "What is your personal philosophy of teaching?"
>
> 2. How can our school, committed to promoting the understanding of all learners, help teachers contribute significantly toward achieving that goal?
>
> 3. What role does teacher/peer observation play in identifying the under-representation of key strategies and processes and existing student achievement and performance gaps?
>
> Wow. Where to begin? First of all, #1 doesn't make any sense. Am I supposed to respond to one question or the other, or am I supposed to respond to the juxtaposition of the two questions? I don't know what the question is getting at and so I have no idea how to respond. Question #2 is such a huge question that I feel completely paralyzed by it. If I am really supposed to answer question #2, I would need more than a few minutes or need the scope of the question to be narrowed down significantly. So, I settle for question #3. I write for a few minutes and then the assistant principal asks us to share our responses.
>
> (2:20 pm) One teacher shares his response to #2. He makes the suggestion that having time in our meetings to share lessons with each other might be beneficial. Another teacher makes the point that it's even better when lessons are shared between teachers from different disciplines. The conversation then devolves into teachers venting about things and whether instituting a protocol for sharing lessons would be helpful or make the process seem too formal. In the end, only one person gets to share a response to the three guiding questions.
>
> (2:40 pm) Assistant principal moves us to the next task. We are to read a handout entitled "Investigating the Key Jobs of Teacher and Student," write comments on it, then share our responses within our small groups. Since the handout doesn't have anything to do with the previous three guiding questions or the previous conversation, this action sends (to me, anyway) the message that what we just did wasn't very important. I'm wondering what those three guiding questions were supposed to guide us to. I'm also very curious to see whether the suggestion about having time to share lessons with each other actually gets picked up in future meetings—there have been lots of other suggestions brought up in previous meetings that seemed to get lots of assent but no action.
>
> (2:50 pm) The four teachers in my group have been reading the handout silently up to this point. One teacher in our group brings up a question about what to do when all of our students perform poorly on a test. It's an important question, but one that is not really related to the assigned task. Nevertheless, our small group has a discussion on this topic. When the principal asks for the small groups to share their responses, we hear some very general comments about teaching. The handout seems to have had little impact on the discussion.

> (3:04 pm) The assistant principal introduces a representative from a local credit union who wants to help us teach students more financial literacy. The meeting ends with some announcements.

Only rarely did I leave one of these weekly professional development meetings feeling invigorated. These were usually meetings in which teachers shared information about the students that we had in common or when the mathematics department met together without an administrator present. Unfortunately, the vast majority of these professional development meetings made me feel as if I had been babysat for an hour. And many of my teacher friends tell me that my experience is not unique.

I recount this incident not to elicit outrage or sympathy, but instead to point out what these professional development meetings say about how teachers are viewed as professionals. Certainly each of us has sat through unproductive committee meetings or workshops. The difference here is that these professional development meetings were mandatory and were the primary mechanism to help us teachers improve our craft. When schools waste this time, teachers are disrespected. When administrators fail to engage teachers with intellectually demanding tasks and questions, the teaching profession as a whole is belittled.

The teaching of mathematics, like mathematics itself, is an endless journey of study. I believe that teaching mathematics can be as intellectually demanding as doing mathematics. If our society could come to see teaching as a job that is emotionally, physically, and intellectually demanding, we would then be able to give teachers the respect they deserve, attract more talented people to the profession, and speed up the pace of pedagogical innovation through the study of teaching.

Lesson 4. It's Not the Written Curriculum That Matters, It's the Assessed Curriculum

Many university mathematicians who take an interest in mathematics education tend to focus on mathematics curricula. For instance, university mathematicians feature prominently in debates about reform versus traditional textbooks that fuel the "math wars". Perhaps the reason for this interest is that textbooks give us an easy way to join conversations about mathematics education. Each of us learned mathematics as children, so feel we have something to contribute to the choice and design of math textbooks. Unfortunately, most of us university mathematicians are very different from the majority of students in our nation who have to study mathematics in high school.

I, too, am interested in mathematics curricula and was excited to teach a range of classes and to use both reform and traditional curricula. However, at the beginning of that year I greatly overestimated the impact of textbooks on student learning.

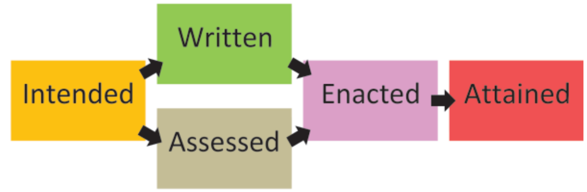

Figure 4. Various meanings of the word "curriculum".

The word "curriculum" has various meanings. The intended curriculum comprises state, district, and school standards that dictate what students are supposed to learn and when they are to learn it and, to some extent, how they are to learn it. The new Common Core State Standards are an example of this. Written curricula are the textbooks that schools and districts choose for teachers, but since teachers vary greatly in their adherence to and usage of textbooks, it is important that we pay attention to the curriculum that they enact. All of these lead to the attained curriculum, a construct for what students actually learn.

And then there's the assessed curriculum. I knew little about this concept before my adventure started, but by the end of the school year I became keenly aware of it. Because we live in an era of accountability and standardized testing, my state and district use various assessments to measure how much students have learned. In a perfect world, the intended curriculum would align with the written and assessed curricula, but in practice they often do not agree. When this happens, teachers find themselves in the awkward position of having to decide how to sacrifice one set of learning intentions for another.

My principal was enthusiastic about a reform Algebra 1 curriculum. I was impressed by many wonderful features of this curriculum and wanted to follow it faithfully, but it did not align with our district's periodic assessments. For example, there was a moment during that year when I had to decide whether to teach my students how to blindly follow a recipe to use the quadratic formula (since they weren't yet ready to understand the derivation of that formula) or continue along the path set by our textbook and let them get all of those questions on the periodic assessment wrong. I chose the former and to this day still feel horrible about that decision. Over time I found my teaching becoming increasing aligned with the assessed curriculum: I reorganized the sequence of topics in this reform curriculum and altered how certain topics were introduced or emphasized. This led to a rather weak implementation of the written curriculum and a less coherent Algebra 1 course.

I believe that assessment is crucial to knowing whether students are learning and whether the strategies that schools and districts employ are working. However, we need to remember that these assessments enforce standards for student learning more powerfully than written curricula. While that may not be a bad thing, thoughtful, well-aligned assessments tend to be expensive and labor intensive (both to develop and to grade). And the likelihood of creating and implementing these kinds of assessments is low given the severe financial condition of most states and districts.

Epilogue

As a final illustration of the kinds of frustration that teachers face, here is an excerpt of a letter I received from my school district a few weeks after the end of the school year.

> Dear YONG, DARRYL:
>
> Our records show that you have received an overpayment as a result of a change that was processed in June 2010. The total adjusted gross amount of your overpayment (reduced by any retirement contribution) is $12,197.66. This letter is intended to advise you of your options in repaying the identified overpayment.

The letter was not signed by anyone, there was no contact person listed, and there was no phone number to call! The letter seemed to make it impossible to contest the overpayment; it only listed options for repayment and threatened referral to a collections agency if the amount was not repaid. If I indeed had been overpaid by that amount, I would have earned only roughly $5,000 for the entire school year. I tried calling the district repeatedly but never reached a person who was able to help. It was at this time that I was thankful to be a member of the California Teachers Association. Someone from my local union took on my case and resolved the problem, though it took several months for the mistake to get cleared up.

Many of my colleagues have asked whether I enjoyed teaching high school. Part of me misses the students that I got to know, part of me longs for the chance to try teaching another year at this school so that I can avoid the mistakes that became apparent with hindsight, but another part of me acknowledges that this experience was probably the most challenging period of my career as an educator thus far. So, while I learned and grew a great deal, I can't say that the experience as a whole was enjoyable.

I am, however, very grateful for the experience. I have a much more nuanced respect for high school teachers now. I didn't realize that high school teachers have a far greater potential to affect the course of a young person's life than college professors—this is because teenagers are so fragile and moldable both as young people and as learners of mathematics. This experience has even affected my teaching at Harvey Mudd College. I am more aware of my students' self-concepts now and how that affects their motivation and performance. I use more formative assessment to guide my teaching. My experiences that year gave me new perspectives about my job and informed the way that I think about and work with teachers. Let us all seek first to understand, then to be understood.

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Archimedes, Gauss, and Stein

Jim Pitman and Nathan Ross

Characterizing the Gaussian Distribution

One of Archimedes' proudest accomplishments was a proof that the surface area of a sphere is equal to the surface area of the tube of the smallest cylinder containing it; see Figure 1. Legend has it that he was so pleased with this result that he arranged to have an image similar to Figure 1 inscribed on his tomb.

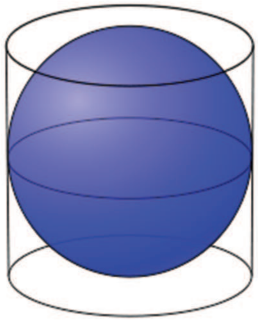

Figure 1. An illustration of the inscription on Archimedes' tomb.

More precisely, in the work *On the Sphere and Cylinder, Book I* as translated on page 1 of [2], Archimedes states that for every plane perpendicular to the axis of the tube of the cylinder, the surface areas lying above the plane on the sphere and on the tube are equal. See Figure 2 for an illustration and see also the discussion around Corollary 7 of [1].

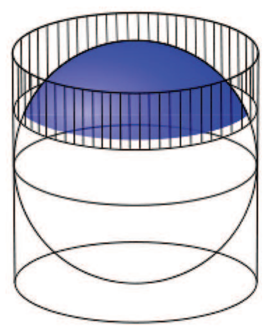

Figure 2. The surface area of the shaded "cap" of the sphere above a plane is equal to the striped surface area on the tube of the cylinder above the same plane.

In probabilistic terms, if a point is picked uniformly at random according to the surface area on the unit sphere in three dimensions, then its projection onto any given axis having origin at the center of the sphere is uniformly distributed on the interval $(-1, 1)$, independent of the angular component in the plane perpendicular to that axis. Formally, we have the following result.

Proposition 1. *If V is uniformly distributed on the interval $(-1,1)$ and if Θ is uniformly distributed on the interval $(0,2\pi)$ and independent of V, then*

$$\left(V, \sqrt{1-V^2}\cos(\Theta), \sqrt{1-V^2}\sin(\Theta)\right)$$

is uniformly distributed on the surface of the two-dimensional sphere of radius one.

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In this article, we take Proposition 1 as a starting point for a discussion of characterizations of the centered Gaussian distribution which arise in Stein's method of distributional approximation. This discussion culminates in Theorem 7. We then generalize some of these results in the section on the beta-gamma algebra to obtain the characterization of the gamma distribution found in Proposition 9 and also mention an analog of Theorem 7 for the exponential distribution. We conclude in the last section with a discussion of some related literature.

To move from Archimedes' result above to characterizing the Gaussian distribution, we state the following result which was first realized by the astronomer Herschel and was made well known by the physicist Maxwell in his study of the velocities of a large number of gas particles in a container; see the introduction of [6].

Proposition 2. *Let* $\mathbf{X} = (X_1, X_2, X_3)$ *be a vector of independent and identically distributed (i.i.d.) random variables. Then* X_1 *has a mean zero Gaussian distribution if and only if, for all rotations* $R : \mathbb{R}^3 \to \mathbb{R}^3$, $R\mathbf{X}$ *has the same distribution as* $\mathbf{X}$.

Propositions 1 and 2 are related by the following observations. It is clear that, if $\mathbf{X}$ is an $\mathbb{R}^3/\{0\}$-valued random vector such that $R\mathbf{X}$ has the same distribution as $\mathbf{X}$ for all rotations R, then $\mathbf{X}/\|\mathbf{X}\|$ is a rotation-invariant distribution on the surface of the two-dimensional unit sphere and is independent of $\|\mathbf{X}\| := \sqrt{X_1^2 + X_2^2 + X_3^2}$. Since the unique rotation-invariant distribution on the surface of a sphere of any dimension is the uniform distribution (Theorem 4.1.2 of [6]), the propositions of Archimedes and Herschel-Maxwell suggest the following characterization of mean-zero Gaussian distributions; we provide a proof and discussion of generalizations in the last section.

Proposition 3. *Let* $\mathbf{X} = (X_1, X_2, X_3)$ *be a vector of i.i.d. random variables. Then* X_1 *has a mean zero Gaussian distribution if and only if, for* V *uniform on* $(-1, 1)$ *and independent of* $\mathbf{X}$,

$$X_1 \stackrel{d}{=} V\sqrt{X_1^2 + X_2^2 + X_3^2}. \tag{1}$$

Here and in what follows, $\stackrel{d}{=}$ denotes equality in distribution of two random variables. The distribution of $\sqrt{X_1^2 + X_2^2 + X_3^2}$, where X_1, X_2, X_3 are independent standard normal variables, is referred to as the Maxwell or Maxwell-Boltzmann distribution; see page 453 of [12].

Proposition 3 characterizes centered Gaussian distributions as the one-parameter scale family of fixed points of the distributional transformation which takes the distribution of a random variable X to the distribution of $V\sqrt{X_1^2 + X_2^2 + X_3^2}$, where X_1, X_2, X_3 are i.i.d. copies of X and V is uniform on $(-1, 1)$ independent of (X_1, X_2, X_3). Such characterizations of distributions as the unique fixed point of a transformation also arise in Stein's method for distributional approximation.

We connect these concepts through the next lemma, which is the fundamental identity underlying Stein's method for Gaussian approximation. This lemma characterizes the Gaussian distribution of a random variable W by an identity relating expectations of functions of W. Stein's method is further developed by results which quantify the idea that if Stein's identity is approximately satisfied by W, then W is approximately Gaussian according to standard metrics on the space of distributions on the line. This framework and analogs for other distributions (e.g., Poisson and exponential) have proved to be very effective in establishing distributional limit theorems with rates of convergence in settings where other techniques (e.g., Fourier transforms and martingale methods) are difficult to apply. See [20] for a basic introduction and further references to the Stein's method literature.

Lemma 4 (Stein's Lemma [21])**.** *A random variable* W *has the mean zero, variance one Gaussian distribution if and only if, for all absolutely continuous functions* f *with bounded derivative,*

$$\mathbb{E}f'(W) = \mathbb{E}Wf(W).$$

We can relate the characterizations provided by Proposition 3 and Lemma 4, but first we need the following definition.

Definition 5. Let X be a random variable with distribution function F and such that $\mu_\alpha := \mathbb{E}|X|^\alpha < \infty$. We define $F^{(\alpha)}$, the α-power bias distribution of F, by the relation

$$dF^{(\alpha)}(x) = \frac{|x|^\alpha dF(x)}{\mu_\alpha},$$

and we write $X^{(\alpha)}$ for a random variable having this distribution. In other words, $X^{(\alpha)}$ has the α-power bias distribution of X if and only if for every measurable function f such that $\mathbb{E}|X|^\alpha|f(X)| < \infty$,

$$\mathbb{E}f(X^{(\alpha)}) = \frac{\mathbb{E}|X|^\alpha f(X)}{\mathbb{E}|X|^\alpha}. \tag{2}$$

Taking $\alpha = 1$ and $X \geqslant 0$, $X^{(1)}$ has the *size-biased* distribution of X, a notion which frequently arises in probability theory and applications [3], [5].

We can now state and prove the following result, which sheds some light on the relationship between Proposition 3 and Lemma 4.

Lemma 6. *If* W *is a random variable with finite second moment and* f *is an absolutely continuous* *function with bounded derivative then, for V uniform on the interval $(-1,1)$ and independent of $W^{(2)}$,*

$$2\mathbb{E}W^2\mathbb{E}f'(VW^{(2)}) = \mathbb{E}Wf(W) - \mathbb{E}Wf(-W).$$

Proof. The lemma is implied by the following calculation:

$$\begin{aligned}\mathbb{E}f'(VW^{(2)}) &= \frac{1}{2}\mathbb{E}\left[\int_{-1}^{1} f'(uW^{(2)})du\right] \\ &= \frac{1}{2}\mathbb{E}\left[\frac{f(W^{(2)}) - f(-W^{(2)})}{W^{(2)}}\right] \\ &= \frac{\mathbb{E}Wf(W) - \mathbb{E}Wf(-W)}{2\mathbb{E}W^2},\end{aligned}$$

where in the final equality we use (2). □

We now have the following main result for the Gaussian distribution, which is essentially a rephrasing of Proposition 2.3 on page 35 of [8].

Theorem 7. *Let W be a random variable with finite second moment. The following are equivalent:*

(i) *W has the standard normal distribution.*

(ii) *For all absolutely continuous functions f with bounded derivative,*

$$\mathbb{E}f'(W) = \mathbb{E}Wf(W).$$

(iii) *$\mathbb{E}W^2 = 1$ and $W \stackrel{d}{=} VW^{(2)}$, where V is uniform on $(-1,1)$ and independent of $W^{(2)}$.*

Proof. The equivalence of the first two items of the proposition is (Stein's) Lemma 4 above.

The fact that (i) implies (iii) follows from Proposition 3 above coupled with the simple fact that for X_1, X_2, X_3 i.i.d. standard normal random variables, the density of $(X_1^2+X_2^2+X_3^2)^{1/2}$ is proportional to $x^2e^{-x^2/2}$ (that is, $(X_1^2+X_2^2+X_3^2)^{1/2}$ has the same distribution as $X_1^{(2)}$).

Finally, we show that (ii) follows from (iii). If $W \stackrel{d}{=} VW^{(2)}$ and $\mathbb{E}W^2 = 1$, then using Lemma 6 we find that, for functions f with bounded derivative,

$$\begin{aligned}\mathbb{E}f'(W) &= \mathbb{E}f'(VW^{(2)}) \\ &= \frac{1}{2}\left(\mathbb{E}Wf(W) - \mathbb{E}Wf(-W)\right) = \mathbb{E}Wf(W),\end{aligned}$$

where in the last equality we use that $W \stackrel{d}{=} -W$, which follows in turn from the fact that $V \stackrel{d}{=} -V$ and hence $-VW^{(2)} \stackrel{d}{=} VW^{(2)}$. □

Remark 8. The equivalence of (i) and (iii) is essentially the content of Proposition 2.3 on page 35 of [8], which uses the concept of the "zero-bias" transformation of Stein's method, first introduced in [11]. For a random variable W with mean zero and variance $\sigma^2 < \infty$, we say that W^* has the zero-bias distribution of W if, for all f with $\mathbb{E}|Wf(W)| < \infty$,

$$\sigma^2\mathbb{E}f'(W^*) = \mathbb{E}Wf(W).$$

We think of the zero-bias transformation acting on probability distributions with zero mean and finite variance, and Stein's lemma implies that this transformation has the centered Gaussian distribution as its unique fixed point. Proposition 2.3 on page 35 of [8] states that, for a random variable W with support symmetric about zero with unit variance, the transformation $W \to VW^{(2)}$ provides a representation of the zero-bias transformation. The equivalence of (i) and (iii) of theorem follows easily from these results.

Beta-Gamma Algebra

The equivalence between (i) and (iii) in Theorem 7 can be generalized as follows. For $r, s > 0$, let G_r and $B_{r,s}$ denote standard gamma and beta random variables having respective densities $\frac{1}{\Gamma(r)}x^{r-1}e^{-x}, x > 0$, and $\frac{\Gamma(r+s)}{\Gamma(r)\Gamma(s)}y^{r-1}(1-y)^{s-1}, 0 < y < 1$, where Γ denotes the gamma function.

Proposition 9. *Fix $p, r, s > 0$. A nonnegative random variable W has the distribution of cG_r^p for some constant $c > 0$ if and only if $W \stackrel{d}{=} B_{r,s}^p W^{(s/p)}$, where $B_{r,s}$ is independent of $W^{(s/p)}$.*

Remark 10. The equivalence in (i) and (iii) of Theorem 7 follows by taking $p = r = 1/2$, $s = 1$ in Proposition 9 and using the well-known fact that for Z having the standard normal distribution, $Z^2 \stackrel{d}{=} 2G_{1/2}$.

The proof of Proposition 9 uses the following result.

Lemma 11. *Let $\alpha, \beta > 0$. If $X \geqslant 0$ is a random variable such that $\mathbb{E}X^\alpha < \infty$, then*

$$(X^{(\alpha)})^\beta \stackrel{d}{=} (X^\beta)^{(\alpha/\beta)}.$$

Proof. By the definition of α/β-power biasing, we only need to show that

$$\mathbb{E}X^\alpha\mathbb{E}f((X^{(\alpha)})^\beta) = \mathbb{E}X^\alpha f(X^\beta) \tag{3}$$

for all f such that the expectation on the left-hand side exists. By the definition of α-power biasing, we have that, for $g(t) = f(t^\beta)$,

$$\mathbb{E}X^\alpha\mathbb{E}g(X^{(\alpha)}) = \mathbb{E}X^\alpha g(X),$$

which is (3). □

Proof of Proposition 9. The usual beta-gamma algebra (see [9]) implies that $G_r \stackrel{d}{=} B_{r,s}G_{r+s}$ where $B_{r,s}$ and G_{r+s} are independent. Using the elementary fact that $G_{r+s} \stackrel{d}{=} G_r^{(s)}$, we find that for fixed $r, s > 0$, G_r satisfies $G_r \stackrel{d}{=} B_{r,s}G_r^{(s)}$. Now applying Lemma 11 to G_r with $\alpha = s$ and $\beta = p$, we have that $W = G_r^p$ satisfies $W \stackrel{d}{=} B_{r,s}^p W^{(s/p)}$ and the forward implication now follows after noting that $(cX)^{(\alpha)} \stackrel{d}{=} cX^{(\alpha)}$.

Now assume that $W \overset{d}{=} B^p_{r,s} W^{(s/p)}$ for fixed $p, r, s > 0$. We show that $W \overset{d}{=} c\, G^p_r$ for some $c > 0$. First, note by Lemma 11 that, if $X = W^{1/p}$, then

$$X \overset{d}{=} B_{r,s} X^{(s)} \tag{4}$$

and we will be done if this implies that $X \overset{d}{=} G_r$. Observe that, by writing $X^{(s)}$, we have been tacitly assuming that $\mathbb{E}W^{s/p} = \mathbb{E}X^s < \infty$, which implies that $\mathbb{E}(B_{r,s}X^{(s)})^s < \infty$ so that using the definition of power biasing yields $\mathbb{E}X^{2s} < \infty$. Continuing in this way, we find that $\mathbb{E}X^{ks} < \infty$ for all $k = 1, 2, \ldots$ and thus that $\mathbb{E}X^q < \infty$ for all $q \geqslant s$. Moreover, writing $a_k := \mathbb{E}X^{ks}$ and taking expectations in (4) after raising both sides to the power k, we have

$$a_k = \mathbb{E}B^{ks}_{r,s} \frac{a_{k+1}}{a_1},$$

where we have again used the definition of power biasing. We can solve this recursion after noting that, for $\alpha > -r$,

$$\mathbb{E}B^{\alpha}_{r,s} = \frac{\Gamma(r+\alpha)\Gamma(r+s)}{\Gamma(r+\alpha+s)\Gamma(r)},$$

to find that, for $k = 0, 1, \ldots,$

$$a_k = \left(\frac{a_1\Gamma(r)}{\Gamma(r+s)}\right)^k \frac{\Gamma(r+sk)}{\Gamma(r)}.$$

For any value of $a_1 > 0$, it is easy to see using Stirling's formula that the sequence $(a_k)_{k\geqslant 1}$ satisfies Carleman's condition

$$\sum_{k=1}^{n} a_{2k}^{-1/2k} \to \infty, \quad \text{as } n \to \infty.$$

Thus, for a given value of a_1, there is exactly one probability distribution having moment sequence $(a_k)_{k\geqslant 1}$ (see the remark following Theorem (3.11) in Chapter 2 of [10]). Finally, it is easy to see that the random variable

$$X^s := \frac{a_1\Gamma(r)}{\Gamma(r+s)} G^s_r$$

has moment sequence $(a_k)_{k\geqslant 1}$. □

Exponential Distribution

The exponential distribution has many characterizing properties, many of which stem from its relation to Poisson processes. For example, by superimposing two independent Poisson processes into one, we easily find that, if Z_1 and Z_2 are independent rate-one exponential variables, then $2\min\{Z_1, Z_2\}$ is also a rate-one exponential (this is in fact characterizing as shown in Theorem 3.4.1 of [6]).

For our framework above, we use the memoryless property of the exponential distribution in the context of renewal theory. In greater detail, for any nonnegative random variable X, we define the renewal sequence generated from X as $(S_1, S_2, \ldots)$, where $S_i = \sum_{k=1}^{i} X_k$ and the X_k are i.i.d. copies of X. For a fixed $t > 0$, the distribution of the length of the interval $[S_{K_t}, S_{K_t+1}]$ containing t and the position of t in this interval depend on t and the distribution of X in some rather complicated way. We can remove this dependence on t by starting the sequence in "stationarity", meaning that we look instead at the sequence $(X', X' + S_1, \ldots)$, where X' has the limiting distribution of $S_{K_t+1} - t$ as t goes to infinity; see Chapter 5, Sections 6 and 7.b of [13].

If X has a continuous distribution with finite mean, then the distribution of X' is the size-biased distribution of X times an independent variable which is uniform on $(0, 1)$ [13]. Heuristically, the memoryless property which characterizes the exponential distribution (Chapter 12 of [4]) implies that the renewal sequence generated by an exponential distribution is stationary (that is, X and X' have the same distribution) and vice versa. The following result implies that this intuition is correct.

Theorem 12 ([16]). *Let W be a nonnegative random variable with finite mean. The following are equivalent:*

(i) *W has the exponential distribution with mean one.*

(ii) *For all absolutely continuous functions f with bounded derivative,*

$$\mathbb{E}f'(W) = \mathbb{E}f(W) - f(0).$$

(iii) *$\mathbb{E}W = 1$ and $W \overset{d}{=} UW^{(1)}$, where U is uniform on $(0, 1)$ and independent of $W^{(1)}$.*

Similar to the case of the normal distribution, the crucial link between (ii) and (iii) of Theorem 12 is provided by the following lemma; the proof is similar to that of Lemma 6.

Lemma 13. *If W is a nonnegative random variable with finite mean and f is an absolutely continuous function with bounded derivative, then*

$$\mathbb{E}W\mathbb{E}f'(UW^{(1)}) = \mathbb{E}f(W) - f(0).$$

Proof of Theorem 12. The equivalence of (i) and (iii) is a special case of Proposition 9 with $r = s = p = 1$, and the equivalence of (ii) and (iii) can be read from Lemma 13 (note in particular that (ii) with $f(x) = 1$ implies that $\mathbb{E}W = 1$). □

Remark 14. For a nonnegative random variable W with finite mean, the transformation $W \to UW^{(1)}$ is referred to in the Stein's method literature as the "equilibrium" transformation, first defined in this context in [16], where Theorem 12 is also proved.

Due to the close relationship between the exponential and geometric distributions, it is not surprising that there is a discrete analog of Theorem 12 with the exponential distribution replaced by the geometric; see [17] for this discussion in the context of Stein's method.

Proof of Proposition 3 and Discussion

Proof of Proposition 3. We will show that, for $n \geqslant 2$ and $Y_1, \ldots, Y_n$ nonnegative i.i.d. random variables, $Y_1 \overset{d}{=} cG_{1/(n-1)}$ for some $c \geqslant 0$ if and only if

$$Y_1 \overset{d}{=} B_{1/(n-1),1}(Y_1 + \cdots + Y_n), \tag{5}$$

where $B_{1/(n-1),1}$ is independent of $(Y_1, \ldots, Y_n)$ and $G_a, B_{a,b}$ are gamma and beta variables as defined above. From this point, (5) with $n = 3$ yields a characterization of the distribution of X^2 after noting that $V^2 \overset{d}{=} B_{1/2,1}$ and if X has a mean zero and variance one normal distribution, then $X^2 \overset{d}{=} 2G_{1/2}$. The proposition then follows since the distribution of X is determined by the distribution of X^2 through the representation (1).

The forward implication is a consequence of Proposition 9 coupled with the fact that $G_{a+b} \overset{d}{=} G_a + G_b$, where G_a and G_b are independent. To establish the result, we assume (5) and show that $Y_1 \overset{d}{=} cG_{1/(n-1)}$. Since we assume that Y_1 is nonnegative, we define the Laplace transform

$$\varphi(\lambda) = \mathbb{E}e^{-\lambda Y_1}, \qquad \lambda \geqslant 0.$$

By conditioning on the value of $B_{1/(n-1),1}$ in (5), we find, for $\lambda > 0$,

$$\begin{aligned}\varphi(\lambda) &= \mathbb{E}\varphi(B_{1/(n-1),1}\lambda)^n \\ &= \frac{1}{n-1}\int_0^1 u^{-(n-2)/(n-1)}\varphi(u\lambda)^n du \\ &= \frac{1}{(n-1)\lambda^{1/(n-1)}}\int_0^\lambda t^{-(n-2)/(n-1)}\varphi(t)^n dt,\end{aligned}$$

where we have made the change of variable $t = u\lambda$ in the last equality. We can differentiate the equation above with respect to λ, which yields

$$\begin{aligned}\varphi'(\lambda) = &-\frac{\lambda^{-n/(n-1)}}{(n-1)^2}\int_0^\lambda t^{-(n-2)/(n-1)}\varphi(t)^n dt \\ &+ \frac{1}{(n-1)\lambda}\varphi(\lambda)^n;\end{aligned}$$

thus

$$\varphi'(\lambda) = \frac{-\varphi(\lambda) + \varphi(\lambda)^n}{(n-1)\lambda}. \tag{6}$$

Consequently we find that φ satisfies the differential equation (6) with boundary condition $\varphi(0) = 1$.

By computing the derivative using (6) and the fact that $0 < \varphi(\lambda) \leqslant 1$ for $\lambda > 0$, we find that, for some constant $c \geqslant 0$,

$$\frac{1 - \varphi(\lambda)^{n-1}}{\lambda\varphi(\lambda)^{n-1}} = c, \qquad \lambda > 0.$$

Solving this equation for $\varphi(\lambda)$ implies that

$$\varphi(\lambda) = (1 + c\lambda)^{-1/(n-1)},$$

which is the Laplace transform of $cG_{1/(n-1)}$, as desired. □

The proof of Proposition 3 and the beta-gamma algebra suggest the following proposition and conjecture.

Proposition 15. *Fix $n \geqslant 2$, $a > 0$ and let $\mathbf{Y} = (Y_1, Y_2, \ldots, Y_n)$ be a vector of nondegenerate i.i.d. random variables such that $Y_1 \geqslant 0$ and $\mathbb{E}Y_1^k < \infty$ for all $k > 1$. Then Y_1 is equal in distribution to cG_a for some constant $c > 0$ if and only if, for $V = B_{a,(n-1)a}$ independent of $\mathbf{Y}$,*

$$Y_1 \overset{d}{=} V(Y_1 + Y_2 + \cdots + Y_n). \tag{7}$$

Proof. The forward implication of the proposition is an easy consequence of the following beta-gamma algebra facts: for G_a, G_b, and $B_{a,b}$ independent, $B_{a,b}G_{a+b} \overset{d}{=} G_a$ and $G_a + G_b \overset{d}{=} G_{a+b}$.

The remaining implication follows easily after using (7) to obtain a recursion relation for the moments of Y_1 which, up to the scale factor, determines those of a gamma distribution with the appropriate parameter. □

The assumption in Proposition 15 that all moments of Y_1 are finite is likely unnecessary; we make the following conjecture.

Conjecture 16. *Proposition 15 holds for each $n \geqslant 2$ and $a > 0$ with no moment assumption on Y_1.*

The forward implication of Proposition 15 is clearly unaffected by removing the moment assumption on Y_1. Conversely, assuming (7), the proof of Proposition 3 above implies the conjecture in the special case where $a = 1/(n-1)$. In the general case, it is possible to follow the proof of Proposition 3, which leads to an integral equation for the Laplace transform of Y_1 and it is only a matter of showing that this integral equation has a unique scale family of solutions. In the case $a = 1/(n-1)$, the integral equation has a simple form from which we are able to deduce the required uniqueness, but in the general case we do not have the analogous argument.

Conjecture 16 is very similar to Lukacs's characterization of the gamma distribution [14] that positive, nondegenerate, independent variables X, Y have the gamma distribution if and only if $X + Y$ and $X/(X + Y)$ are independent. However, it does not appear that this result can be used to show the difficult implication of the conjecture. Note additionally that Lukacs's result also characterizes beta distributions as the only distributions which can be written as $X/(X + Y)$ independent of $X + Y$ for positive, nondegenerate, independent variables X, Y. Thus, a question related to our conjecture is that, if (7) holds for independent variables $Y_1, \ldots, Y_n$ and V, does this imply that V has a beta distribution?

Conjecture 16 is connected to the observation of Poincaré (see the introduction of [15]) that the coordinates of a point uniformly chosen on the $(n-1)$-dimensional sphere of radius $\sqrt{n}$ are asymptotically distributed as independent standard Gaussians. Analogous to the discussion in the introduction, we can realize these uniformly distributed points as $\sqrt{n}R^{-1}(X_1, \ldots, X_n)$, where $X_1, \ldots, X_n$ are independent standard normal variables and $R = (X_1^2 + \cdots + X_n^2)^{1/2}$. Squaring these coordinates, Poincaré's result implies that $nX_1^2/(X_1^2 + \cdots + X_n^2)$ is asymptotically distributed as X_1^2. Since $X_1^2 \overset{d}{=} 2G_{1/2}$, taking the limit as $n \to \infty$ on the right side of (7) with $a = 1/2$ yields a related fact.

The forward implication of Proposition 3 is evidenced also by the creation of a three-dimensional Bessel process by conditioning a one-dimensional Brownian motion not to hit zero. Indeed, a process version of Proposition 3 is involved in the proof of the "$2M - X$" theorem provided in [19]; see the section above on beta-gamma algebra and especially Section 2.3 of [7]. More generally, process analogs of the beta-gamma algebra can be found in Section 3 of [7].

Some extensions of the characterizations discussed in this article to more complicated distributions can be found in the recent work [18].

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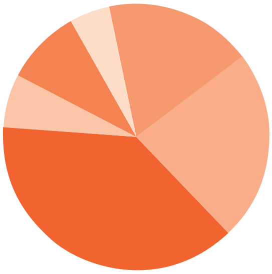


Fall 2011 Departmental Profile Report

Richard Cleary, James W. Maxwell, and Colleen Rose

This report presents a profile of mathematical sciences departments at four-year colleges and universities in the United States, as of fall 2011. The information presented includes the number of faculty in various categories, undergraduate and graduate course enrollments, number of bachelor's and master's degrees awarded during the preceding year, and the number of graduate students.

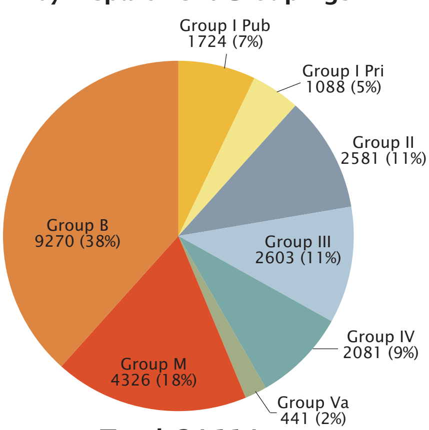
Data collected earlier from these departments on recruitment and hiring and faculty salaries were presented in the Report on 2010-2011 Academic Recrutiment and Hiring (pages 796–800 of the June/July 2012 issue of *Notices of the AMS*) and the 2011–2012 Faculty Salaries Report (pages 410–415 of the March 2012 issue of *Notices of the AMS*).

Detailed information, including tables which traditionally appeared in this report, is available on the AMS website at `www.ams.org/annual-survey/survey-reports.`

Faculty Size

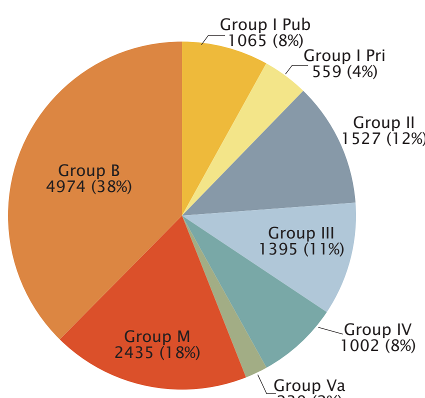
Changes in the numbers of faculty from 2010 to 2011 were modest except for a decrease in faculty in Group B. The estimated number of full-time faculty in all departments is 24,114 with 22,033 of these in all mathematics departments combined (Groups I, II, III, Va, M, and B), down 4% from 23,023 last year. The majority of this decrease is the result of the 12% decrease in estimated full-time faculty in Group B, down 1,240 to 9,270 (with a standard error of 202.) Full-time faculty among the doctoral mathematics departments combined (Groups I–III & Va) increased 2% to 8,437 from 8,297 last year. In the mathematics departments combined the number of nondoctoral full-time faculty is 3,743 (with a standard error of 99), down 2% from 3,817 last year. The total part-time faculty in all mathematics departments combined is estimated to be 5,955 (with a standard error of 164), down 2% from 6,067 last year.

Figure F.1: All Full-time Faculty by Department Groupings



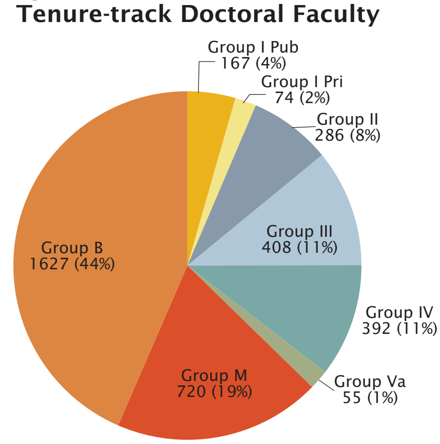
Total: 24,114

Figure F.2: Full-time Tenured Doctoral Faculty



Total: 13,196

Figure F.3: Full-time Untenured, Tenure-track Doctoral Faculty



Total: 3,729

Richard Cleary is a professor in the Department of Mathematical Sciences at Bentley University. James W. Maxwell is AMS associate executive director for special projects. Colleen A. Rose is AMS survey analyst.

Doctoral Faculty

The estimated number of full-time doctoral faculty in all mathematics departments combined (Groups I-III, Va, M and B) is 18,289 (with a standard error of 197), down 5% from last year's number of 19,206. For these same groups combined, total doctoral tenured faculty decreased 7% to 12,194. Essentially all of the decrease is due to a reported decrease of just over 1,000 for Group B; the standard error of this estimate is 188.

Figure D.1: Gender of Full-time Doctoral Faculty
Total: 20,244

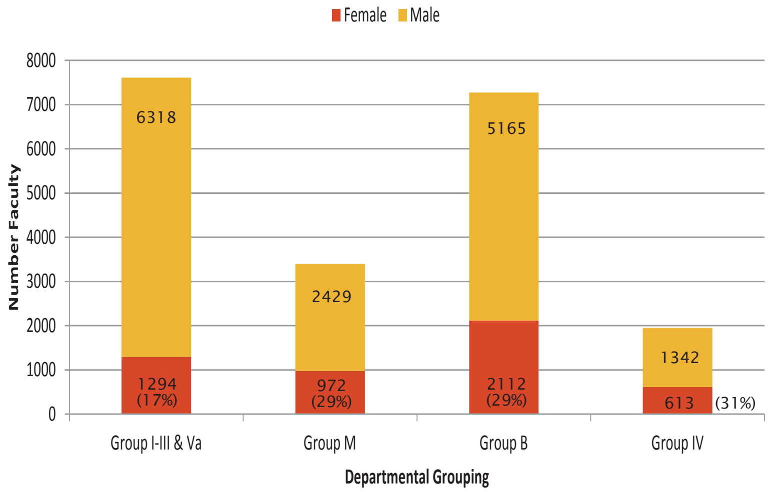
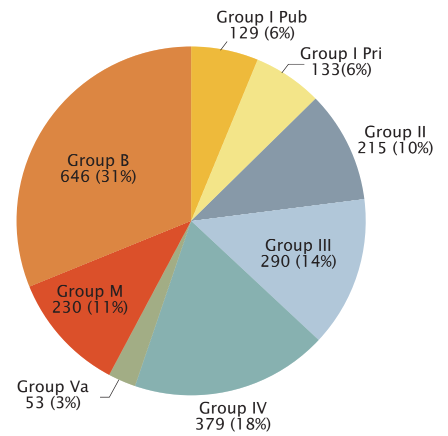


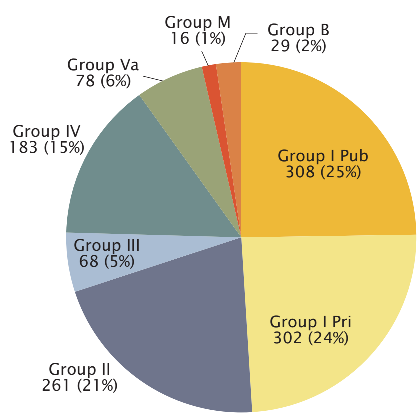
Figure D.2: Non-tenure-track Doctoral Faculty (excluding Postdocs)



Total: 2,075

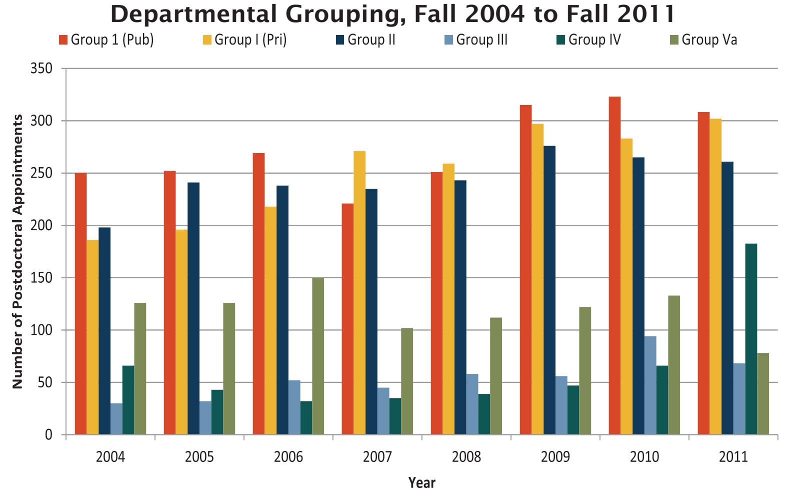
Postdoctoral appointments among the doctoral mathematics departments dropped to 1,018 for fall 2011. This is a 1% decrease from last year and 13% of the total full-time doctoral faculty in these departments. Females hold 22% of all postdoctoral appointments. Since 2004 total postdoctoral appointments have increased 40% and females holding postdocs increased 39% to 258 from 229. Postdoctoral appointments as a percentage of total full-time doctoral faculty, which held steady at 11% from 2005 to 2007 then increased slightly each year from 2008 to 2010 when it reached a high of 14%, has dropped to 13% this year.

Figure D.3: Full-time Postdoctoral Faculty



Total: 1,246

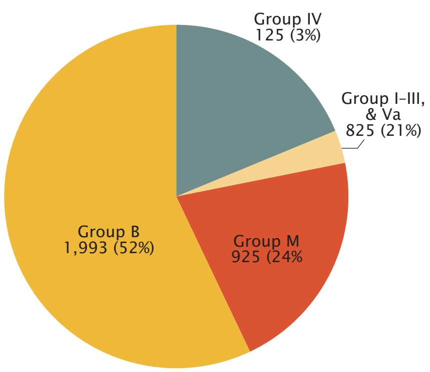
Figure D.4: Postdoctoral Faculty, by Year and Departmental Grouping, Fall 2004 to Fall 2011



Nondoctoral Faculty

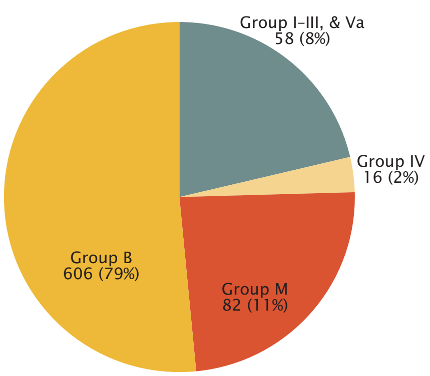
The estimated number of nondoctoral full-time faculty in all mathematics departments combined (Groups I–III, Va, M and B) is 3,743. This is down 2% from last year and is 17% of all full-time faculty. 204 of the nondoctoral faculty in all mathematics departments are untenured, tenure-track faculty, 6% of all untenured tenure-track faculty in these groups. Nondoctoral full-time non-tenure-track faculty (including postdocs) decreased to 2,793; this is 75% of all nondoctoral mathematics faculty. There are 213 full-time nondoctoral untenured, tenure-track faculty some of whom are likely still in the process of completing their Ph.D.

Figure ND.1: Full-time Nondoctoral Faculty by Departmental Grouping



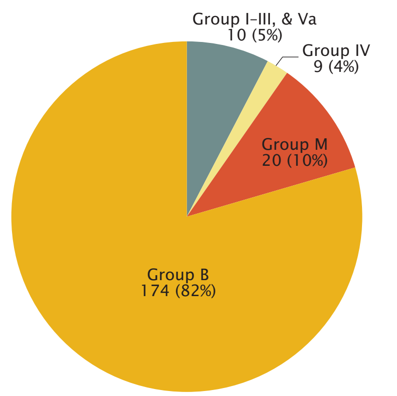
Total: 3,868

Figure ND.2: Full-time Nondoctoral Tenured Faculty



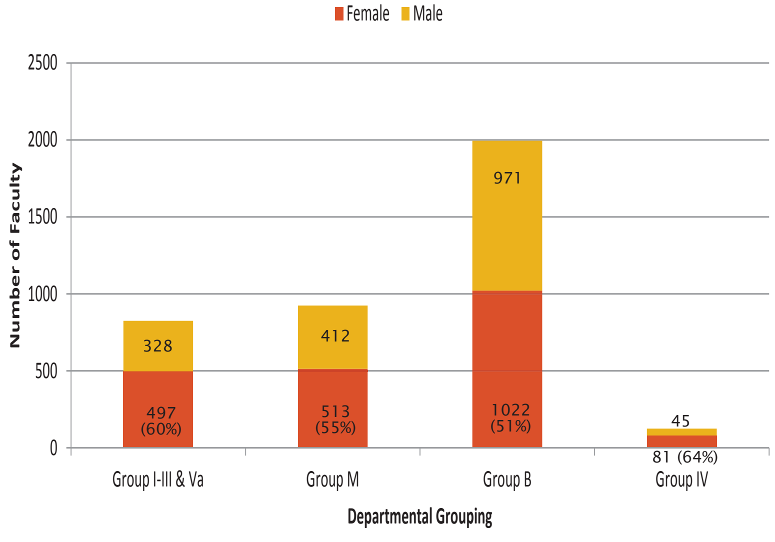
Total: 762

Figure ND.3: Full-time Nondoctoral Untenured, Tenure-track Faculty



Total: 213

Figure ND.4: Gender of Full-time Nondoctoral Faculty
Total: 3,868

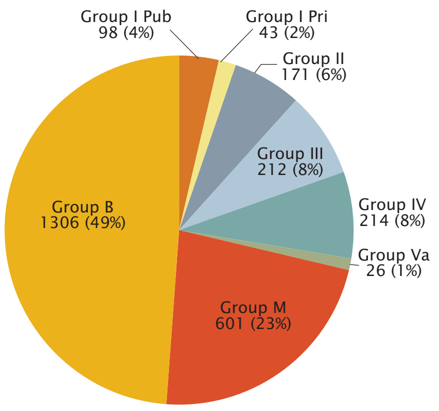


- Females account for 54% of full-time nondoctoral faculty in all mathematics groups combined (the same as last year), compared to females accounting for 29% of all full-time faculty.
- Total part-time nondoctoral faculty in all doctoral mathematics departments combined (Groups I-III, and Va) is 700, 64% of all part-time faculty in these groups.

Female Faculty

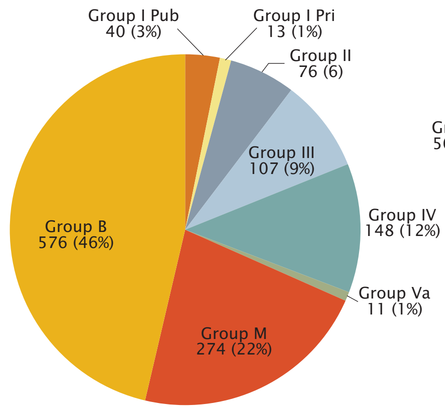
For the combined mathematics departments (Groups I-III, Va, M and B), women comprised 29% (6,409 with a standard error of 91) of the full-time faculty (22,033) in fall 2011. For the doctoral mathematics departments combined (Groups I-III, and Va), women comprised 14% of the combined doctoral-holding tenured and tenure-track faculty and 27% of the doctoral-holding non-tenure-track (including postdocs) faculty in fall 2011. For Group M faculty these same percentages are 28 and 39, and for Group B faculty they are 29 and 34, respectively. Among the nondoctoral full-time faculty in all math departments combined, women comprise 54%. Females account for 41% of all part-time faculty in mathematics departments combined.

Figure FF.1: Tenured Female Doctoral Faculty



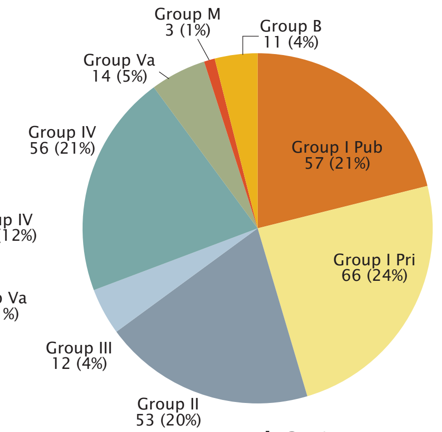
Total: 2,670

Figure FF.2: Untenured, Tenure-track Female Doctoral Faculty



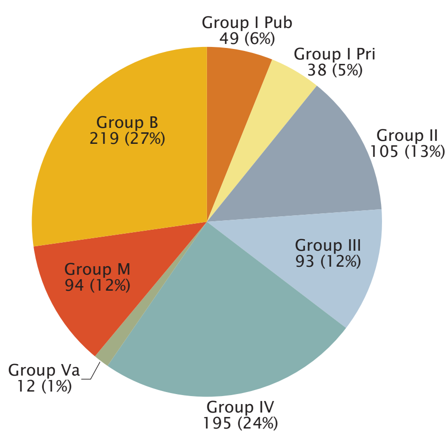
Total: 1,244

Figure FF.3: Postdoctoral Female Faculty



Total: 271

Figure FF.4: Female Doctoral Non-tenure-track Faculty (excluding Postdocs)



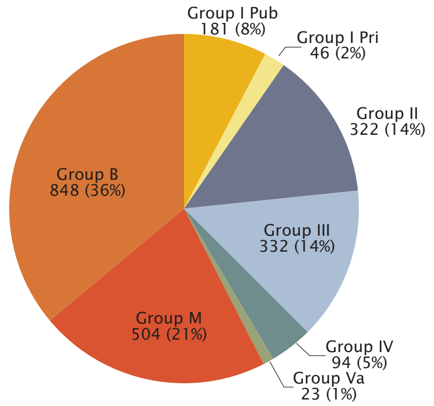
Total: 805

- 44% of all female faculty reported are in Group B. This group also reported the highest percentage of full-time female faculty (34%), while Group Va reported the lowest (15%).
- Females hold 22% of all postdoctoral appointments; the number of female postdocs increased slightly in Groups I (Pri), IV, Va, and B. 33% of all female postdocs in doctoral mathematics departments combined are found in Group I (Pri). This group reported the highest percentage (22%) of female postdocs.
- 53% of all part-time female faculty among the mathematics departments combined are found in Group B.

Undergraduate Course Enrollments

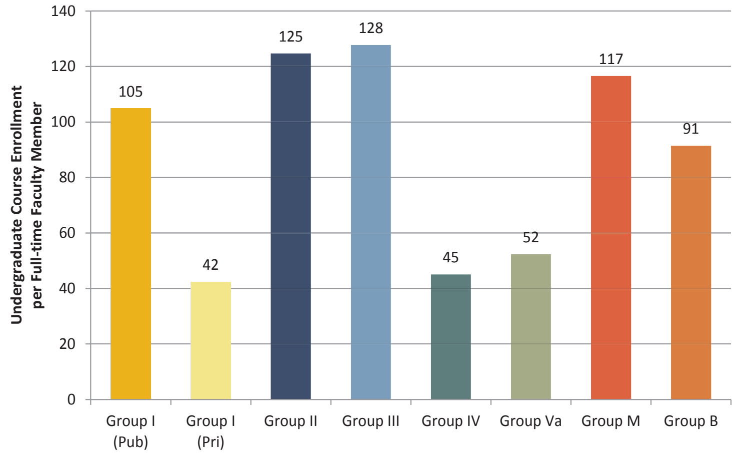
Total undergraduate enrollments for all groups combined decreased by 3% (68,000) to 2,350,000 (with a standard error of 23,000); most of this decrease came from Group B which decreased 14% (138,000) to 848,000 (with a standard error of 20,000). With fall 2011 we see a slight increase in the number of undergraduate course enrollments per full-time faculty member in all groups except Groups IV and Va.

Figure UE.1: Undergraduate Course Enrollments by Department Groupings (Thousands)



Total Undergraduate Enrollments (thousands): 2,350

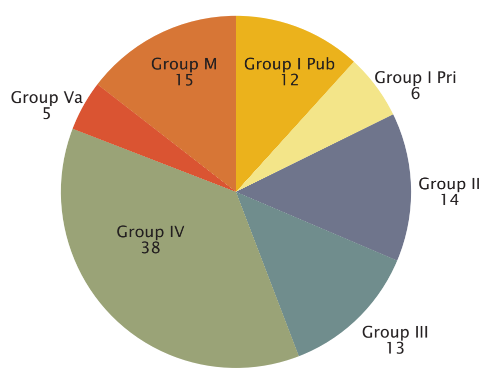
Figure UE.2: Undergraduate Course Enrollment per Full-Time Faculty Members, Fall 2011



Graduate Course Enrollments

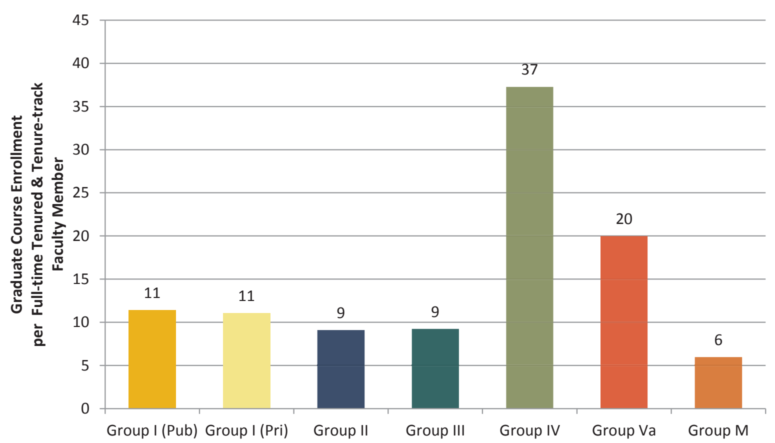
Total graduate course enrollments have increased by 7% (6,000) to 103,000 (with a standard error of 2,000). However, increases in the number of graduate course enrollments per full-time tenured/tenure-track faculty member occurred in all groups except Groups I (Pub) and M which remained flat.

Figure GE.1: Graduate Course Enrollments by Department Groupings (Thousands)



Total Graduate Enrollments (thousands): 103

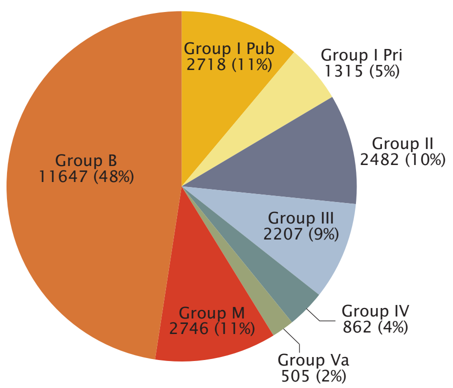
Figure GE.2: Graduate Course Enrollment per Full-Time Tenured and Tenure-track Faculty Member, Fall 2011



Undergraduate Degrees Awarded

The estimated number of undergraduate degrees awarded during 2010-2011 by all mathematics departments combined (Groups I–III, Va, M and B) is 23,621 (with a standard error of 503), up 1% from last year's estimate of 23,438. Females accounted for 44% (10,293) of these degrees, a 2% increase over last year. This year's estimated number of undergraduate degrees awarded included 367 statistics-only and 1,835 computer-science only.

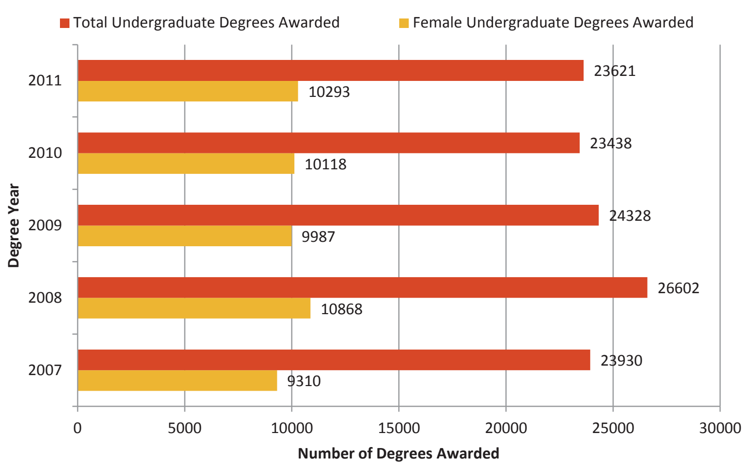
Figure UD.1: Undergraduate Degrees Awarded by Department Groupings



Total Degrees Awarded: 24,483

- All groups reported an increase in the number of degrees awarded except for Group M, Group B reported the largest increase, up 707 from last year.
- Group B awarded 49% of all the degrees, up from 47% last year in all mathematics departments combined.
- Group IV reported a 13% increase in degrees awarded.
- Total statistics-only degrees dropped in all mathematics departments combined by 25% to 367.
- Males were more likely to receive combined statistics-only or computer science-only degrees. About 14% of males earned such degrees compared to just 7% of females.

Figure UD.2: Undergraduate Degrees Awarded
Groups I, II, III, Va, M & B Combined



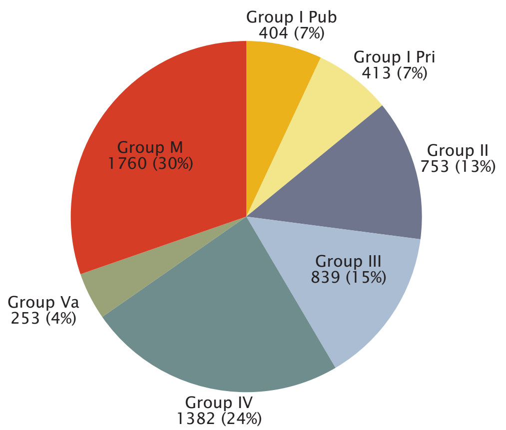
Comparing undergraduate degrees awarded this year with those awarded in 2007:

- Degrees awarded have decreased 1% overall.
- Degrees awarded to females increased by 11%.
- The percentage of total degrees awarded to females increased from 39% to 44%.

Master's Degrees Awarded

The estimated number of master's degrees awarded during 2010-2011 in all mathematics departments combined (Groups I-III, Va, and M) is 4,423, a 4% increase from last year's estimate of 4,265. This year's estimated graduate degrees included 478 statistics-only and 250 computer science-only degrees. Departments reported a slight increase in the number of degrees awarded to females, 1,745.

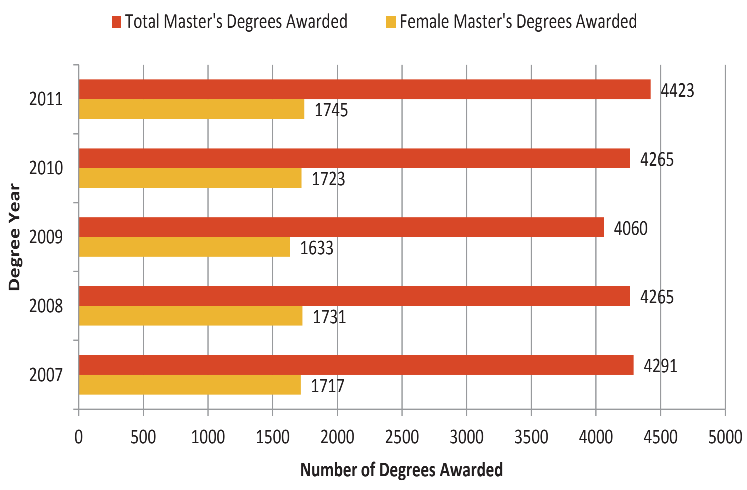
Figure MD.1: Master's Degrees Awarded by Department Groupings



Total Degrees Awarded: 5,805

- Looking at all mathematics departments:
  - Group M awarded the highest percentage of degrees (40%, down from 41% last year).
  - Group Va awarded the fewest degrees (6%, up from 5% last year). This group reported the largest percentage increase in degrees awarded; up 21% to 253 from 209 reported last year.
  - Females received 39% of all degrees awarded among all the mathematics departments combined; down from 40% last year.
  - Group III awarded the largest percentage of degrees to females (45%), while Group I (Pri) awarded the smallest percentage (24%).
  - 17% of degrees awarded to females in all mathematics departments combined were in statistics-only or computer science-only, compared to 16% for males.
- Group IV awarded 1,382 degrees, an increase of 10% from last year; females received 47% of these degrees.

Figure MD.2: Master's Degrees Awarded
Groups I, II, III, Va, M & B Combined



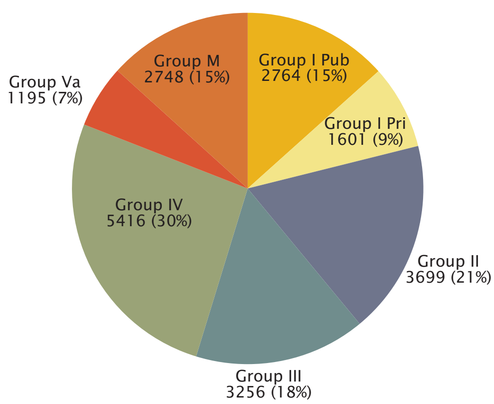
Comparing master's degrees awarded this year with those awarded in 2007:

- Total degrees awarded have increased 3% overall.
- Total degrees awarded to females dropped from 40% to 39%.

Graduate Students

The total number of full-time graduate students in all mathematics departments combined is 15,262, down from 16,138 in fall 2010. The total number of full-time graduate students in doctoral mathematics departments combined (Groups I-III, & Va) is 12,514 (down from 13,048). The number of U.S. citizens among the doctoral mathematics departments combined decreased 7% to 6,951 and the number of U. S. citizen first-year students decreased 1% to 1,827. For Group M, full-time graduate students decreased 11% to 2,748, the number of U.S. citizens is 2,169 (down from 2,428), and the number of first-year students is 1,244 (down from 1,266). Group IV reported full-time graduate students as 5,416, up from 5,065.

Figure GS.1: Graduate Students by Department Groupings



Total Graduate Students: 20,678

- Full-time graduate students decreased in all groups except Groups Va and IV which increased 12% and 7%, respectively.
- Group I (Pri) had the largest percentage decrease in graduate students with 14% (down 265 from 1,866 to 1,601), while Group M had the largest number decrease—down 342 from 3,090 to 2,748.
- Females account for 36% (7,415) of the full-time graduate students; all groups reported decreases except Groups III, IV and Va.
- First-year graduate students in Groups I (Pub), 1 (Pri) and M decreased by 13%, 7% and 2% respectively. Group III increased by 9%, all others increased slightly.
- U.S. citizen graduate students decreased 7% across the doctoral mathematics departments.
- Total part-time graduate students in all doctoral mathematics departments combined increased 1%, while Groups M decreased by 2% and Group IV increased by 17%.

Table GS.2: Full-Time Graduate Students in Groups I, II, III, & Va by Gender and Citizenship, Fall 2006–2011

	2006	2007	2008	2009	2010	2011
Total full-time graduate students	**10984**	**10937**	**10883**	**11286**	**13048**	**12514**
Female	3279	3249	3193	3248	3839	3773
% Female	30%	30%	29%	29%	29%	30%
% U.S. Ciizen	56%	56%	55%	56%	57%	56%
% Underrepresented minorities [1]	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%
Total first-year graduate students	**2960**	**2964**	**2924**	**3040**	**3313**	**3288**
Female	961	950	870	904	1019	1077
% Female	32%	32%	30%	30%	31%	33%
% U.S. Ciizen	55%	56%	56%	55%	51%	50%
% Underrepresented minorities	10.0%	10.0%	10.0%	10.0%	9.0%	9.0%

[1] Underrepresented minorities includes any person having origins within the categories *American Indian or Alaska Native, Black or African American, Hispanic or Latino, and Native Hawaiian or Other Pacific Islander*.

Looking at Table GS.2 we see that although the numbers and percentages have fluctuated somewhat among the categories, the numbers of full-time, and female, and first-year graduate students have dropped this year, after reaching a six-year high last year, as has the percentage of U.S. citizens. The number of full-time and full-time first-year graduate students remain 12% and 11%, respectively, above their level in 2006.

Remarks on Statistical Procedures

The questionnaire on which this report is based, "*Departmental Profile*", is sent to all doctoral and master's departments. It is sent to a stratified random sample of Group B departments, the stratifying variable being the undergraduate enrollment at the institution.

The response rates vary substantially across the different department groups. For most of the data collected on the Departmental Profile form, the year-to-year changes in a given department's data are very small when compared to the variations among the departments within a given group. As a result of this, the most recent prior year's response is used (imputed) if deemed suitable. After the inclusion of prior responses, standard adjustments for the remaining nonresponse are then made to arrive at the estimates reported for the entire groups.

Standard errors were calculated for some of the key estimates for Groups I, II, III, and Va combined, for Groups M and B, and for Group IV. Standard errors are calculated using the variability in the data and can be used to measure how close our estimate is to the true value for the population. As an example, the number of full-time faculty in Group M is estimated at 4,326 with a standard error of 62. This means the actual number of full-time faculty in Group M is most likely between 4,326 plus or minus two standard errors, or between 4,202 and 4,450. This is much more informative than simply giving the estimate of 4,326.

Estimates are also given for parameters that are totals from all groups, such as the total number of full-time faculty. For example, an estimate of the total number of full-time faculty in all groups but group IV is 22,033, with a standard error of 206.

The careful reader will note that a row or column total may differ slightly from the sum of the individual entries. All table entries are the rounded values of the individual projections associated with each entry, and the differences are the result of this rounding (as the sum of rounded numbers is not always the same as the rounded sum).

Other Sources of Data

Visit the AMS website at `www.ams.org/annual-survey/other-sources` for a listing of additional sources of data on the Mathematical Sciences.

Survey Response Rates

Departmental Profile
Department Response Rates

Department Group	Number	Percent	Imputed[1]
Group I (Public)	20 of 25	80%	4
Group I (Private)	21 of 23	91%	2
Group II	51 of 56	91%	4
Group III	66 of 81	81%	8
Group IV (Statistics)	41 of 58	71%	12
Group IV (Biostatistics)	23 of 35	66%	5
Group Va	17 of 21[2]	77%	2
Group M	70 of 179	39%	50
Group B	263 of 595[3]	44%	83

1 See paragraph two under 'Remarks on Statistical Procedures.'

2 The population for Group Va is slightly less than for the Doctorates Granted Survey because four programs do not formally "house" faculty, teach undergraduate courses, or award undergraduate degrees.

3 This is the sampled population, the total population for Group B is 1,012.

Group Descriptions

The data in this report is presented for departments divided into groups according to several characteristics, the principal one being the highest degree offered in the mathematical sciences. Doctoral-granting departments of mathematics are further subdivided according to their ranking of "scholarly quality of program faculty" as reported in the 1995 publication *Research-Doctorate Programs in the United States: Continuity and Change.*

Group I is composed of 48 departments with scores in the 3.00–5.00 range. Group I Public and Group I Private are Group I departments at public institutions and private institutions, respectively.

Group II is composed of 56 departments with scores in the 2.00–2.99 range.

Group III contains the remaining U.S. departments reporting a doctoral program, including a number of departments not included in the 1995 ranking of program faculty.

Group IV contains U.S. departments (or programs) of statistics, biostatistics, and biometrics reporting a doctoral program.

Group V contains U.S. departments (or programs) in applied mathematics/applied science, operations research, and management science which report a doctoral program.

Group Va is applied mathematics/applied science; Group Vb, which was no longer surveyed as of 1998–99, was operations research and management science.

Group M contains U.S. departments granting a master's degree as the highest graduate degree.

Group B contains U.S. departments granting a baccalaureate degree only.

Listings of the actual departments which compose these groups are available on the AMS website at `www.ams.org/annual-survey/groups_des`.

WHAT IS... Essential Dimension?

Zinovy Reichstein

Informally speaking, the essential dimension of an algebraic object is the minimal number of independent parameters one needs to describe it. This notion was introduced in [1], where the objects in question were field extensions of finite degree. The general definition below is due to A. Merkurjev.

Essential Dimension of a Functor

Fix a base field k and let $\mathcal{F}$ be a covariant functor from the category of field extensions K/k to the category of sets. We think of $\mathcal{F}$ as specifying the type of algebraic object under consideration and $\mathcal{F}(K)$ as the set of algebraic objects of this type defined over K. For a field extension K/K_0, the natural ("base change") map $\mathcal{F}(K_0) \to \mathcal{F}(K)$ allows us to view an object defined over K_0 as also being defined over the larger field K. Any object $\alpha \in \mathcal{F}(K)$ in the image of this map is said to *descend* to K_0. The *essential dimension* $\mathrm{ed}(\alpha)$ is defined as the minimal transcendence degree of K_0/k, where α descends to K_0.

For simplicity we will assume that $\mathrm{char}(k) = 0$ from now on. Much of what follows remains true in prime characteristic (with some modifications).

Example 1. Let $\mathcal{F}(K)$ be the set of isomorphism classes of nondegenerate n-dimensional quadratic forms defined over a field K. Every quadratic form over K can be diagonalized. That is, q is K-isomorphic to the quadratic form $(x_1, \dots, x_n) \mapsto a_1x_1^2 + \dots + a_nx_n^2$ for some $a_1, \dots, a_n \in K^*$. Hence, q descends to $K_0 = k(a_1, \dots, a_n)$ and $\mathrm{ed}(q) \leqslant n$.

Example 2. Let $\mathcal{F}(K)$ be the set of equivalence classes of K-linear transformations $T\colon K^n \to K^n$. Here, as usual, K-linear transformations are considered equivalent if their matrices are conjugate over K. If T is represented by an $n \times n$ matrix (a_{ij}), then T descends to $K_0 = k(a_{ij} \mid i, j = 1, \dots, n)$, so that a priori $\mathrm{ed}(T) \leqslant n^2$. However, this is not optimal; we can specify T more economically by its rational canonical form R. Recall that R is a block-diagonal matrix $\mathrm{diag}(R_1, \dots, R_m)$, where each R_i is a companion matrix. If $m = 1$ and $R = R_1 = \begin{pmatrix} 0 & \dots & 0 & c_1 \\ 1 & \dots & 0 & c_2 \\ & \ddots & & \vdots \\ 0 & \dots & 1 & c_n \end{pmatrix}$, then T descends to $k(c_1, \dots, c_n)$ and thus $\mathrm{ed}(T) \leqslant n$. A similar argument shows that $\mathrm{ed}(T) \leqslant n$ for any m.

Example 3. Let $\mathcal{F}(K)$ be the set of isomorphism classes of elliptic curves defined over K. Every elliptic curve X over K is isomorphic to the plane curve cut out by a Weierstrass equation $y^2 = x^3 + ax + b$, for some $a, b \in K$. Hence, X descends to $K_0 = k(a, b)$ and $\mathrm{ed}(X) \leqslant 2$.

In many instances one is interested in the "worst case scenario", i.e., in the number of independent parameters that may be required to describe the "most complicated" objects of a particular kind. With this in mind, we define the essential dimension $\mathrm{ed}(\mathcal{F})$ of the functor $\mathcal{F}$ as the supremum of $\mathrm{ed}(\alpha)$ taken over all $\alpha \in \mathcal{F}(K)$ and all K. We have shown that $\mathrm{ed}(\mathcal{F}) \leqslant n$ in Examples 1 and 2 and $\mathrm{ed}(\mathcal{F}) \leqslant 2$ in Example 3. We will later see that, in fact, $\mathrm{ed}(\mathcal{F}) = n$ in Example 1. One can also show that $\mathrm{ed}(\mathcal{F}) = n$ in Example 2 and $\mathrm{ed}(\mathcal{F}) = 2$ in Example 3.

Essential Dimension of an Algebraic Group

Of particular interest are the Galois cohomology functors $\mathcal{F}_G$ given by $K \mapsto H^1(K, G)$, where G is an algebraic group over k. Here, $H^1(K, G)$ denotes the set of isomorphism classes of G-torsors (otherwise known as principal homogeneous spaces)

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over Spec(K). For many groups G this functor parametrizes interesting algebraic objects. For example, $H^1(K, \mathrm{O}_n)$ is the set of isomorphism classes of n-dimensional quadratic forms over K (in other words, $\mathcal{F}_{\mathrm{O}_n}$ is the functor of Example 1), $H^1(K, \mathrm{PGL}_n)$ is the set of isomorphism classes of central simple algebras of degree n over K, $H^1(K, G_2)$ is the set of isomorphism classes of octonion algebras over K, etc. (On the other hand, the functors $\mathcal{F}$ in Examples 2 and 3 are not of the form $\mathcal{F}_G$ for any algebraic group G.) The essential dimension of $\mathcal{F}_G$ is called *the essential dimension of* G and is denoted by $\mathrm{ed}(G)$.

Algebraic groups of essential dimension zero are precisely the *special groups*, introduced by J-P. Serre in the 1950s. An algebraic group G over k is called special if $H^1(K, G) = \{1\}$ for every field K/k. For example, SL_n and Sp_{2n} are special for every n. Over an algebraically closed field of characteristic zero, special groups were classified by A. Grothendieck. The essential dimension $\mathrm{ed}(G)$ may be viewed as a numerical measure of how much G differs from being special.

Symmetric Groups

Computing $\mathrm{ed}(\mathrm{S}_n)$ is closely linked to the classical problem of simplifying polynomials of degree n in one variable by a Tschirnhaus transformation and may be viewed as an algebraic variant of Hilbert's 13th problem [1]. In his 1884 "Lectures on the Icosahedron", F. Klein classified faithful finite group actions on the projective line $\mathbb{P}^1$ and used this classification to show that, in our terminology, $\mathrm{ed}(\mathrm{S}_5) = 2$. More generally, J. Buhler and I showed (by a different method) that $\mathrm{ed}(\mathrm{S}_n) \geqslant \lfloor n/2 \rfloor$ for any n, and $\mathrm{ed}(\mathrm{S}_n) \leqslant n - 3$ for $n \geqslant 5$; see [1]. Using these inequalities one easily finds $\mathrm{ed}(\mathrm{S}_n)$ for $n \leqslant 6$. For larger n the only additional bit of insight we have is via birational classifications of finite group actions on low-dimensional unirational varieties (over an algebraically closed field), extending Klein's original approach. In dimension 2 this yields $\mathrm{ed}(\mathrm{A}_6) = 3$ (due to Serre) and in dimension 3, $\mathrm{ed}(\mathrm{A}_7) = \mathrm{ed}(\mathrm{S}_7) = 4$ (due to A. Duncan). Serre's argument is based on the Enriques-Manin-Iskovskikh classification of rational G-surfaces, and Duncan's is based on the recent work on rationally connected G-threefolds by Yu. Prokhorov. In higher dimensions this approach appears to be beyond the reach of Mori theory, at least for now. The exact value of $\mathrm{ed}(\mathrm{S}_n)$ remains open for every $n \geqslant 8$.

Projective Linear Groups

The value of $\mathrm{ed}(\mathrm{PGL}_n)$ is intimately connected with the theory of central simple algebras. An important open conjecture, due to A. A. Albert, is that every division algebra of prime degree p is cyclic. Suppose that the base field k contains a primitive pth root of unity. Then the essential dimension of a cyclic division algebra is easily seen to be 2. Thus $\mathrm{ed}(\mathrm{PGL}_p) \geqslant 2$, and if this inequality happens to be strict for some p, then Albert's conjecture fails. The value of $\mathrm{ed}(\mathrm{PGL}_p)$ is 2 for $p = 2$ or 3 and is unknown for any other prime.

The problem of computing $\mathrm{ed}(\mathrm{PGL}_n)$ first arose in C. Procesi's pioneering work on universal division algebras in the 1960s. The inequality $\mathrm{ed}(\mathrm{PGL}_n) \leqslant n^2$ proved by Procesi has since been strengthened (see [3]), but the new upper bounds are still quadratic in n. In the 1990s B. Kahn asked if $\mathrm{ed}(\mathrm{PGL}_n)$ grows sublinearly in n, i.e., if there exists a $C > 0$ such that $\mathrm{ed}(\mathrm{PGL}_n) \leqslant Cn$ for every n. By the primary decomposition theorem we lose little if we assume that n is a prime power. Until recently, the best known lower bound was $\mathrm{ed}(\mathrm{PGL}_{p^r}) \geqslant 2r$. This has been dramatically improved by A. Merkurjev, who showed that $\mathrm{ed}(\mathrm{PGL}_{p^r}) \geqslant (r-1)p^r + 1$ for any prime p and any $r \geqslant 2$. In particular, this inequality answers Kahn's question in the negative. Surprisingly, essential dimension is not a Brauer invariant; there are central simple algebras A of degree 4 such that $\mathrm{ed}(\mathrm{M}_2(A)) < \mathrm{ed}(A)$. Little is known about essential dimension of Brauer classes.

Cohomological Invariants

Let G be an algebraic group over k. A cohomological invariant of G of degree n is a morphism of functors $\mathcal{F}_G \to H^n$, where $H^n(K)$ is the nth Galois cohomology group. The coefficient module can be arbitrary; in the examples below it will always be $\mathbb{Z}/2\mathbb{Z}$. (Observe that $H^n(K)$ is a group, whereas, in general, $\mathcal{F}_G(K) = H^1(K, G)$ has no group structure.) Serre noted that if k is algebraically closed and G admits a nontrivial cohomological invariant of degree n, then $\mathrm{ed}(G) \geqslant n$. Letting G be the orthogonal group O_n, so that $\mathcal{F}_G$ is the functor considered in Example 1, and applying the above inequality to the cohomological invariant $\mathcal{F}_G \to H^n(K)$ which takes a quadratic form $q = a_1x_1^2 + \cdots + a_nx_n^2$ to its nth Stiefel-Whitney class $(a_1) \cdots (a_n) \in H^n(K)$, we obtain $\mathrm{ed}(\mathrm{O}_n) \geqslant n$ and thus $\mathrm{ed}(\mathrm{O}_n) = n$ (we showed that $\mathrm{ed}(\mathrm{O}_n) \leqslant n$ in Example 1). Another interesting example, also due to Serre, is the degree 5 invariant of the exceptional group F_4, which gives rise to the inequality $\mathrm{ed}(F_4) \geqslant 5$.

Nontoral Finite Abelian Subgroups

Nontoral finite abelian subgroups first arose in the foundational work of A. Borel on the cohomology of classifying spaces for compact Lie groups. Nontoral finite abelian subgroups of algebraic groups were subsequently studied by T. Springer, R. Steinberg, R. Griess, and many others. In a special group such as SL_n, every finite abelian subgroup is contained in a torus. Ph. Gille, B. Youssin, and I generalized this as follows: if $A \subset G$ is a finite abelian subgroup, then $\mathrm{ed}(G) \geqslant \mathrm{rank}(A) - \mathrm{rank}(Z_G(A)^0)$. Here G is connected and reductive, $\mathrm{rank}(A)$ is the minimal number of generators of A, $Z_G(A)^0$ is the connected component of the centralizer of A in G, and the rank of $Z_G(A)^0$ is the dimension of its maximal torus. (Note that the above inequality is of interest only if A is nontoral; otherwise the right-hand side is $\leqslant 0$.) For example, the exceptional group $G = E_8$ has a self-centralizing subgroup $A \simeq (\mathbb{Z}/2\mathbb{Z})^9$; hence $\mathrm{ed}(E_8) \geqslant 9$. I am not aware of any other proof of the last inequality. In particular, no nontrivial cohomological invariants of E_8 of degree 9 are known.

Spinor Groups

Over the past few years there has been rapid progress in the study of essential dimension, based on an infusion of methods from the theories of algebraic stacks and algebraic cycles. These developments are beyond the scope of the present note; please see the surveys [2, 3] for an overview and further references. I will, however, mention one unexpected result that has come up in my joint work with P. Brosnan and A. Vistoli: it turns out that the essential dimension of the spinor group Spin_n increases exponentially with n. This has led to surprising consequences in the theory of quadratic forms. Note that $\mathcal{F}_{\mathrm{Spin}_n}$ is closely related to n-dimensional quadratic forms with trivial discriminant and Hasse-Witt invariant, very much in the spirit of Example 1, and that there are no high rank finite abelian subgroups in Spin_n to account for the exponentially high value of $\mathrm{ed}(\mathrm{Spin}_n)$. Are there high-degree cohomological invariants of Spin_n? We do not know.

Further Reading

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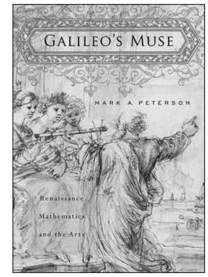
Galileo’s Muse: Renaissance Mathematics and the Arts



Reviewed by Anthony Phillips

Galileo’s Muse: Renaissance Mathematics and the Arts
Mark A. Peterson
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Galileo Galilei (1564–1642) is a pivotal figure in the development of Western science. Albert Einstein called him “the father of modern physics—indeed, of modern science altogether” [5]. More recently, Stephen Hawking wrote: “Galileo, perhaps more than any other single person, was responsible for the birth of modern science” [13].

Galileo’s trial and condemnation by the Inquisition in 1633 have become an international symbol of authority triumphing over knowledge. Since the issue was the structure of the solar system, the scandal has put in relief Galileo’s contributions to astronomy and cast into relative shadow the fundamental changes that he wrought in our intellectual approach to the natural sciences. These are surely what Einstein and Hawking refer to, and these are the subject of *Galileo’s Muse*.

Galileo’s stature as the father of modern science derives from his insistence on experiment as the way to verify hypotheses about nature and his recognition of mathematics as the medium in which hypotheses and experiments could be compared. As he says [7, Vol. 8, 212]:

> [reference to an experiment] is habitual and appropriate in those sciences which apply mathematical demonstrations to statements about nature, as we see with perspectivists, astronomers, mechanicians, musicians and others; they confirm their principles with experiments that may be perceived by the senses; these principles are the foundation for the whole ensuing structure.” [1]

We now know that advances in the sciences grow not only out of previous scientific work but also from the culture in which scientists live. Seeking out those roots in culture is especially interesting when the advances in question seem to break with scientific tradition. Gerald Holton, for example, set out “to explore how the cultural milieu Einstein found himself in resonated with and conditioned his science” [14]. He found a possible source of Einstein’s striving for uniform explanations of disparate phenomena in the influence of Goethe, a poet who had “an especially strong grip on the German imagination” of the day and who argued for “the primacy of unity in scientific thinking.”

Mark Peterson has carried out a similar program for Galileo. Rather than looking to literature, he maintains “that Galileo drew upon mathematical traditions in the arts in his scientific work.” (There is a powerful hint in the Galilean quotation above, which sets music and perspective on a par with astronomy and mechanics as experimental and mathematically deductive sciences.)

This review is organized to give an account of the main lines of Peterson’s argument, focusing more closely and more critically on the points most relevant to the development of mathematics. Full disclosure: I am a mathematician, which gives me a professional concern with scientific detail that may be out of place in judging a book written for a very wide audience, and I am also part Florentine,

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[1] *Translations from Italian are mine, except as noted. In this instance “experiments that may be perceived by the senses” for* sensate esperienze *differs from the “well-chosen experiments” that Peterson uses, following* [8]. *This conforms to the usage of the time* [6].

which gives me a personal interest in anything that concerns one of that city's most illustrious sons. I am not a historian of science. Some of the book's content, most notably the section on the *Oratio*, is possibly controversial in that context; I am not in a position to evaluate this material except to assess plausibility or nonplausibility for nonspecialists.

Peterson's strategy in *Galileo's Muse* is to sketch a selective panorama of the intellectual atmosphere in which Galileo developed, the late sixteenth century in Florence. Into this sketch is interpolated material about Galileo's life and scientific work, organized so as to highlight the effect of the artistic/literary milieu on the development of Galileo's scientific ideas.

Galileo's Muse begins with a section on Galileo as a humanist and on the classical legacy, those scientific works from (mainly Greek) antiquity that were available to Galileo and to his fellow scholars. Peterson reminds us that Galileo was the son of a musician and music theorist and that his early training was in the humanities. Galileo wrote elegant Latin, played the lute as well as any professional, developed an artistic taste so exquisite that the best painters of the period came to him for advice; his scientific career began only when he came upon Euclid, at about age twenty. Peterson might have added that Galileo was a connoisseur of literature and is still considered to be one of the best writers of Italian prose, if not the best of all.

There follow four two-chapter sections on the arts: Poetry, Painting, Music, Architecture. The book ends with three additional chapters and an epilogue. Two of those chapters cover the mathematics and science of the period and summarize how Galileo's humanist formation helped him transform them. The last concerns a document, the *Oration in Praise of Mathematics*, by Galileo's student Niccolò Aggiunti, which seems to reflect Galileo's thought and may even contain his own words. The epilogue is a brief examination of the Copernican controversy as seen in the context of Galileo's entire scientific life.

Peterson's "Poetry" section is mostly a search for mathematical elements in Dante's *Paradiso*. This is of interest in itself but does not seem to have any direct bearing on the subject of the book. I'll only say that I find his interpretation of the transcendental end of the poem in terms of the irrationality/unconstructability of π intriguing but too far-fetched to be useful.

The Visual Arts: Perspective, Error and *Chiaroscuro*

The great changes in art that occurred during the Renaissance included a new, quantitative approach to the visual world. As Peterson tells us, Filippo Brunelleschi was not satisfied with reading about classical proportions in Vitruvius: he went to Rome in 1405 and measured the remaining monuments. Leon Battista Alberti's *Della Pittura* (1435) gave a detailed explanation of how to draw a pavement correctly in perspective. It involved measuring the distance from the "eye" to the picture-plane and using that distance in a plane-geometric construction. Galileo trained as an artist and knew the perspective construction. In fact, the distinguished painter Cigoli (Lodovico Cardi, 1559–1613), a close lifelong friend, maintained that Galileo had taught him all the perspective he knew.

So art had become to some extent imbued with mathematics: mostly geometry, but with some actual measurement. Peterson suggests we look at it the other way: Renaissance art contributed to pulling geometry out of its abstract, platonic existence and into close contact with the real world of working artists; Galileo was part of this process. At the same time, as Peterson points out, artists like Piero della Francesca were explicitly aware of the accommodation necessary when applying a perfect theory to an imperfect medium; Peterson reasons that this sensibility was incorporated by Galileo into his understanding of the unavoidable error in any measurement (see below).

Peterson also remarks that Galileo's proficiency as an artist would have entailed a knowledge of *chiaroscuro*, the technique of using shading to convey relief. The training would have helped him correctly interpret the patterns of light and dark he observed on the surface of the moon as indications that the moon, far from being smooth, had mountain ranges and deep valleys. This line of thought appears, considerably elaborated, in a 1984 article by Samuel Edgerton [4], who writes, "I shall argue that we have here a clear case of cause and effect between the practice of Italian Renaissance Art and the development of modern experimental science."

Music: Tension on Strings

Galileo was closely tied to the contemporary community of artists, but his links to the world of music and music theory were even tighter. His father, Vincenzo Galilei (c. 1520–1591) was a renowned performer on the lute and a prominent music theorist; Marin Mersenne defers to him [18] in his 1625 *La Vérité des Sciences*. Most of Vincenzo's theoretical publications were devoted to the vexing and age-old problem of tuning.

The diatonic scale (our *do-re-mi-fa-sol-la-ti-do* or one of its cyclic permutations) was known to the Babylonians [16]; our names for the tones are more recent. The diatonic scale has five whole steps, *do-re-mi* and *fa-sol-la-ti*, along with two half steps, *mi-fa, ti-do*. Babylonians also had identified the most consonant musical intervals: the octave (eighth), the fifth, and the fourth, named for their span (8, 5, or 4 notes in the diatonic scale, starting from *do*). The Pythagorean discovery that these three intervals correspond to notes sounded by strings (of equal composition and tension) with length ratios 2:1, 3:2, and 4:3 brought music and mathematics together. But the alliance was always uneasy. Mathematicians wanted to make every interval correspond to a ratio of whole numbers. For example, the difference between the fourth and the fifth, i.e., the interval *fa-sol*, had to correspond to the ratio 9:8 (since $\frac{9}{8} \cdot \frac{4}{3} = \frac{3}{2}$). Since $\frac{9}{8}$ is not a perfect square, there was no rational way to make *mi-fa* half of *fa-sol*. And if some ratio of magnitudes could be found for *mi-fa*, there was still a problem, since $(\frac{9}{8})^6 \neq 2$. Many, many solutions were tried; all had to fall short somewhere. Artistic and technological progress in Europe (polyphony, placement of frets on lutes, tuning of harpsichords) meant that the theoretical tuning problems of antiquity had serious practical consequences. Peterson surveys this situation in some detail.

Vincenzo Galilei was an enthusiastic participant in the theoretical musical ferment of the day, but with a difference. In his writings on tuning, he constantly refers to *esperienza*, which sometimes means "experience" and sometimes definitely means "experiment". For example, in his 1589 *Discorso …* [10, p. 128] he writes, concerning the acoustical properties of metal strings versus gut: "Everyone can verify this as he pleases by experiment."

Vincenzo's experiments went beyond tinkering with instruments into a full-scale test of a physical law. Here the scientific innovation was profound enough (it made Vincenzo perhaps the first experimentalist in the history of European science [2]) that people have wanted to see Galileo involved in the process. One must keep in mind that Vincenzo and Galileo never mentioned each other in their published writings and that in Viviani's and Niccolò Gherardini's biographies [7, Vol. 19], which present themselves as based on conversations with Galileo, there is no mention of musical experiments at all; we only know that Galileo was living at home in the years directly before Vincenzo published the *Discorso* and that Galileo inherited Vincenzo's papers. Whether or not father and son performed these experiments together, as Peterson suggests, the story is worth repeating.

It had been thought throughout the Middle Ages that to raise the note produced by a plucked string to a note one octave higher, one could shorten the length by one-half *or double the tension*. The tension part was (probably incorrectly) attributed to Pythagoras by authorities of the late Roman Empire: Boethius, Macrobius, and Nichomachus, who wrote [17, p. 84]: "The weight on one string was twelve pounds, while on the other was six pounds. Being therefore in double ratio, it produced the octave, the ratio being evidenced by the weights themselves." Vincenzo challenged this statement in the *Discorso* [10, p. 104]: "Experiment…shows us that he who from two strings of equal length, thickness and quality would want to hear the Diapason [the octave], would need to hang from them weights that were not in the double…but in the quadruple proportion. The fifth will be heard whenever from the same strings one hangs weights in proportion 9:4 (*dupla sesquiquarta*), the fourth from those which would be [in proportion] 9:16 and the whole tone 9:8 from the [proportion] 64:81." On the next page, criticizing another traditional belief, he wrote: "This doctrine was published as the truth by Pythagoras, a man of very great authority; it was so well believed that even today it is accepted by some, who seek no further, satisfied just by Pythagoras having said it."

Vincenzo reported an additional experiment in one of the three essays, unpublished until recently [11], written after the *Discorso* and thus in the period 1588–1591. He reported that "the same thing [hearing the octave] will happen if equal weights are suspended from strings the thicknesses of which are in quadruple proportion, provided the length and goodness are the same."

Galileo's *Two New Sciences* was published some forty years after the experiments his father described. The late music historian Claude Palisca, after speculating on whether Vincenzo influenced Galileo or vice-versa, wrote, "While the possibility of such an influence is only conjectural, it is a striking fact that Galileo, in the section on consonances in the *Dialogues Concerning Two New Sciences*, repeats in the conversation between the two interlocutors, Sagredo and Salviati, the thought process that is documented in the discourses of Vincenzo Galilei" [18]. Galileo has Sagredo run through the relations between pitch and length, tension or thickness and justify them by reference to "true (*verissime*) experiments", but with no reference to where, by whom, or exactly how those experiments were carried out. In particular, Sagredo asserts that substituting a string of one fourth the thickness will give a note one octave higher. (Note that "thickness" must be interpreted as cross-sectional area for this to be correct). Salviati later suggests an improvement: the higher string should have one fourth the *weight*; this refinement obviates the thickness/cross-section

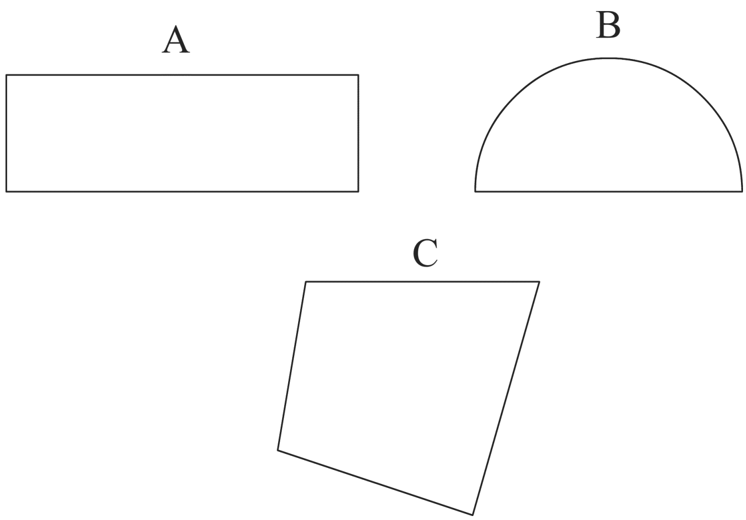

Figure 1. Galileo's illustration of three "magnitudes of the same type".

ambiguity and allows the rule to be applied to strings of different material. Galileo also goes beyond his father's experiments in relating pitch to frequency and in explaining the perception of consonance in terms of coherent vibrations of the eardrum.

From the evidence, to say that Galileo drew upon mathematical traditions in music theory would be a substantial understatement. He grew up exposed to reliance on physical experiment and also to the willingness to challenge traditional authority. This was in the domain of music theory, but the principles have wide application. Galileo spoke of his father's experiments as if they were his own and integrated them into his thought about periodic motion in general. On the other hand, the importance of the legacy of his father's scientific attitude towards tradition cannot be precisely gauged but should not be underestimated.

The Legacy of Antiquity

There is a substantial difference between the mathematics of 1500 and that of 1650. While algebra maintained a steady course through those times, the mathematics of magnitude changed radically. From a strictly mathematical viewpoint, the account of Galileo's participation in this change is the central part of *Galileo's Muse*, because it is part of the process by which we came to grips with real numbers.

The problem of how to extend arithmetic to quantities which might not be rational had already preoccupied the Greeks. Euclid's Book V, Definition 5, traditionally attributed to Eudoxus, states what it means for two *ratios of magnitudes* to be equal:

> Magnitudes are said to be in the same ratio, the first to the second and the third to the fourth, when, if any equimultiples whatever be taken of the first and third, and any equimultiples whatever of the second and fourth, the former equimultiples alike exceed, are alike equal to, or alike fall short of, the latter equimultiples respectively taken in corresponding order.

In modern symbols, the definition of $\alpha : \beta = \gamma : \delta$ becomes

$$\forall\ m, n \in \mathbf{N}\ m\alpha \ \substack{>\\=\\<}\ n\beta \Leftrightarrow m\gamma \ \substack{>\\=\\<}\ n\delta.$$

Anachronistic replacement of β and δ by the unit gives

$$\forall\ \frac{n}{m} \in \mathbf{Q}^+\ \alpha \ \substack{>\\=\\<}\ \frac{n}{m} \Leftrightarrow \gamma \ \substack{>\\=\\<}\ \frac{n}{m},$$

suggestive of the modern definition of reals in terms of rationals *via* Dedekind cuts.

This definition did not have a smooth journey through the following centuries. As Peterson tells us [20, p. 43], it was badly garbled in the early translations into Arabic, and the ensuing nonsense assumed mystical significance during the Middle Ages. A correct rendition did not appear until around 1500 in Bartolomeo Zamberti's translation from the Greek, in time to be available to Galileo. Galileo considered it important enough to merit a long gloss in the projected Day Five of *Two New Sciences*, where he explains the composition of proportions using this example (Figure 1):

> Imagine two magnitudes A, B of the same type; the magnitude A will have a certain proportion to B; and now imagine another magnitude C placed amongst them, also of the same type: whatever proportion the magnitude A has to B is said to be composed of the two intermediate proportions, i.e., of that one which A has to C and of that one which C has to B" [7, Vol. 8, p. 360].

Galileo's choice of figures forces his readers to think of magnitudes, and their ratios, as having their own existence beyond the arithmetic of the counting numbers.

When he comes to physical laws, Galileo states them in terms of equality of ratios of magnitudes. The late Galileo scholar Stillman Drake considered this a drawback: "The price Galileo paid for rigor in the avoidance of algebra and the use of Eudoxian proportion theory was that his mathematical physics was restricted to comparisons of ratios" [9, Introduction, p. xxiii]. I believe this is a misunderstanding. Galileo measured time intervals using a water clock. There was no useful unit of time available to him, but working with a constant flow allowed him to correctly reckon the relative lengths of time intervals, exactly what he needed for a concise formulation of his law of falling bodies. The advantage of equations and functions in the development of calculus and in the full elaboration of laws of motion lay in the future.

The relations between ratios that Galileo published were based on ratios of measurements he had carried out. Folio 117v[2] in the collection of his manuscript notes in the Biblioteca Nazionale Centrale in Florence—first published in 1973 by Stillman Drake (see [3]; he dates it to 1608)—gives a nice example. In this experiment the inputs were the heights (300, 600, 800, 828, 1000 *punti*; a *punto* is slightly less than a millimeter) at which a ball was released to roll down a track. At the end of the track the ball was deflected to the horizontal and allowed to fall to the floor, 828 *punti* below. The outputs were the horizontal distances (800, 1172, 1238, 1340, 1500 *punti*) the ball had traveled after leaving the track and before hitting the ground. Galileo's theory of uniform acceleration due to gravity predicted that if H_1, H_2 were two release heights, D_1, D_2 the corresponding horizontal traces, then the ratio $D_1 : D_2$ should be the same as the ratio $\sqrt{H_1} : \sqrt{H_2}$. He used the first output measurement (800) to predict what the other four should be; he recorded in his notes the predicted values, the measurements, and the differences: 41, 22, 11, 40. Galileo famously wrote in *Il Saggiatore* that the book of nature is "written in mathematical language, and the characters are triangles, circles and other geometric figures…" [7, Vol. 6, p. 232]. What he did not write (the words did not then exist), and what this experiment beautifully exemplifies, was that the link between the geometric figures of theory and the book of nature as manifested in the laboratory was the exacting measurement of magnitudes in terms of real numbers.

There are in fact very few numbers in *Two New Sciences*, and those are all integers. Most of them are in Day Four, which contains three tables giving properties of trajectories with initial angles ranging from 1 to 89 degrees. Two of them give the height and the width of a semiparabola, assuming a constant initial velocity that is chosen so that initial angle 45° gives range 10000 (the units are not mentioned). The third gives the energy required to achieve the range 10000, assuming that initial angle 45° will require the kinetic energy of a fall from 5000 of the same units. Although the entries in the table are whole numbers, their large size guarantees several significant digits most of the time. In the first table, for example, the values go from 349 (for 1° and 89°) and 698 (for 2° and 88°) to 10000, with all the other angles giving four digits. This practice is congruent with the format of the mathematical tables of the time. In the table of tangents that Galileo used for the first table, the tangent of 45° was recorded as 10000, as he tells us. James Napier's use of the decimal point in his 1614 table of logarithms is said to have contributed to its rapid diffusion throughout Europe [15], but he used it sparingly: he records the sine of 90° as 1000000.0.

There is one work of Galileo's that he may have planned to publish but never did and that shows him at work with what are essentially finite decimals. Along with his 1596 *La Bilancetta*, he prepared two tables listing samples of various substances with their weights in air and in water. These tables were not published during his lifetime but are appended to *La Bilancetta* in Volume 1 of [7]. Let's call the two weights w_1 (in air) and w_2 (in water); the weights are recorded in *grani* (1 *grano* = 0.049g [1]) as integers plus a fraction, with denominators mostly low powers of 2. To be comparable, the pairs of weights are all normalized to have weight in air equal to 576, the weight of Galileo's Gold sample. Normalized relative weights $576 \times w_2/w_1$ are computed for seventeen of the samples. Of those, thirteen have denominator 100, two have denominator 60, one has denominator 2, and one is whole. For me, the predominance of denominator 100 strongly suggests that Galileo was carrying long division past the units and recording the next two digits with rounding. For example, one sample of copper has $w_1 = 179\frac{9}{16}$ and $w_2 = 159$. Division yields $576 \times w_2/w_1 = 510.039\ldots$; Galileo records $510\frac{4}{100}$.[3]

These three examples show Galileo at work with numbers. In the first the *punto*, his unit of length, is small enough with respect to the scale of his experiment for three or four significant figures to be achieved by whole numbers of *punti*. In the second his use of a trigonometric table with $\tan 45° = 10000$ similarly allows four significant figures from whole numbers. In the third we see decimal fractions with denominator 100 and again four or five significant figures. Why did Galileo, writing in 1638, never use the decimal point? It had been over twenty years since Simon Stevin's logarithmic tables; Galileo's friend Clavius

[2] *The page is reproduced in* [3]. *An interactive image is now available through the Biblioteca Nazionale Centrale via the Museo Galileo in Florence and the Max Plank Institute for the History of Science in Berlin,* `http://www.imss.fi.it/ms72/INDEX.HTM`.

[3] *Galileo records* $510\frac{15}{100}$ *and* $510\frac{75}{100}$ *for two other measurements from this sample and another. Peterson asserts that "Galileo only scaled the first sample in each pair [of samples]. Not scaling the second one, as if to avoid the embarrassment of seeing how different it was, is a bit odd, but psychologically not hard to understand." In this one case, his account is incorrect.*

had published a table with decimal points as far back as 1593 [12]. The answer may well be that he did not need it. One can speculate that he was leery of a notation that implied a possible infinity of digits trailing off to the right, but as far as I know there is no evidence one way or the other. Galileo's published works stay on traditional, solid ground with whole numbers and proportions of magnitudes, while his notebooks and his table of densities show the essential role that measurements, reported in numbers, played in his scientific work.

This is a different view of Galileo's mathematical position from that proposed in *Galileo's Muse*. Peterson emphasizes Galileo's use of proportions in lieu of numbers. "The notion of proportion, central in all the arts, took on a new significance in Galileo's work" [20, (p. 289)]. This statement has an additional problem: "proportion" in the arts means linear proportion; the proportions that Vincenzo and Galileo used, of one number with the square root or the $\frac{3}{2}$ power of another, do not make artistic sense. It is true that "is proportional to" is an essential connector in physics, but such proportionalities as $\ddot{x} \sim -\sin(x)$, the equation for the pendulum, are not those that artists consider; adding a friction term to produce $m\ddot{x} + k\dot{x} + a\sin(x) = 0$ generalizes proportions to linear combinations, which are still only special cases of equations of motion. So calling physics "the science of proportionalities in nature", as Peterson does (p. 291), is not completely appropriate.

The Architecture of Dante's *Inferno*: Scaling Problems

One of Galileo's most penetrating observations concerns scaling. This is in fact the first of the "Two New Sciences". As Peterson presents it, Galileo argues that the weight of a beam scales as its volume, but its strength as its cross-section, and concludes that any beam, scaled up geometrically, will eventually collapse under its own weight.[4] He extends the lesson to biology: "Nature could not make a horse as large as twenty, or a giant ten times as tall as a man, except either by miracle or by substantially changing the proportions of the limbs, and in particular of the bones, making them much, much thicker than ordinary ones" [7, Vol. 8, pp. 52–53]. Peterson relates this insight to Galileo's work on the architecture of Hell, as organized and depicted by Dante in the *Inferno* section of the *Divine Comedy*.

Here are the relevant facts that are known today.

- Galileo gave two lectures in 1588 to the Florentine Academy, where he defended the model of Dante's Hell due to Antonio Manetti (1423–1497). Manetti had given a mathematically precise description of its location, extent, and structure. The overall shape was a cone with vertex at the center of the Earth, axis passing through Jerusalem and radius one twelfth of the earth's circumference, some 2,000 of our miles. The cone was essentially hollow (the Circles of Hell were terraces around the interior), with a roof some 500 miles thick. The lectures were very well received. In one of the lectures he argued from a scale model that the roof of Hell would be perfectly stable.
- In 1589 Galileo began a professorship at Pisa (controlled by Florence since 1509). He was appointed by Grand Duke Ferdinand I after being highly recommended by Guidobaldo dal Monte, a marquis and a well-respected mathematician.
- In 1592 Galileo was named professor of mathematics in Padua in the Venetian Republic. "In his first years there he…consulted for the Venetian Arsenal concerning the placement of oars on large ships" [20, p. 229].
- In 1594 Luigi Alamanni tried without success to have Galileo send him a copy of the *Inferno* lectures.
- In 1609 Galileo wrote to Antonio de' Medici: "And just lately I have succeeded in finding all the conclusions, with their proofs, pertaining to forces and resistances of pieces of wood of various lengths, sizes, and shapes, and by how much they would be weaker in the middle than at the ends, and how much more weight they can sustain if the weight were distributed over the whole rather than concentrated at one place, and what shape wood should have in order to be equally strong everywhere: which science is very necessary in making machines and all kinds of buildings, and which has never been treated before by anyone." (Translation from [19]; this item is not mentioned in *Galileo's Muse*.)
- Galileo's first biographer, Vincenzo Viviani, who lived "in Galileo's house during his last years, collecting Galileo's stories" [20, (p. 230)] does not mention the *Inferno* lectures.

[4] *More specifically, Galileo argues with moments, and concludes that the strength is proportional to the diameter cubed and inversely proportional to the length. This is what is taught today, except that for rectangular beams, instead of diameter cubed we have width times the square of the height.*

- In 1638 Galileo published *Two New Sciences*, where the scaling of the strength with respect to linear dimensions is discussed in detail. He introduces the topic at the start of Day 1: his interlocutors are, or just were, at the Venice Arsenal and ponder what they had heard from one of the workmen in charge ("that good old fellow"): a large military galley under construction was in need of extra support to prevent "its breaking its back under the huge weight of its own vast bulk, a trouble to which smaller craft are not subject" [7, Vol. 8, pp. 49–50].
- When Galileo's stand-in, Salviati, explains that "there is a limit [in size] beyond which neither nature nor art can exceed: exceed, I say, while always keeping the same proportions and the same material," his interlocutor Sagredo reacts emotionally: "I feel my brain turning over and, like a cloud suddenly opened by lightning, my mind being flooded by a momentary and unusual light." [7, Vol. 8, pp. 49–50].

Peterson interprets the circumstantial evidence here quite reasonably. Galileo's defense of Manetti had been terribly flawed: the posited roof of Hell would have collapsed instantly under its own weight; he would have realized the error after moving to Padua, perhaps literally at the Venetian Arsenal. Since the *Inferno* lectures came just before he assumed his professorship at Pisa, knowledge of the error would have been extremely embarrassing to him and to his sponsors. That prospect would have concentrated his mind to work out the theory correctly; at the same time he would have done his best to avoid any further attention being paid to the lectures. One incongruity is Peterson's suggestion that the analysis may have been done "very soon after the Inferno Lectures;" this contrasts with the "recently" in Galileo's 1609 letter to Antonio de' Medici. It is also unfortunate that no reference is given for Peterson's assertion about Galileo's consulting for the Arsenal during his first years in the Venetian Republic. But this does not detract from the main point: it is very plausible that the detailed study of the architecture of Hell led Galileo to his trail-blazing study of strength of materials and of scaling laws.

The *Oration in Praise of Mathematics*

The *Oration* was written in Latin under the name of Niccolò Aggiunti and published in 1627. Peterson advances and defends the hypothesis that this work not only reflects the thoughts of Galileo (Aggiunti, twenty-seven years old at that time, had been "a devoted follower of Galileo for four years") but in many places reproduces the words of the master himself. Peterson's arguments are manifold and quite convincing (at least to me). Nevertheless, the *Oration* was not chosen by Antonio Favaro, the editor of Galileo's twenty-volume complete works, for inclusion in that series even though Favaro did include many ancillary documents besides Galileo's own writings. Some of Peterson's most compelling evidence comes from the *Oration* itself. Here is one of several quotations from the work:

> All earthly objects show forth the divine mathematics to those who observe them with close attention. They proclaim with utmost clarity that God is the Archgeometer: the movements of the stars; the balance of the earth; the absorption by plants of moisture from the ground through fibrous pipes; the penetration of the moisture to the leaves by means of veins running through the whole trunk and branches; the swimming, flight and crawling of fishes, birds and reptiles—obviously a subtle hidden mathematics underlies all these phenomena.

As Peterson remarks, "The Orator flatly contradicts Ptolemy's sharp distinction between philosophical mathematics and earthly physics," an opinion that "would be someday unremarkable but was close to unthinkable in 1627" and not what one might expect from "a young professor of mathematics".

Comparison of this passage with, say, the "Fable of the Sounds" in *Il Saggiatore*, keeping in mind the several translations involved,[5] makes it quite plausible that we are listening to Galileo's own twice-filtered voice.

Whether or not we accept the *Oration* as completely Galilean, it is hard not to enjoy the Orator's enthusiastic account of how "charming, thrilling and useful" it is to use a microscope, quoted at length by Peterson on p. 282.

Exposition, Divulgation, and the Appropriateness of Accuracy

Galileo's Muse is a good read. The style is comfortably conversational,[6] veering only occasionally into the colloquial. The book bubbles with ideas, insights, and delicious bits of historical detail. Most mathematicians will be amazed to learn that

[5] *Hypothetically, Aggiunti translated Galileo's Italian into Latin; this translation into English is due to Philippa Gould.*
[6] *The text is abundantly but discreetly footnoted; the notes are gathered at the back of the book and grouped by page number, an excellent practice.*

Dante's model for the entire universe was topologically a 3-sphere, with God and Satan at the poles; it's all spelled out in *Paradiso*, Canto XXVIII.

The easy reading and the immediacy of the story come at a price. In *Galileo's Muse* there is a hypothetical sentence on almost every page, usually correctly characterized as such. There are also hundreds of real facts, references, quotations from the period, and historically documented occurrences. The reader must constantly remember whether we are in "did" or "must have done" territory. Most of the time this is not a problem, but in places the boundary becomes fuzzy. The student reading "Pythagoras used his knowledge benevolently,…" (p. 168) may forget the "according to stories" seven sentences before and may not realize that almost nothing is known about the historical figure Pythagoras, certainly not whether he used his knowledge benevolently. This sentence, as well as "Pythagoras discovered the small integer ratios in music" on the next page, has to be interpreted as a statement about a semimythical figure. Similarly (I referred to this point earlier), when reading about Vincenzo Galilei's musical experiments with strings and weights, we find "His son Galileo…must have participated in these experiments." The "must have" is a red flag, of course. But then we read, "they repeated the experiments …," "they found…," "they had to quadruple the weight…," "[Galileo's] first encounter with the issue of measurement uncertainty must have been this experiment in music," "the Pythagorean experiments on tension and musical pitch that Galileo conducted with his father…" (p. 257), as if it were a known fact that Galileo took part in his father's experiments. But it is not.

Scientists writing for a general audience, especially about the history of science, are in dangerous territory. Data are often lacking, the existing data are often unreliable, but the methods and logic have to be airtight; when they cannot be so, this circumstance should be fully understood by the reader. How to achieve this understanding without weighing down the text with a noxious drone of caveats is a conundrum. But creating false impressions must be avoided.

Readers of *Galileo's Muse* may expect, from the subtitle, a survey of the arts and mathematics in the Renaissance. I spoke above of a selective panorama; in fact, the choice of topics is somewhat more haphazard. Besides material that is germane to the thesis of the work, some is included just because it makes such a good story (the topology of Paradise mentioned above or the Cardano-Tartaglia *imbroglio* or speculation about what Luca Pacioli and Leonardo da Vinci actually thought of each other). But it is a good story and gives the reader a lively introduction to a period of ferment in art, music, and mathematics, and to Galileo, whose wide-encompassing intellect brought them all together.

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Science Lives: Video Portraits of Great Mathematicians

> In mathematics, beauty is a very important ingredient… The aim of a mathematician is to encapsulate as much as you possibly can in small packages—a high density of truth per unit word. And beauty is a criterion. If you've got a beautiful result, it means you've got an awful lot identified in a small compass.
>
> *—Michael Atiyah*

Hearing Michael Atiyah discuss the role of beauty in mathematics is akin to reading Euclid in the original: You are going straight to the source. The quotation above is taken from a video of Atiyah made available on the Web through the Science Lives project of the Simons Foundation. Science Lives aims to build an archive of information about the main developments in mathematics in the twentieth century, recounted by some of the people responsible for those developments. Through videotaped conversations and biographical narratives, Science Lives provides engrossing personal glimpses of a vibrant field and the people who have shaped it.

The foundation hopes to create a comprehensive, lasting resource that will be widely available to students of mathematics and to the public. It is anticipated that the series will eventually be broadened to include interviews with luminaries across all the basic sciences.

So far, twenty-five videotaped conversations have been made, and as of August 2012 nine have been posted on the site. The videos were made by George Csicsery, a filmmaker who has created several acclaimed documentaries about mathematicians. His hand in making the videos is unmistakable, not only in the quality of the images and sound but also in the aesthetic choices of camera angle and background. For each video there are links to biographical materials available on the Web. In addition, some of the videos are accompanied by narrative profiles written by noted mathematics biographers.

Hugo Rossi, director of the Science Lives project, said that the first criterion for choosing a person to profile is the significance of his or her contributions in "creating new pathways in mathematics, theoretical physics, and computer science." A secondary criterion is an engaging personality. With two exceptions (Atiyah and Isadore Singer), the Science Lives videos are not interviews; rather, they are conversations between the subject of the video and a "listener", typically a close friend or colleague who is knowledgeable about the subject's impact in mathematics. The listener works together with Rossi and the person being profiled to develop a list of topics and a suggested order in which they might be discussed. "But, as is the case with all conversations, there usually is a significant amount of wandering in and out of interconnected topics, which is desirable," said Rossi.

The videos have an intimate, relaxed feeling and convey a clear sense of personality. The conversations were carried out in places of comfort to the subject, Rossi said: for John Nash, in old Fine Hall at Princeton University; for Pierre Deligne, in the library at the Institute for Advanced Study; for Yuri Manin, in his home. "We have learned from Csicsery that the environment is a very important factor in the quality of the conversation," Rossi noted.

The conversations cover topics of interest to the people being profiled, consistent with the goal of providing insight into mathematical developments of the twentieth century. The technical level of the conversations therefore varies according to the interests of the profile subjects and the topics discussed. The amount of personal material also varies according to how much the profile subjects wish to discuss their personal lives. The videos are organized into short chapter-like sections with descriptive titles so that viewers can steer to the conversational threads they will find most interesting. There are also keys that delineate general themes, such as history, philosophy, mathematics, and the mathematics profession; asterisks indicate parts that are more technical. The total time of each interview is about two hours.

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Science Lives Conversations

Videos available on the Science Lives website (https://simonsfoundation.org/mps-science-lives):

Michael Atiyah

Egbert Brieskorn (listener: Anna Pratoussevich)

Pierre Deligne (listener: Robert D. MacPherson)

Friedrich Hirzebruch (listener: Matthias Kreck)

Robert D. MacPherson (listener: Robert Bryant)

Yuri Manin (listener: David Eisenbud)

Paul J. Sally Jr. (listener: Diane Hermann)

Isadore M. Singer

Chen-Ning Yang (listener: George Sterman)

... And More To Come

Conversations with the following individuals have been filmed and are in the editing stages.

Alfred Aho (listener: Mihalis Yannakakis)

Alexandre Chorin (listener: Jamie Sethian)

William Browder (listeners: Alejandro Adem, Andrew Ranicki, and Sylvain Cappell)

John H. Conway (listener: Alex Ryba)

Michael Freedman (listener: Robion Kirby)

Phillip Griffiths (listener: Mark Green)

Mikhail Gromov (listener: Alfredo Hubard)

Richard Karp (listener: Christos Papadimitriou)

Robion Kirby (listener: Michael Freedman)

Peter Lax (listener: Robert Kohn)

Laszlo Lovasz (listener: Avi Wigderson)

Cathleen Morawetz (listeners: Marsha Berger and Margaret Wright)

John Nash (listeners: Harold Kuhn and Charles Fefferman)

Louis Nirenberg (listener: Jalal Shatah)

James Simons (listener: Jeff Cheeger)

Elias Stein (listeners: Charles Fefferman)

S.R. Srinivasa Varadhan (listener: Jalal Shatah)

By providing a vivid and personal look at some of the great recent developments in mathematics, Science Lives helps to bring human faces to a subject that is often seen as impersonal and forbidding. It is an inspiring and edifying resource for mathematicians, students, and the general public.

— Allyn Jackson

About the Simons Foundation

The Simons Foundation was established in 1994 by mathematician and investor James Simons and his wife, Marilyn. The foundation's mission is to advance the frontiers in research in mathematics and the basic sciences.

The Simons Foundation has supported many institutions and individuals in the mathematical sciences around the globe. It has helped fund the building of lecture facilities at the Mathematical Sciences Research Institute in Berkeley and at the Institut des Hautes Études Scientifiques outside Paris as well as the creation of the Simons Center for Geometry and Physics at Stony Brook University. In 2010 the foundation launched its Mathematical and Physical Sciences program, which awards grants via open application procedures and also supports the Science Lives project. The latest addition to the program is the Africa Mathematics Project, intended to bolster mathematics scholarship on the African continent. In addition to Science Lives, the foundation's website offers a series of articles and videos of interest to mathematicians, including the Simons Science Series, Simons Symposia, and the videos of George Hart.

The foundation also supports research in the life sciences and autism research.

Please visit the website simonsfoundation.org for more information.

Applications Wanted: NSF Graduate Research Fellowships

Meredith Berthelson and Jennifer Slimowitz Pearl

Many students getting ready to graduate with their baccalaureate degree contemplate graduate studies or are planning to continue their education. One of the major obstacles can be funding: students who have just finished their undergraduate education may not want to add more tuition bills to the pile. If only there were a way to help them continue their education and execute some of the research that they wish to do. Ah, but there is! One of the most valuable funding mechanisms for mathematics and statistics graduate students is the National Science Foundation's (NSF) Graduate Research Fellowship Program (GRFP). The director of the Division of Mathematical Sciences at NSF, Sastry Pantula, stated, "[The] NSF Graduate Research Fellowship (or an Honorable Mention in the competition) is certainly a feather in any future scientist's cap! There are many well-qualified mathematics and statistics students in this country, and I would love to see many, many more of them take advantage of this excellent opportunity."

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What are the key elements of the fellowship? It is a five-year award that is worth US$126,000. The NSF Graduate Fellow receives three years of support (usable over a five-year period). For each of these three years, the Fellow receives a US$30,000 stipend, and the graduate institution receives a US$12,000 educational allowance to cover tuition and all required fees. The Fellow also has access to international research opportunities and to supercomputing resources.

To be eligible, an applicant must be either a U.S. citizen, national, or permanent resident and be an early-career graduate student pursuing a research-based master's or doctoral degree in an NSF-supported field. In mathematical and statistical sciences, the following categories are included: Algebra, Number Theory, and Combinatorics; Analysis; Applied Mathematics; Biostatistics; Computational and Data-Enabled Science; Computational Mathematics; Computational Statistics; Geometric Analysis; Logic or Foundations of Mathematics; Mathematical Biology; Probability; Statistics; Topology; or Other (related fields not included in the list). Applicants must be planning to enroll in an accredited institution in the United States by the fall following the announcement of the award. Anyone who has already received a graduate degree is not eligible.

Adam Kapelner, Nicholas Brubaker, and Gina-Maria Pomann, three current NSF Graduate Fellows, hammer home the importance of some of these requirements. Adam received his bachelor's degree in mathematics and computer science at Stanford University and is currently working on his Ph.D. in

Tips for Students

To enter the competition, you need to submit a complete application via NSF FastLane (`https://www.fastlane.nsf.gov/grfp`). The application consists of a personal statement, description of previous research experience, proposed plan of research, and transcripts. In addition, three letters of reference must be submitted separately via FastLane by the reference writers. Reviewers evaluate the applications on the basis of the two National Science Board criteria: Intellectual Merit and Broader Impacts. For Intellectual Merit, you will need to demonstrate your academic capability and other conventional requisites for scholarly, scientific study. Details such as the ability to plan and conduct research, work on a team as well as independently, and interpret and communicate research are useful. To demonstrate Broader Impacts, convey how your research will contribute on a larger scale to society and the breadth of its audience. Will it encourage diversity, broaden opportunities, and allow participation of all citizens in science and research? If so, this should be evident to the reviewer. Examples of Broader Impacts activities may be accessed at `http://www.nsf.gov/pubs/gpg/broaderimpacts.pdf`.

When preparing the application, you should be clear and specific so that the reviewer doesn't struggle as he or she is reading the application. Describe your experiences—whether they are personal, professional, or educational—that have been factors in your preparation and that have driven you to pursue graduate study. Be detailed about your involvement in any scientific research activities and what you learned from those experiences. If you have not been involved with any direct research, then describe any activities that you believe have prepared you to start research. Also, don't make the reader try to glean from your writing that you "could" be a leader in some capacity. Instead, describe your leadership potential directly. How do you see yourself contributing to research, education, and innovation? Provide the reviewers with a picture of your career aspirations and specific goals you hope to accomplish. You need to sell yourself in your application.

statistics at the Wharton School of the University of Pennsylvania. His research involves machine learning and model selection. He says the GRFP gave him time to immerse himself in his research and, as a result, to submit and publish his work in various journals. He is helping lead the charge in assisting interested students in his department with their applications to the GRF. When asked what advice Adam could give students applying to the GRF, he stated his best recommendation would be for candidates to describe their research experience. "Can you make an impact in science? You need to illustrate your potential in research." He also acknowledged that he heard about the fellowship through a friend who thought it might be beneficial when applying to graduate school.

Nicholas Brubaker is on track to graduate with his Ph.D. in applied mathematics in 2013 from the University of Delaware. His research focuses on modeling soap films interacting with electric, magnetic, and gravitational fields. Nicholas attended Millersville University in Pennsylvania, where he received his bachelor's degree in mathematics with a focus on applied mathematics. As with Adam, the GRF has given Nicholas not only time to do his research but also the opportunity to publish two papers and to have another two manuscripts in review. Nicholas's advice to students interested in applying is to give yourself time and to keep trying. "Apply as many times as you can! If you don't get it the first time, don't get discouraged." He also stated that even if a student does not receive the GRF, the application process is still helpful, as it helps one plan for a graduate career.

Gina-Maria Pomann is pursuing her Ph.D. in statistics at North Carolina State University. Her research interests are functional data analysis with applications to magnetic resonance imaging and dynamic treatment regimens. She feels that the GRF, in combination with her AT&T Labs Fellowship, has allowed her to work on an array of different projects as well as with different mentors. Gina-Maria started out earning an A.S. degree from Middlesex County College and then transferred to the College of New Jersey, where she earned her bachelor's in mathematics with a minor in statistics. Gina first learned about graduate school and the GRF at the Mathematical Sciences Research Institute Undergraduate Program (MSRI-UP). MSRI-UP also took Gina and her fellow participants to a Society for Advancement of Chicanos and Native Americans in Science (SACNAS) conference, where the students were further informed about the GRF as well as other opportunities. Her advice to students seeking a GRF is, "Get as much undergraduate research experience as possible!" She states that her early research experiences helped her focus her research interests and helped her to write her GRF application.

For the official NSF solicitation, visit the Division of Graduate Education website `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=6201`. For more information and tips from awardees and reviewers, go to the GRFP website at http://www.nsfgrfp.org or contact: 1-866-NSF-GRFP (673-4737), email: `info@nsfgradfellows.org`. For access to the online applications, user guides, and other official announcements, logon to the FastLane website at `https://www.fastlane.nsf.gov/grfp/`. The next deadline for applications for GRFs in the mathematical sciences is **November 13, 2012**.

The Open Textbook Revolution

Steven E. Barkan

There is a movement afoot to disrupt the traditional college textbook market. Although it is probably too early to call this movement a revolution, despite this essay's title, this change is coming slowly but surely, and instructors and students will only benefit. This movement is the "open" textbook movement, and it is challenging the dominance of the traditional textbook market.

A few huge companies dominate the traditional college textbook market: Cengage/Wadsworth, McGraw-Hill, Pearson, Wiley, and some others. They are fine companies, and they produce excellent, peer-reviewed textbooks that summarize the major knowledge that undergraduates should be expected to know.

However excellent these textbooks are, they are also very expensive. Many and perhaps most of the leading textbooks in the major core courses in a college curriculum cost at least \$150 in hardcover when they are new and increasingly more than \$200. Many paperback texts in core courses cost well over \$100. College algebra and elementary and intermediate algebra textbooks at major publishers cost between \$166 and \$175 at the time of this writing. Across the United States, college students pay between \$600 and \$1,200 annually for their course textbooks, depending on which study one reads [1].

Why are traditional textbooks so expensive? A major reason is that they are very expensive to produce. They are full of color photographs, maps, and other features for today's visually-oriented students. They are also typically accompanied by PowerPoint slides and other supplements. Permission fees, typesetting, and other production costs must also be paid. As well, it takes many people to produce a core textbook: developmental editors, copyeditors, production and design specialists, and so forth. All these people must be paid through textbook proceeds. All these production costs for core textbooks can easily end up in the hundreds of thousands of dollars and often more than that. Large publishers also have huge marketing and sales forces whose salaries and expenses contribute to textbook prices.

Although traditional textbooks must perforce be very expensive, publishers have a low profit margin on any one textbook. The income that publishers derive from the average textbook equals only about 7 percent of the cost of the textbook, with the rest of the cost going to meet publishers' expenses, authors' royalties, and bookstore expenses and income [1].

Many students, as many as two-thirds in some surveys, report they have been unable to buy at least one textbook because it is too expensive [1]. Textbook prices are especially burdensome for low-income students at community colleges and public universities. When students cannot afford to buy textbooks, their grades suffer, and they are more likely to drop out of school.

Against this backdrop, the rise of open textbooks (also called open-source textbooks) is an exciting development that is a win-win situation for students and instructors alike. An open textbook is a textbook that, first and foremost, is published online and available there for students to use for free (yes, free!). Anyone with Internet access anywhere in the world can read an open textbook. Many open textbooks are also customizable:

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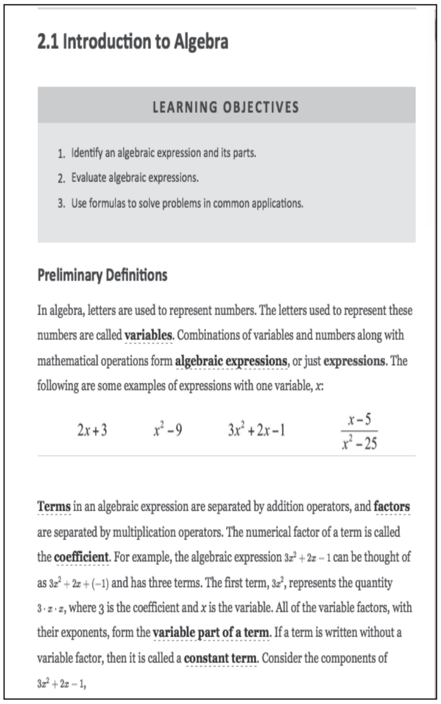

2.1 Introduction to Algebra

LEARNING OBJECTIVES

1. Identify an algebraic expression and its parts.
2. Evaluate algebraic expressions.
3. Use formulas to solve problems in common applications.

Preliminary Definitions

In algebra, letters are used to represent numbers. The letters used to represent these numbers are called **variables**. Combinations of variables and numbers along with mathematical operations form **algebraic expressions**, or just **expressions**. The following are some examples of expressions with one variable, x:

$$2x+3 \qquad x^2-9 \qquad 3x^2+2x-1 \qquad \frac{x-5}{x^2-25}$$

Terms in an algebraic expression are separated by addition operators, and **factors** are separated by multiplication operators. The numerical factor of a term is called the **coefficient**. For example, the algebraic expression $3x^2+2x-1$ can be thought of as $3x^2+2x+(-1)$ and has three terms. The first term, $3x^2$, represents the quantity $3\cdot x\cdot x$, where 3 is the coefficient and x is the variable. All of the variable factors, with their exponents, form the **variable part of a term**. If a term is written without a variable factor, then it is called a **constant term**. Consider the components of $3x^2+2x-1$,

instructors may modify the order of chapters or of topics within a chapter, and they can add or delete material that suits the needs of their courses.

A natural question concerns the quality of open textbooks. Anyone can put almost anything on the Web; much of what is on the Web is excellent, and much is schlock or worse. Happily, a growing number of open textbooks are peer-reviewed and match or exceed the quality of traditional textbooks. And they do so at a much, much lower cost.

I have written an introductory sociology text and a social problems text for the first and largest open textbook publisher, Flat World Knowledge (FWK; `flatworldknowledge.com`), founded about five years ago by two former Pearson executives [2]. I have also written five textbooks for traditional publishers. My experience as an author for both sorts of books is strikingly similar.

Like my traditional publishers, FWK has textbook proposals and manuscripts intensively peer-reviewed. Some three dozen sociologists from various institutional settings reviewed my introductory text either in part or in whole from the proposal stage until the copyediting stage. Also, like my traditional publishers, FWK has professionals guide a book's development through the design, copyediting, and proofreading stages until it is finally ready for publication.

Again, as with my traditional publishers, I receive royalties from my FWK books. I obviously do not get a royalty when students read my books free online, but I do get a royalty when they access the books via a variety of low-cost alternatives (about \$40 for a print black-and-white copy and about \$35 for a PDF and eBook version). Students enjoy this flexibility, and the majority purchase a print copy or electronic version. I'm pleased with the royalties I've received so far, but I am also pleased to know that I'm saving students a lot of money if they choose to read it online. As a professor for more than thirty years at a state university serving many first-generation students, I am very aware of the financial problems many college students face; for these students, open textbooks are a godsend.

At the time of this writing, FWK published or was about to publish textbooks in elementary algebra, intermediate algebra, and statistics (`http://bit.ly/FWK-Math`). Consistent with FWK's open model, students may read these books free online or purchase them in other alternatives for \$25 to \$40, depending on the format. If 100 students in a large college algebra course each bought a new copy of their \$170 traditional textbook (and many will not), they would pay \$17,000 altogether. With an FWK open algebra book, these same 100 students could potentially pay nothing, or at most \$4,000. The savings to students are certainly considerable, and they are more likely overall to read the book because they are more likely to be able to afford it.

Students can afford FWK books, but how can FWK afford to produce them? In answering this question, I should stress first of all that FWK does not ask its authors to take on typesetting, copyediting, or any other tasks that traditional textbook authors do not perform. Rather, FWK has reduced its costs by harnessing technology to achieve specific efficiencies in production, marketing, and other areas. As this screen shot from FWK's elementary algebra book shows, its books are indistinguishable from those of traditional companies. They are professional textbooks in every respect, and they are free or inexpensive.

The success of FWK's approach is seen in the fact that three of its books, including my introductory text, have won the "Texty" Textbook Excellence Award from the Text and Academic Authors Association. The company's book list, adoptions (from individual instructors and also from institutional licensing arrangements at several colleges and universities), and revenues are growing rapidly.

When I first heard about FWK's open model a few years ago, I still remember saying to myself, "That just makes so much sense!" Now that I am an open textbook author twice over, I continue to hold that opinion, only more so. Open textbooks are the wave of the future because they make so much sense for students and instructors alike. As these books continue to transform the textbook market, what is now a small movement may indeed become a revolution. I have high hopes that one day we will regard the \$200 textbook as we now regard the slide rule: a quaint relic of a bygone era.

References

[1] Office of Operations Review and Audit, *Textbook Costs in Higher Education*, University of Wisconsin System, Madison, WI, 2007.

[2] Chow, Christine, Going digital: Flat world knowledge and the emergence of the online college curriculum, *Access to Knowledge* **4**(1), 2012, 1–7.

Mathematical Sciences in the FY 2013 Budget

Samuel M. Rankin III

Highlights

- The National Science Foundation's (NSF) Division of Mathematical Sciences (DMS) budget is estimated to increase by 3.0 percent over FY 2012 to $245 million.
- Department of Defense (DOD) funding for the mathematical sciences is estimated to grow by 7.3 percent over FY 2012 to $129 million.
- The aggregate funding for the mathematical sciences in the Department of Energy (DOE) is estimated to increase by 18.3 percent.

Introduction

Research in the mathematical sciences is funded primarily through the National Science Foundation, the Department of Defense (including the National Security Agency), the Department of Energy, and the National Institutes of Health (NIH). NSF is the federal agency with the largest budget for the mathematical sciences. Sixty-four percent of all federal support for academic research in the mathematical sciences comes from NSF, and it is the only agency that supports mathematics research broadly across all fields. The majority of research in the mathematical sciences in the United States is performed by academic researchers. DOD, DOE, and NIH support mathematical sciences research that contributes to their missions.

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Trends in Federal Support for the Mathematical Sciences

Even in the current economic and political climate, the FY 2013 Budget Request increases federal total research by 3.3 percent over FY 2012. This includes a 1.5 percent increase for basic research and a 5.0 percent increase for applied research. NSF increases research by 4.2 percent, the DOE Office of Science by 4.5 percent, and DOD by 0.2 percent. These amounts translate into increases for the mathematical sciences in these agencies: NSF (3.0 percent), DOE (18.3 percent), and DOD (7.3 percent). See Table 1.

Research in the mathematical sciences contributes to the country's intellectual capacity and enables discovery in fields of science and engineering. Advances in many areas such as medicine, cyber security, and weather prediction depend on mathematical sciences research, and today's world of large complex data sets and powerful computing environments require continuing development of sophisticated mathematical and statistical tools.

National Science Foundation (NSF). The Division of Mathematical Sciences (DMS)[1] is housed in the NSF Directorate of the Mathematical and Physical Sciences (MPS). DMS has essentially two modes of support: (1) research and education grants, and (2) institutes. Grants include individual investigator awards; awards for groups of researchers, including multidisciplinary; and educational and training awards. Each year typically 60 percent of the DMS budget is available for new research grants, and the remaining 40 percent is used primarily to fund continuing grants made in previous years.

The division supports core research programs in algebra and number theory, analysis,

[1] `http://www.nsf.gov/div/index.jsp?div=DMS`

Table 1. Mathematical Sciences in the Federal R & D Budget (budget authority in millions of dollars)

	FY 2011 Actual	FY 2012 Budget	**FY2013 Estimate**	Change Amount	FY 12–13 Percent
National Science Foundation					
Mathematical Sciences	240	238	245	7	3.0
Department of Defense	118	121	129	9	7.3
Air Force Off. of Sci. Res.	58	47	52	4	9.3
Army Research Office	16	16	16	0	0.0
Def. Adv. Res. Proj. Agency	16	28	28	0	0.0
Natl. Security Agency	6	6	7	0	7.3
Office of Naval Research	22	24	28	4	16.7
Department of Energy	98	90	106	16	18.3
Applied Mathematics	46	46	50	4	8.6
SciDAC*	53	44	57	13	28.3

Source: Agency budget justifications and other agency communication.
All figures rounded to the nearest million.
Changes calculated from unrounded figures.
**Scientific Discovery through Advanced Computing*

applied mathematics, computational mathematics, geometry and topology, mathematical biology, probability, combinatorics and foundations, and various areas within statistics. In FY 2013, through the OneNSF Framework, DMS will participate in the Cyber-Infrastructure Framework for the 21st Century Science and Engineering (CIF21); Cyber-enabled Materials Manufacturing, and Smart Systems (CEMMSS); Science, Engineering, and Education for Sustainability (SEES); Secure and Trustworthy Cyberspace (SaTC); and Expeditions in Education (E^2). Additionally, DMS will take part in the Research at the Interface of Biological, Mathematical, and Physical Sciences (BioMaPS) program.

Air Force Office of Scientific Research (AFOSR). Portfolios for the mathematical sciences at AFOSR are found in the Directorate of Mathematics, Information, and Life Sciences and the Directorate of Physics and Electronics. The AFOSR mathematics program includes specific portfolios in dynamics and control; multiscale modeling; computational mathematics; mathematical modeling of cognition and decision; optimization and discrete mathematics, electromagnetics; and sensing, surveillance, and navigation. For additional information on focus areas within each of these portfolios, refer to the AFOSR Research Areas webpage.[2]

Army Research Office (ARO). The Mathematics Sciences Division, housed in the Information Sciences Division,[3] manages the following programs: modeling of complex systems, probability and statistics, biomathematics, and numerical analysis. The division plays an essential role in developing the fundamental understanding that underpins the modeling, analysis, design, and control of complex phenomena and large-scale systems which are of critical interest to the army. Areas of application include communication networks, image analysis, pattern recognition, test and evaluation of new systems, sensor networks, network science, autonomous systems, and mathematics of biological systems. The division also works closely with the Computing Sciences Division and Network Science Division of ARO to develop mathematical theory for systems control, information processing, information assurance, network design, and data fusion.

Defense Advanced Research Projects Agency (DARPA). The Defense Sciences Office (DSO)[4] and the Microsystems Technology Office (MTO) inside DARPA both have mathematics programs cutting across mathematics and its applications. Current programs include Focus Areas in Theoretical Mathematics, Knowledge Enhanced Compressive Measurement, Sensor Topology for Minimal Planning, 23 Mathematical Challenges, Protein Design Processes, and Algorithms.

National Security Agency (NSA). As the largest employer of mathematicians in the United States, NSA has a vested interest in maintaining a healthy academic mathematics community in the United

[2]`http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=8973`

[3]`http://www.arl.army.mil/www/default.cfm?page=185`

[4]`http://www.darpa.mil/default.aspx`

States. The Mathematical Sciences Program (MSP)[5] of NSA administers a grants program that supports undirected fundamental research in the areas of algebra, number theory, discrete mathematics, probability, and statistics. The grants program also accepts proposals for conferences and workshops in these research areas, together with proposals for Research Experiences for Undergraduates and other special projects that advance the U.S. mathematics community at the college level and above. In addition to these grants, MSP supports an in-house faculty sabbatical program for university professors and others to perform research at NSA. The program administrators are especially interested in supporting initiatives that encourage the participation of underrepresented groups in mathematics, such as women, African-Americans, and other minorities.

Office of Naval Research (ONR). The ONR Mathematics, Computers, and Information Research Division's scientific objective is to establish rigorous mathematical foundations and analytical and computational methods that enhance understanding of complex phenomena and enable prediction and control for naval applications in the future.[6] Basic research in the mathematical sciences is focused on analysis and computation for multiphase, multimaterial, multiphysics problems; predictability of models for nonlinear dynamics; electromagnetic and acoustic wave propagation; data analysis and understanding; information theoretical approaches for signal processing; optimization; modeling and exploiting hybrid control of large, dynamic complex networks; and computational foundations for machine reasoning and intelligence to support autonomous decision making. Also of interest are computational framework and formal methods for secure and autonomic computing systems and quantum information sciences, a new start-up program in FY 2013.

Department of Energy (DOE). Mathematics at DOE is funded through the Office of Advanced Scientific Computing Research (ASCR),[7] one of the interdisciplinary research offices within DOE's Office of Science. Research supported by ASCR underpins computational science throughout DOE. ASCR funding for the mathematical sciences is found primarily in the Applied Mathematics program and the Scientific Discovery through Advanced Computing (SciDAC) program. The Applied Mathematics activity supports the research, development, and application of applied mathematical models, methods, and algorithms to understand complex physical, chemical, biological, and engineered systems related to the department's mission. SciDAC investments address dramatically accelerating progress in scientific computing that delivers breakthrough scientific results through partnerships between applied mathematicians, computer scientists, and scientists from other disciplines. These efforts apply results from applied mathematics and computer science core research to scientific applications sponsored by other Office of Science programs.

National Institutes of Health (NIH). NIH funds mathematical sciences research through the National Institute of General Medical Sciences (NIGMS)[8] and the National Institute of Biomedical Imaging and Bioengineering (NIBIB).[9] Mathematical sciences areas of interest are those that support the missions of NIGMS and NIBIB. The NIGMS Division of Biomedical Technology, Bioinformatics, and Computational Biology supports research for understanding complex biological systems. Research and training funded by the division join biology with computer science, engineering, mathematics, and physics. Grants in computational biology support development of modeling and simulation tools and methods for analyzing and disseminating computational models. NIBIB supports the mathematical sciences through the Discovery Science and Technology Division research program area, Mathematical Modeling, Simulation and Analysis.

[5] http://www.nsa.gov/research/math_research/index.shtml

[6] http://www.onr.navy.mil/Science-Technology/Departments/Code-31/All-Programs/311-Mathematics-Computers-Research.aspx

[7] http://www.science.energy.gov/ascr/

[8] http://www.nigms.nih.gov/About/Overview/cbcb.htm

[9] http://www.nibib.nih.gov/Research/ProgramAreas/MathModeling

Mathematics People

2012 Simons Investigators Named

The Simons Foundation has named twenty-one mathematicians, theoretical physicists, and theoretical computer scientists as Simons Investigators for 2012, the inaugural year of the program. The Simons Investigators program provides a stable base of support for outstanding scientists, enabling them to undertake long-term study of fundamental questions. The names and institutions of the awardees whose work involves the mathematical sciences and brief excerpts from the prize citations follow.

MANJUL BHARGAVA of Princeton University pursues algebraic number theory and the geometry of numbers in the tradition of Gauss and Minkowski. His overarching goal in this work is to count the basic objects of number theory and to make computational conclusions about their asymptotics. For example, it is conjectured that, in a certain natural sense, the average rank of the group of rational points of an elliptic curve defined over the rationals is 1/2. Bhargava and his student Shankar recently showed that it is less than 1. Previously, it was not even known whether the average rank is finite. In joint work with Dick Gross, Bhargava has also shown that the number of rational points on the majority of hyperelliptic curves is bounded by a certain small number independent of the genus of the curve.

ALICE GUIONNET of the Massachusetts Institute of Technology has done very important work on the statistical mechanics of disordered systems (and in particular the dynamics and aging of spin glasses), random matrices (with an emphasis on the combinatorics of maps), and operator algebra/free probability. She has extended the large deviation principle to the context of Voiculescu's free probability theory, and, in collaboration with Cabanal-Duvillard, Capitaine, and Biane, she proved various large deviation bounds in this more general setting. These bounds enabled her to prove an inequality between the two notions of free entropy given by Voiculescu, settling half of the most important question in the field. With her former students M. Maida and E. Maurel-Segala and more recently with Vaughan Jones and D. Shlyakhtenko, Guionnet has studied statistical mechanics on random graphs through multimatrix models. Their work on the general Potts models on random graphs branches out in promising directions within operator algebra theory.

CHRISTOPHER D. HACON of the University of Utah has produced some of the most important contributions to higher-dimensional algebraic geometry since Mori's in the 1980s. Hacon and his coauthors have solved major problems concerning the birational geometry of algebraic varieties, including the characterization of irregular varieties, boundedness theorems for pluricanonical maps, a proof of the existence of flips, the completion of the minimal model program for varieties of general type, and bounds for the order of automorphism groups of varieties of general type. His work has also led to solutions of other problems, such as the existence of moduli spaces for varieties of general type and the ascending chain condition for log canonical thresholds.

PAUL SEIDEL of the Massachusetts Institute of Technology has done major work in symplectic geometry, in particular on questions inspired by mirror symmetry. His work is distinguished by an understanding of abstract algebraic structures, such as derived categories, in sufficiently concrete terms to allow one to derive specific geometric results. On the abstract side, Seidel has made substantial advances toward understanding Kontsevich's homological mirror symmetry conjecture and has proved several special cases of it. In joint papers with Smith, Abouzaid, and Maydanskiy, he has investigated the symplectic geometry of Stein manifolds. In particular, work with Abouzaid constructs infinitely many nonstandard symplectic structures on any Stein manifold of sufficiently high dimension.

AMIT SINGER of Princeton University works on a broad range of problems in applied mathematics, solving specific applied problems and employing sophisticated theory to allow the solution of general classes of problems. Among the areas to which he has contributed are diffusion maps, cryoelectron microscopy, random graph theory, sensor networks, graph Laplacians, and diffusion processes. His recent work in electron microscopy combines representation theory with a novel network construction to provide reconstructions of structural information on molecules from noisy two-dimensional images of populations of the molecule.

Terence Tao of the University of California Los Angeles has produced more than 200 publications in just fifteen years, spanning collaborations with nearly seventy mathematicians and establishing himself as a major player in the disparate fields of harmonic analysis, partial differential equations, number theory, random matrices, and more. He has made deep contributions to the development of additive combinatorics through a blend of harmonic analysis, ergodic theory, geometry, and number theory, establishing this field as central to the modern study of many mathematical subjects. This work has led to extraordinary breakthroughs in our understanding of the distribution of primes, expanders in groups, and various questions in theoretical computer science. For example, Green, Tao, and Ziegler have proved that any finite set of linear forms over the integers, of which no two are linearly dependent over the rationals, all take on prime values simultaneously infinitely often, provided there are no local obstructions.

Horng-Tzer Yau of Harvard University is one of the world's leading probabilists and mathematical physicists. He has worked on quantum dynamics of many-body systems, statistical physics, hydrodynamical limits, and interacting particle systems. Yau approached the problems of the quantum dynamics of many-body systems with tools he developed for statistical physics and probability. More recently, he has been the main driving force behind some stunning progress on bulk universality for random matrices. With Laszlo Erdős and others, Yau has proved the universality of the local spectral statistics of random matrices, a problem that was regarded as the main challenge of random matrix theory.

Sanjeev Arora of Princeton University has played a pivotal role in some of the deepest and most influential results in theoretical computer science. He started his career with a major contribution to the proof of the PCP (probabilistically checkable proofs) theorem, widely regarded as the most important result in complexity theory in the last forty years. The PCP theorem states roughly that every proof, of any length, can be efficiently converted into a special format in which correctness can be verified with high probability by reading small parts of it. The PCP theorem revolutionized our understanding of optimization problems and opened new directions in coding, cryptography, and other areas. Arora is also known for his breakthroughs in approximation algorithms, having solved long-standing open problems. Notable examples include his algorithms for the Euclidean traveling salesman problem and for the sparsest cut in a graph. He has made important contributions in many other areas, including the unique games conjecture (a conjectured strengthening of the PCP theorem) and the power and limitations of hierarchies of linear and semidefinite programs.

Shafrira Goldwasser of the Massachusetts Institute of Technology has had tremendous impact on the development of cryptography and complexity theory. Starting with her thesis on "semantic security", she laid the foundations of the theory of cryptography. She created rigorous definitions and constructions of well-known primitives, such as encryption schemes (both public and private key versions) and digital signatures, and of new ones that she introduced, such as zero-knowledge interactive proof systems invented with Micali and Rackoff. Continuing her work on interactive proofs which allow a probabilistic polynomial time algorithm to verify mathematical proofs via interaction with a powerful prover, she and her coauthors extended the notion of interactive proofs to two-prover systems. They turned out to be of great significance in complexity theory, paving the way to the equivalent formulation of PCP. The expressive power of two-prover systems is huge (nondeterministic exponential time). Furthermore, she and her coauthors showed the connection between a scaled down variant of these systems and the hardness of approximation results for NP-hard problems, which led to the PCP theorem. On the algorithmic front, a problem of great significance is that of recognizing (and generating) prime numbers. Goldwasser and Kilian designed efficient probabilistic primality provers, which output short proofs of primality, based on the theory of elliptic curves. Together with Goldreich and Ron, Goldwasser originated the field of combinatorial property testing, devising a class of sublinear algorithms to test properties in dense graphs.

Russell Impagliazzo of the University of California San Diego has made many deep contributions to cryptography and complexity theory. He and his collaborators showed that one-way functions exist if and only if pseudorandom generators exist. In other words, one can generate sequences of bits for which it is computationally hard to predict the next bit with accuracy much better than random guessing if and only if there are easy-to-compute functions that are hard to invert on the average. He also showed that there are worlds in which certain cryptographic primitives are strictly inequivalent. For example, there are worlds in which one-way functions exist but public-key encryption is not possible. One of his major contributions in complexity theory is the exponential-time hypothesis and its implications. The hypothesis states that there are problems for which it is hard to speed up the brute-force solution even by a small amount. Impagliazzo helped establish the first complete problem for this class. In joint work with Avi Wigderson, he showed that if there are problems in exponential time that require exponential-sized circuits to solve, then any efficient algorithm that uses randomization has an equivalent, efficient one that does not.

Jon Kleinberg of Cornell University is best known for his contributions in establishing the computational foundations for information retrieval and social networks. His information-retrieval work includes the use of link analysis (e.g., hubs and authorities) for ranking, classification, and identifying web communities, the web as a graph, and understanding the success of latent semantic analysis. His work in algorithmic social networks (a field that he can be said to have started) includes the understanding of "small worlds" and decentralized search, analysis of bursty streams, and influence spread in social networks. Kleinberg has done work in many other fields, including approximation algorithms, communications networks, queuing theory, clustering, computational geometry, bioinformatics, temporal analysis of data streams, algorithmic game theory, online algorithms, and distributed computing.

Daniel Spielman of Yale University has done important work in theoretical computer science, applied mathematics, and operations research. His work on smoothed analysis of linear programming provides mathematical justification for why the simplex method to solve problems works well in practice even though worst-case analysis shows that there are instances in which it takes exponential time. A small random perturbation converts any linear programming instance into one that, with high probability, is solved efficiently by the simplex algorithm. Similar perturbation results hold for many other problems and provide an alternative to worst-case analysis, which may be too pessimistic. His codes based on expander graphs achieve near-optimal rate and nearly linear time encoding and decoding algorithms.

Michael Brenner of Harvard University has collaborated with biologists, physicists, and engineers from a variety of subfields. His work seamlessly integrates analytical and computational approaches to solve problems ranging from fundamental issues in fluid mechanics to engineering design to the evolution of protein functionality and from the aerodynamics of whale flippers to the ejection of fungal spores. Particularly noteworthy are his achievements in understanding the singularities and nonlinearities that control how droplets, jets, and sheets of fluid change shape and break up. His work in this area has potential impact for optimizing devices ranging from inkjet printers to cell sorters. His research has also led to the development of general methods for simplifying the dynamical models of many coupled oscillators that arise in contexts such as atmospheric chemistry.

Hirosi Ooguri of the California Institute of Technology is a mathematical physicist and string theorist whose work on Calabi-Yau manifolds has yielded important new insights into the D-brane structures crucial to string theory. His work on the relationship of supersymmetric gauge theories to string theory and to gravity has fostered the rapid development of the AdS/CFT correspondence, which relates quantum properties of gauge theories to solutions of higher-dimensional classical field equations in the presence of black holes and curved space-time. He is perhaps best known for his innovations in the use of topological string theory to compute Feynman diagrams in superstring models.

—From a Simons Foundation announcement

Yun Awarded 2012 SASTRA Ramanujan Prize

Zhiwei Yun of Stanford University has been awarded the 2012 SASTRA Ramanujan Prize. This annual prize is awarded for outstanding contributions to areas influenced by the Indian genius Srinivasa Ramanujan. The age limit for the prize has been set at thirty-two, because Ramanujan achieved so much in his brief life of thirty-two years. The prize carries a cash award of US$10,000. Because 2012 is the 125th anniversary of the birth of Srinivasa Ramanujan, the prize will be given in New Delhi (India's capital) on December 22 (Ramanujan's birthday).

The prize citation reads as follows: "Zhiwei Yun has made fundamental contributions to several areas that lie at the interface of representation theory, algebraic geometry, and number theory. Yun's Ph.D. thesis on global Springer theory at Princeton University, written under the direction of Professor Robert MacPherson of The Institute for Advanced Study, is opening up whole new vistas in the Langlands program, which represents one of the greatest developments in mathematics in the last half-century. Springer theory is the study of Weyl group actions on the cohomology of certain subvarieties of the flag manifold called Springer fibers. Yun's global Springer theory deals with Hitchin fibers instead of Springer fibers (taking the lead from earlier work on Hitchin fibers by Gérard Laumon and the 2010 Fields Medalist Bao-Châu Ngô) which he uses to determine the actions of affine Weyl groups on cohomology. His work is expected to lead to a geometric and functorial understanding of the Langlands program. Many papers by him on global Springer theory have arisen from his Ph.D. thesis; one appeared in 2011 in *Advances in Mathematics* and another will soon appear in *Compositio Mathematica*.

"Bao-Chau Ngô was awarded the 2010 Fields Medal for his proof of the Fundamental Lemma in the Langlands program. Yun has made a major breakthrough in the study of the Fundamental Lemma formulated by Jacquet and Rallis in their program of proving the Gross–Prasad conjecture on relative trace formulas. Yun's understanding of Hitchin fibrations enabled him to reduce the Jacquet–Rallis fundamental lemma to a cohomological property of the Hitchin fibration. This work, considered a gem of mathematics, appeared in 2011 in the *Duke Mathematical Journal*. Yun has collaborated with Ngô and Jochen Heinloth on a seminal paper on Kloosterman sheaves for reductive groups, which will appear in the *Annals of Mathematics*. In this wonderful joint paper, Ngô, Heinloth, and Yun re-prove a unicity result of Gross on automorphic representations over the rational function field and use the geometric Langlands theory to effect the construction of l-adic local systems.

"Yun has also done significant work in algebraic geometry. His recent article with Davesh Maulik on the Macdonald formula for curves with planar singularities will appear in the *Journal für die reine und angewandte Mathematik*. Yun's most recent work on the uniform construction of motives with exceptional Galois groups is considered to be a fundamental breakthrough. A construction like Yun's was sought by Fields Medalists Serre and Grothendieck for over forty years, and Yun's work is considered one of the most exciting developments in the theory of motives in the last two decades."

Zhiwei Yun was born in Changzhou, China, in 1982. He received his bachelor's degree from Peking University in 2004 and his Ph.D. from Princeton University in 2009. He was a visiting member at the Institute for Advanced Study in 2009–2010 and held the C. L. E. Moore instructorship at the Massachusetts Institute of Technology during 2010–2012. In fall 2012 he joined the mathematics faculty at Stanford University.

The 2012 Prize Committee consisted of Krishnaswami Alladi (chair), Frits Beukers, Kathrin Bringmann, Benedict Gross, Kenneth Ribet, Robert Vaughan, and Ole Warnaar. Previous winners of the SASTRA Ramanujan Prize include Manjul Bhargava and Kannan Soundararajan (2005), Terence Tao (2006), Ben Green (2007), Akshay Venkatesh (2008), Kathrin Bringmann (2009), Wei Zhang (2010), and Roman Holowinsky (2011).

—From a SASTRA Ramanujan Prize announcement

Willwacher Awarded Lichnerowicz Prize

THOMAS WILLWACHER of Harvard University has been awarded the 2012 Lichnerowicz Prize in Poisson Geometry for his "deep and fundamental contributions to Poisson geometry, combining techniques from quantum field theory, homological algebra, and graph complexes." According to the prize citation, "his results include proofs of Kontsevich's cyclic formality conjecture for cochains and Tsygan's cyclic formality conjecture for chains. Together with Severa, he established the homotopy equivalence between Kontsevich's and Tamarkin's formalities of the little disk operad. More recently, he proved that the cohomology of the Kontsevich graph complex is isomorphic to the Grothendieck-Teichmueller Lie algebra."

The André Lichnerowicz prize in Poisson Geometry for notable contributions to Poisson geometry is awarded every two years to researchers who completed their doctorates at most eight years before the awarding of the prize. The prize is named in memory of André Lichnerowicz (1915–1998), whose work was fundamental in establishing Poisson geometry as a branch of mathematics.

—Eckhard Meinrenken, University of Toronto

MAA Awards Presented

The Mathematical Association of America (MAA) presented several awards at its Summer MathFest in Madison, Wisconsin, in August 2012.

The Carl B. Allendoerfer Awards, established in 1976, are made to authors of expository articles published in *Mathematics Magazine* and carry a cash prize of US$500. The awardees for 2012 are: P. MARK KAYLL, "Integrals Don't Have Anything to Do with Discrete Math, Do They?", *Mathematics Magazine* **84**, no. 2 (2011), pp. 108–119; and JOHN A. ADAM, "Blood Vessel Branching: Beyond the Standard Calculus Problem", *Mathematics Magazine* **84**, no. 3 (2011), pp. 196–207.

The Trevor Evans Award, first awarded in 1996, is made to authors of exceptional articles accessible to undergraduates and published in *Math Horizons*. The award carries a cash prize of US$250. The awardees for 2012 are: NATHAN CARTER and DAN KALMAN, "Harvey Plotter and the Circle of Irrationality", *Math Horizons* **19**, no. 2 (2011), pp. 10–13.

The Lester R. Ford Awards, established in 1964, are made to authors of expository articles published in the *American Mathematical Monthly* and carry a cash prize of US$500. The awardees for 2012 are: DAVID A. COX, "Why Eisenstein Proved the Eisenstein Criterion and Why Schönemann Discovered It First", *American Mathematical Monthly* **118**, no. 1 (2011), pp. 3–21; RAVI VAKIL, "The Mathematics of Doodling", *American Mathematical Monthly* **118**, no. 2 (2011), pp. 116–129; PETER SARNAK, "Integral Apollonian Packings", *American Mathematical Monthly* **118**, no. 4 (2011), pp. 291–306; and GRAHAM EVEREST and THOMAS WARD, "A Repulsion Motif in Diophantine Equations", *American Mathematical Monthly* **118**, no. 7 (2011), pp. 584–598.

The George Pólya Awards, established in 1976, are made to authors of expository articles published in the *College Mathematics Journal* and carry a cash prize of US$500. The awardees for 2012 are: LESLIE A. CHETEYAN, STEWART HENGEVELD, and MICHAEL A. JONES, "Chutes and Ladders for the Impatient", *College Mathematics Journal* **42**, no. 1 (2011), pp. 2–8; and T. S. MICHAEL, "Guards, Galleries, Fortresses, and the Octoplex", *College Mathematics Journal* **42**, no. 3 (2011), pp. 191–200.

Established in 2004, the Annie and John Selden Prize for Research in Undergraduate Mathematics Education honors a researcher who has established a significant record of published research in undergraduate mathematics education and who has been in the field at most ten years. The prize carries a cash award of US$500. The 2012 prizewinner is LAURA ALCOCK of the Mathematics Education Centre at Loughborough University. "Dr. Alcock's work is theoretically based, product-oriented, and pedagogically sound," the prize citation states. "She has a deep understanding of mathematical content that is evident in all her writing."

The Henry L. Alder Award for Distinguished Teaching by a Beginning College or University Mathematics Faculty Member was established in 2003 to honor beginning college or university faculty members whose teaching has been extraordinarily successful and whose effectiveness in teaching undergraduate mathematics is shown to have influence beyond their own classrooms. The award carries a cash prize of US$1,000. The awardees for 2012 are KATHRYN LEONARD of California State University Channel Islands, SUSAN MARTONOSI of Harvey Mudd College, and MICHAEL POSNER of Villanova University.

—From an MAA announcement

Martin Named Jefferson Fellow

CLYDE MARTIN of Texas Tech University has been named a Jefferson Fellow for 2012. His research interests include control theory and the development and analysis of mathematical and statistical models in agriculture, the environment, and medicine.

The Jefferson Science Fellows program was established in 2003 as an initiative of the science and technology adviser to the U.S. secretary of state to further build capacity for science, technology, and engineering expertise within the U.S. Department of State. The program is based on the premise that science and technology make fundamental contributions to the security, economic, health, and cultural foundations of modern societies and are integral to the development and implementation of foreign policy. Fellows serve one-year assignments working full time in the Department of State or the U.S. Agency for International Development, then remain available as consultants after returning to their academic careers.

—From the Jefferson Science Fellows website

Haldane, Kane, and Zhang Receive 2012 Dirac Medal

The Abdus Salam International Centre for Theoretical Physics (ICTP) has announced the Dirac Medalists for 2012, three condensed matter physicists who furthered the understanding of the strange conductive qualities of topological insulators. The winners are DUNCAN HALDANE of Princeton University, CHARLES KANE of the University of Pennsylvania, and SHOUCHENG ZHANG of Stanford University.

First awarded in 1985, the Dirac Medal is given in honour of P. A. M. Dirac, one of the greatest physicists of the twentieth century and a staunch friend of ICTP. It is awarded annually on Dirac's birthday, August 8, to scientists who have made significant contributions to theoretical physics. The medalists also receive a prize of US$5,000. The Dirac Medal is not awarded to Nobel Laureates, Fields Medalists, or Wolf Foundation Prize winners, although many Dirac Medalists have proceeded to win these prestigious prizes.

—From an ICTP announcement

Camacho Receives SACNAS Award

ERIKA T. CAMACHO of Arizona State University has received the 2012 Distinguished Undergraduate Institution Mentor Award from SACNAS (Society for Advancement of Hispanics/Chicanos and Native Americans in Science).

Camacho's passion is to continue the work and legacy of her mentors, including high school math teacher Jaime Escalante, in creating educational opportunities for individuals from marginalized communities. She involves students in her work at the interface of mathematics and its applications to biology and sociology. Her leadership, scholarship, and mentoring have won her national recognition. She has served on the Diversity Advisory Committee of the Society for Industrial and Applied Mathematics and the Mathematics Task Force of SACNAS.

—From a SACNAS announcement

d'Alembert and Decerf Prizes Awarded

Every two years the Société Mathématique de France awards the d'Alembert Prize. Established in 1984, the prize is intended to encourage mathematical works in the French language and the exposition of mathematics for the general public. It recognizes an article, book, radio or television broadcast, film, or other project that is designed to improve understanding of mathematics and its recent developments.

The d'Alembert Prize for 2010 was awarded to A. ALVAREZ, E. GHYS, and J. LEYS for their film *Dimensions: A Mathematical Promenade* and its associated website (`http://www.dimensions-math.org/`). The film has been appreciated by viewers all over the world for its high graphical and artistic quality and the simplicity with which it introduces geometric concepts. Originally made in French, the film has been translated into many different languages.

The 2012 d'Alembert Prize was presented to ROBIN JAMET for his work on communicating about mathematics with young people, most notably the "Magic Math" project of Science et Vie Junior, and to SHAULA FIORELLI VILMART and PIERRE-ALAIN CHÉRIX for their "popularization triptych" at the Museum of the History of Science in Geneva, for a project of the Swiss Mathematical Society, and for the publication *Les Jeux Sont Faits*, a collaborative effort with Radio Television Switzerland.

In 2012 the SMF also awarded the Anatole Decerf Prize, which was established to promote the pedagogy of mathematics. The 2012 Decerf Prize was awarded to FRANCIS LORET for his work in mathematics education and popularization and to *Accromath*, a Canadian publication that is distributed free of charge and that maintains high scientific and pedagogical quality.

—Allyn Jackson

Singh Awarded Inaugural Leelavati Prize

SIMON SINGH, author, journalist, and television producer, was awarded the inaugural Leelavati Prize for outstanding contributions to public outreach in mathematics by an individual. The award was presented at the 2010 International Congress of Mathematicians (ICM) of the

International Mathematical Union (IMU) and will be given every four years at the ICM.

Singh studied physics at the Imperial College London and later got his doctorate in particle physics working at Emmanuel College, Cambridge University, as well as at CERN, Geneva. In 1990 he joined the BBC and in 1996 directed an award-winning documentary, *Fermat's Last Theorem*, also the title of his 1997 book. He is also the author of *The Code Book: The Secret History of Codes and Code Breaking* (1999) and has produced television and radio series about mathematics.

—From an ICM announcement

PECASE Awards Announced

Three young scientists whose work involves the mathematical sciences have received Presidential Early Career Awards for Scientists and Engineers (PECASE) from President Obama. They were among twenty nominated by the National Science Foundation (NSF). Suzanne M. Shontz of Pennsylvania State University was honored "for exemplary research in computational and data-enabled science and engineering that bridges applied mathematics, computer science, and scientific applications, and for contributions to education, including new curricula and approaches that encourage diversity in this emerging field." Mariel Vazquez of San Francisco State University was recognized "for excellent interdisciplinary and international research at the interface of mathematics and biology and for creativity and dedication to recruiting, training, mentoring, and helping students from underrepresented groups achieve their goals." Brent R. Waters of the University of Texas at Austin was honored "for visionary research on novel encryption methods that provide powerful new tools in computer security, an area of national importance, and for service on an election study group, which provided valuable outreach and tangible impact on the community."

—From an NSF announcement

China Girls Mathematical Olympiad

Eight young women formed the U.S. team to compete at the 11th annual China Girls Mathematical Olympiad (CGMO). All won medals, including one who achieved a perfect score. The girls-only international competition was held in Guangzhou in August 2012.

Gold medals were awarded to Victoria Xia, sixteen, from Vienna, Virginia—she received a perfect score and won her second consecutive gold medal—who will be a junior at the Thomas Jefferson High School for Science and Technology; Danielle Wang, fifteen, from Campbell, California, a sophomore at Westmont High School, who also won a gold medal last year; and Alicia Weng, sixteen, from West Hills, California, who will be a junior at North Hollywood High School. Silver medals were won by Cynthia Day, seventeen, from San Jose, California, who recently graduated from Lynbrook High School and will be a freshman at Stanford University this fall (she was also a medalist at the 2009 and 2010 CGMO); Courtney Guo, sixteen, a U.S. citizen who is a junior at the International School of Beijing in China; Laura Pierson, twelve, from Oakland, California, who is the youngest student to ever compete on the U.S. team (she will be a seventh-grader this fall at Hillcrest Middle School); and Jingyi Zhao, sixteen, from Culver, Indiana, who will be a junior this fall at Culver Academies. A bronze medal was awarded to Gabriella Studt, sixteen, from Silver Spring, Maryland, who begins her junior year at Montgomery Blair High School.

The highly competitive Math Olympiad consists of a rigorous two-day examination. On each day, the girls were presented with four proof-based math problems and had four hours in which to solve them. This year, the CGMO drew 204 girls from ten countries: Japan, Russia, Korea, the United States, the Philippines, Hong Kong, Macau, Taipei, Singapore, and China. Founded in 2002, the CGMO began as a regional competition for teams of female students from China and other eastern Asian countries. It was later expanded to invite teams from more countries. The first team from the United States was sent in 2007. The girls on the U.S. team wrote an online travelogue that shared their impressions during their trip to the 2012 CGMO (see `http://www.msri.org/cgmo/2012`).

The participation of the U.S. team in the CGMO is sponsored by the Mathematical Sciences Research Institute (MSRI) in Berkeley and the Mathematical Association of America (MAA). The team's eight secondary school students were chosen from the top ranks of female finalists in the 2012 USA Mathematical Olympiad (USAMO). The team's head coach is Zuming Feng, a math teacher on the faculty of Phillips Exeter Academy, who has been the leader of the USA International Mathematical Olympiad (IMO) team and the director of the Mathematical Olympiad Summer Program (MOSP) since 2003. Former U.S. team members and gold medalists Jennifer Iglesias, who enters Carnegie Mellon University's Ph.D. program in mathematics this fall, and Sherry Gong, who will begin a Ph.D. program in mathematics at the Massachusetts Institute of Technology, returned again as assistant coaches to help coach the team in China and during the team's training in June at the MAA-run MOSP at the University of Nebraska at Lincoln.

Funding for the program is provided by the Akamai Foundation; Delta Air Lines, Inc.; the MAA; MSRI; the National Science Foundation; the S. S. Chern Foundation; and the Sunlin and Priscilla Chou Foundation.

—From an MSRI news release

Prizes of the European Mathematical Society

The European Mathematical Society (EMS) awarded ten prizes at the Sixth European Congress of Mathematics in Krakow, Poland, in July 2012. The EMS Prizes were awarded to young researchers (not over the age of thirty-five who are European or who work in Europe) for excellence in contributions to mathematics. The awardees, their affiliations, and brief citations follow.

Simon Brendle of Stanford University was honored "for his outstanding results on geometric partial differential equations and systems of elliptic, parabolic, and hyperbolic types, which have led to breakthroughs in differential geometry, including the differentiable sphere theorem, the general convergence of Yamabe flow, the compactness property for solutions of the Yamabe equation, and the Min-Oo conjecture."

Emmanuel Breuillard of Université Paris-Sud, Orsay, was honored "for his important and deep research in asymptotic group theory, in particular on the Tits alternative for linear groups and on the study of approximate subgroups, using a wealth of methods from very different areas of mathematics, which has already made a long-lasting impact on combinatorics, group theory, number theory and beyond."

Alessio Figalli of the University of Texas at Austin was recognized "for his outstanding contributions to the regularity theory of optimal transport maps, to quantitative geometric and functional inequalities, and to partial solutions of the Mather and Mañé conjectures in the theory of dynamical systems."

Adrian Ioana of the University of California San Diego was honored "for his impressive and deep work in the field of operator algebras and their connections to ergodic theory and group theory, and in particular for solving several important open problems in deformation and rigidity theory, among them a long-standing conjecture of Connes concerning von Neumann algebras with no outer automorphisms."

Mathieu Lewin of the University of Cergy-Pontoise was recognized "for his groundbreaking work in rigorous aspects of quantum chemistry, mean field approximations to relativistic quantum field theory, and statistical mechanics."

Ciprian Manolescu of the University of California Los Angeles was honored "for his deep and highly influential work on Floer theory, successfully combining techniques from gauge theory, symplectic geometry, algebraic topology, dynamical systems, and algebraic geometry to study low-dimensional manifolds, and in particular for his key role in the development of combinatorial Floer theory."

Grégory Miermont of Université Paris-Sud 11 was recognized "for his outstanding work on scaling limits of random structures, such as trees and random planar maps, and his highly innovative insight in the treatment of random metrics."

Sophie Morel of Harvard University was honored "for her deep and original work in arithmetic geometry and automorphic forms, in particular the study of Shimura varieties, bringing new and unexpected ideas to this field."

Tom Sanders of the University of Oxford was recognized "for his fundamental results in additive combinatorics and harmonic analysis, which combine in a masterful way deep known techniques with the invention of new methods to achieve spectacular applications."

Corinna Ulcigrai of the University of Bristol was honored "for advancing our understanding of dynamical systems and the mathematical characterizations of chaos, and especially for solving a long-standing fundamental question on the mixing property for locally Hamiltonian surface flows."

—From an EMS announcement

Pi Mu Epsilon Student Paper Presentation Awards

Pi Mu Epsilon (PME), the U.S. honorary mathematics society, makes annual awards to recognize the best papers by undergraduate students presented at a PME student paper session. This year PME held a session in conjunction with the Mathematical Association of America MathFest in Madison, Wisconsin, August 1–3, 2012. The AMS and the American Statistical Association sponsor awards to student speakers for excellence in exposition and research. Each awardee received a check for US$150. The names, chapters, institutions, and paper titles of the award-winning students follow.

Beth Bjorkman, Michigan Iota Chapter, Grand Valley State University, "Columnar transposition ciphers"; Ashley Broadwell, California Xi Chapter, Pepperdine University, "A generating function for inversions on pattern avoiding involutions"; Nathaniel Card, Wisconsin Epsilon Chapter, Carthage College, "Benford melodies: A senior thesis on stochastic composition"; Wilson Cheung, New York Alpha Delta Chapter, SUNY Geneseo, "Contracting and rotating ellipses"; Marissa Clougher, Illinois Iota Chapter, Elmhurst College, "Universal Niven number representations"; Sarah Hellig, New Jersey Epsilon Chapter, St. Peter's College, "When prisoners enter battle"; Erik Miller, Wisconsin Delta Chapter, St. Norbert College, "From golf balls to airplanes; What are the powers of dimples?"; Candice Nielsen, Illinois Iota Chapter, Elmhurst College, "Vertex polygons"; Mario Sracic, Ohio Xi Chapter, Youngstown State University, "Outer Automorphisms of S_6"; and Sarah Wesley, Illinois Iota Chapter, Elmhurst College, "Niven numbers and cryptography".

—From a Pi Mu Epsilon announcement

Mathematics Opportunities

American Mathematical Society Centennial Fellowships

Invitation for Applications for Awards for 2013–2014
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 2013–2014 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, 2001, and September 1, 2010). Applications will be accepted from those currently holding a tenured, tenure-track, postdoctoral, or comparable (at the discretion of the selection committee) position at an institution in North America. Applications should include a cogent plan indicating how the fellowship will be used. The plan should include travel to at least one other institution and should demonstrate that the fellowship will be used for more than reduction of teaching at the candidate's home institution. The selection committee will consider the plan in addition to the quality of the candidate's research and will try to award the fellowship to those for whom the award would make a real difference in the development of their research careers. Work in all areas of mathematics, including interdisciplinary work, is eligible.

Deadline: The deadline for receipt of applications is **December 1, 2012**. The award recipient will be announced in February 2013 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

AMS Epsilon Fund

The AMS Epsilon Fund awards grants to summer mathematics programs that support and nurture mathematically talented high school students in the United States. The deadline to apply for funding for summer 2013 programs is **December 15, 2012**. Applications are now taken online at MathPrograms.org (`http://www.mathprograms.org`). For more information about the program and updated application information, go to `http://www.ams.org/programs/edu-support/epsilon/emp-epsilon`. For more information contact the AMS Membership and Programs Department by email at `prof-serv@ams.org` or by telephone at 800-321-4267, ext. 4170.

—AMS announcement

Call for Nominations for IMU Prizes

The International Mathematical Union (IMU) has announced a new prize to be awarded every four years at the International Congress of Mathematicians (ICM). The

Leelavati Prize will be awarded for outstanding contributions to increasing public awareness of mathematics as an intellectual discipline and the crucial role it plays in diverse human endeavors. Nominations may be made of individuals who have contributed to the visibility of mathematics through books; films; plays; television or radio shows; museum exhibits, activities, or fairs; public lectures; Internet activities for mathematics; or other means. The prize carries a cash award of 1 million Indian rupees (approximately US$18,000) and is sponsored by Infosys. For more information about the prize, see the website `http://www.mathunion.org/general/prizes/leelavati/details/`.

The IMU is also calling for nominations for its other prizes: the Fields Medals, the Rolf Nevanlinna Prize, the Carl Friedrich Gauss Prize, the Chern Medal, and the Emmy Noether Lecture. For nomination guidelines, see the website `http://www.mathunion.org/general/prizes/nomination-guidelines/`.

Nominations for all prizes should be sent to the committee chairs; their names, addresses, and email addresses can be found at the website `http://www.mathunion.org/general/prizes/prize-committee-chairs/2014/`.

The deadline for nominations for prizes to be given at the 2014 ICM in Seoul, Korea, is **December 31, 2012**.

—From an IMU announcement

Jefferson Science Fellows Program

The Jefferson Science Fellows (JSF) program at the U.S. Department of State is intended to involve the American academic science, technology, and engineering communities in the formulation and implementation of U.S. foreign policy. Each fellow will spend one year at the U.S. Department of State or the U.S. Agency for International Development (USAID) for an on-site assignment in Washington, D.C., that may also involve extended stays at U.S. foreign embassies and/or missions. Each fellow will receive a stipend of up to US$50,000. An additional US$10,000 is awarded for travel associated with their assignments at the U.S. Department of State/USAID. Following the fellowship year, the Jefferson Science Fellow will return to his or her academic career but will remain available to the U.S. Department of State for short-term projects over the following five years. The JSF program is administered by the National Academies and is supported through a partnership of the U.S. science, technology, and academic communities, professional scientific societies, and the U.S. Department of State. The deadline for applications is **January 13, 2013**. For further information, email `jsf@nas.edu`, telephone 202-334-2643, or see the website `http://sites.nationalacademies.org/PGA/Jefferson/PGA_046612`.

—From a National Academies announcement

NSF Graduate Research Fellowships

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

Fellows benefit from a three-year annual stipend of US$30,000 along with a US$10,500 cost of education allowance for tuition and fees, opportunities for international research and professional development, and the freedom to conduct their own research at any accredited U.S. institution of graduate education they choose

The next deadline to apply for to the GRFP is **November 14, 2012**. For further information, visit the website `http://www.nsfgrfp.org/`.

—From NSF announcements

Editor's Note: This issue of the *Notices* carries the article "Applications Wanted: NSF Graduate Research Fellowships", by Meredith Berthelson and Jennifer Slimowitz Pearl. Written by two NSF staffers, the article is geared specifically toward students in the mathematical sciences who wish to apply for the fellowships.

AMS Congressional Fellowship

The AMS, in conjunction with the American Association for the Advancement of Science (AAAS), will sponsor a Congressional Fellow from September 2013 through August 2014. The fellow will spend the year working on the staff of a Member of Congress or a congressional committee as a special legislative assistant in legislative and policy areas requiring scientific and technical input.

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

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

Deadline for applications is **February 15, 2013**. Applicants must have a Ph.D. or an equivalent doctoral-level degree in the mathematical sciences by the application deadline. For further information, please consult the website at `http://www.ams.org/programs/ams-fellowships/ams-aaas/ams-aaas-congressional-fellowship`, or contact the AMS Washington Office at 202-588-1100, email: `amsdc@ams.org`.

—AMS Washington Office

AAUW Educational Foundation Fellowships and Grants

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

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

—From AAUW website

NRC-Ford Foundation Fellowships

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

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

Sixty Predoctoral Fellowships will be awarded. These fellowships provide three years of support for individuals engaged in graduate study leading to a Doctor of Philosophy (Ph.D.) or Doctor of Science (Sc.D.) degree. The online application deadline is **November 14, 2012**.

Thirty-five Dissertation Fellowships will be awarded. These fellowships provide one year of support for individuals working to complete a dissertation leading to a Ph.D. or Sc.D. degree. The online application deadline is **November 19, 2012**.

Approximately twenty Postdoctoral Fellowships will be awarded. These fellowships provide one year of support for individuals engaged in postdoctoral study after the attainment of the Ph.D. or Sc.D. degree. The online application deadline is **November 19, 2012**.

Awards will be announced in April 2013. For further information, visit the website `http://sites.nationalacademies.org/pga/fordfellowships/`, or contact: Fellowships Office, Keck 576, National Research Council, 500 Fifth Street, NW, Washington, DC 20001; tel: 202-334-2872; fax: 202-334-3419; email: `infofell@nas.edu`.

—From the Ford Foundation Fellowships website

AWM Essay Contest

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

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

The deadline for the 2013 AWM Essay Contest is **January 31, 2013**. AWM is also currently seeking women mathematicians to volunteer as the subjects of these essays. For more information or to sign up as a volunteer, contact the contest organizer, Heather Lewis, at `hlewis5@naz.edu`.

—AWM announcement

AMS Department Chairs Workshop

The annual workshop for department chairs will be held a day before the start of the Joint Mathematics Meetings in San Diego, California, on Tuesday, January 8, 2013, from 8:00 a.m. to 6:30 p.m. This one-day session for mathematical sciences department chairs is organized in a workshop format so as to stimulate discussion among attendees. Sharing ideas and experiences with peers creates an environment that enables attending chairs to address departmental challenges from new perspectives.

Workshop leaders will be: Timothy Hodges, professor and graduate program director, Department of Mathematical Sciences, University of Cincinnati; Helen Roberts, professor and chair, Department of Mathematical Sciences, Montclair State University; Alex Smith, professor and chair, Department of Mathematics, University of Wisconsin-Eau Claire; and Michel Smith, professor and chair, Department of Mathematics and Statistics, Auburn University.

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

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

—AMS Washington Office

Mathematics Research Communities 2013

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

Those accepted into the program will receive support for the summer conference and will be partially supported for their participation in the Joint Mathematics Meetings that follow in January 2014. The summer conferences of the MRC are held in the breathtaking mountain setting of the Snowbird Resort, Utah, where participants can enjoy the natural beauty and a collegial atmosphere. The program also includes discussion networks by research topic and a longitudinal study of early career mathematicians.

Four conferences will be held in summer 2013, on the following topics.

Week 1a: June 9–15, 2013: **Complex Dynamics**. Organizers: Laura DeMarco, University of Illinois at Chicago; Adam Epstein, University of Warwick; Sarah Koch, Harvard University.

Week 1b: June 9–15, 2013: **Tropical and Nonarchimedean Analytic Geometry**. Organizers: Matt Baker, Georgia Institute of Technology; Sam Payne, Yale University.

Week 2: June 16–22, 2013: **Geometric Group Theory**. Organizers: Ruth Charney, Brandeis University; Tullia Dymarz, University of Wisconsin, Madison; Dan Margalit, Georgia Institute of Technology; Kim Ruane, Tufts University; Kevin Wortman, University of Utah.

Week 3: June 25–July 1, 2013: **Regularity Problems for Nonlinear Partial Differential Equations Modeling Fluids and Complex Fluids**. Organizers: Peter Constantin, Princeton University; Gautam Iyer, Carnegie Mellon University; Igor Kukavica, University of Southern California; Helena Nussenzveig-Lopes, Universidade Federal do Rio de Janeiro; Jiahong Wu, Oklahoma State University.

Individuals within one to two years prior to the receipt of their Ph.D.'s, or within one to three years after receipt of their Ph.D.'s, are welcome to apply. The MRC program is open to individuals who are U.S. citizens, as well as to those who are affiliated with U.S. institutions. A few international participants may be accepted. Women and underrepresented minorities are especially encouraged to apply. All participants are expected to be active in the full MRC program. Detailed instructions and the online application will be available on November 1, 2012.

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

For further information on Mathematics Research Communities, visit the website `http://www.ams.org/programs/research-communities/mrc-13` or contact Ellen J. Maycock at `ejm@ams.org`.

—AMS announcement

EDGE Summer Program 2013

The EDGE Program (Enhancing Diversity in Graduate Education) was launched in 1998 with the goal of strengthening the ability of women students to successfully complete graduate programs in the mathematical sciences. The program has a special emphasis on inclusion of women from underrepresented groups.

EDGE sponsors a summer program consisting of two core workshops in analysis and algebra/linear algebra, as well as minicourses in vital areas of mathematical research in pure and applied mathematics. The program brings in short-term visitors from academia and industry, guest lecturers, and graduate student mentors, and also holds problem sessions. A follow-up mentoring program and support network is established with the participants' respective graduate programs.

Applicants to the program should be women who are: (1) graduating seniors who have applied to Ph.D. programs in the mathematical sciences; (2) recent recipients of undergraduate degrees who are now entering Ph.D.

programs; or (3) first-year Ph.D. students. All applicants should have completed standard junior-senior level undergraduate courses in analysis and abstract algebra. Women from minority groups who fit one of the above three categories are especially encouraged to apply. Final acceptance to the program is contingent upon acceptance to a Ph.D. program in the mathematical sciences.

Pending funding, the EDGE 2013 Summer Program will be held at New College Florida. A stipend plus travel, room, and board will be awarded to participants. The application deadline for the program is **Monday, February 25, 2013**. Acceptance to the program will be announced in April.

For further information, visit the website `http://www.edgeforwomen.org/`.

—EDGE announcement

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

The National Science Foundation (NSF) is sponsoring a summer research program in Australia, China, Japan, Korea, Taiwan, New Zealand, and Singapore for U.S. graduate students during the summer of 2013. The East Asia and Pacific Summer Institutes (EAPSI) provide U.S. graduate students in science and engineering with firsthand research experience in the aforementioned countries; an introduction to the science and science policy infrastructure of the respective locations; and orientation to the culture and language. The primary goals of EAPSI are to introduce students to East Asian and Pacific science and engineering in the context of a research laboratory and to initiate personal relationships that will better enable them to collaborate with foreign counterparts in the future. The institutes last approximately eight weeks (ten weeks in Japan) from June to August and are administered in the United States by the NSF.

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

The deadline for full proposals is **November 8, 2012**. Proposers are required to prepare and submit all proposals for this announcement/solicitation through the FastLane system. Further information and detailed instructions are available at `http://www.nsf.gov/pubs/2012/nsf12498/nsf12498.htm?WT.mc_id=USNSF_25&WT.mc_ev=click #awd_info` (or `http://tinyurl.com/cqgnexu`).

—From an NSF announcement

News from the Fields Institute

The Fields Institute in Toronto, Canada, invites applications for postdoctoral fellowships to participate in the Thematic Program on Calabi-Yau Varieties: Arithmetic, Geometry, and Physics during the 2013–2014 academic year. The fellowships provide for a period of engagement in research and participation in the activities of the Institute. In addition to regular postdoctoral support, one visitor for each six-month program will be awarded the Institute's prestigious Jerrold E. Marsden Postdoctoral Fellowship.

Applicants seeking postdoctoral fellowships funded by other agencies (such as NSERC or international fellowships) are encouraged to request the Fields Institute as their proposed location of tenure and should apply to the Institute for a letter of invitation.

Qualified candidates who will have recently completed a Ph.D. in a related area of the mathematical sciences are encouraged to apply. The deadline for applications is **December 15, 2012**, although late applications may be considered. For more information, see the website `http://www.fields.utoronto.ca/honours/postdoc.html`.

The Fields Institute is committed to diversity and welcomes applications from women, members of First Nations or visible minorities, persons with disabilities, members of sexual minority groups, and others who may contribute to the diversity of ideas.

—From a Fields Institute announcement

News from IPAM

The Institute for Pure and Applied Mathematics (IPAM), a National Science Foundation (NSF) mathematics institute located at the University of California Los Angeles, offers programs that encourage cross-disciplinary collaboration. IPAM holds long- and short-term research programs and workshops throughout the academic year for junior and senior mathematicians and scientists who work in academia, the national laboratories, and industry.

IPAM will be attending the Joint Math Meetings in San Diego on January 9–12, 2013. A reception sponsored by all of the mathematical sciences institutes will take place on Wednesday, January 9, from 5:30 to 8:00 p.m. in San Diego Ballroom B at the Marriott. Additionally, several students in our Research in Industrial Projects for Students (RIPS) program will present posters in the MAA Undergraduate Poster Session on Friday, January 11, 2013, 3:30–5:30 p.m., in Exhibit Hall B2, San Diego Convention Center.

Currently, IPAM is in the midst of its long program on Materials Defects: Mathematics, Computation, and Engineering. Researchers from mathematics, physics, materials science, and computer science are in residence at IPAM, and a series of workshops is in progress. The final two workshops will be held in November and December; more information is available at `http://www.ipam.ucla.edu/programs/md2012/`.

Next summer, IPAM will sponsor a graduate summer school on computer vision from July 22 to August 9, 2013. The application deadline is **March 31, 2013**. IPAM will also offer its undergraduate program, Research in Industrial Projects for Students (RIPS), in both Los Angeles and Hong Kong. The application deadline for RIPS is **February 12, 2013**.

Finally, IPAM is pleased to announce that Fields Medalist Wendelin Werner will give a series of talks during our annual Green Family Lecture Series, to be held the week of June 3, 2013. Details will be posted in the spring.

Following is a list of upcoming programs at IPAM. See the website `www.ipam.ucla.edu` for detailed information and to find application and registration forms.

Winter Workshops. You may apply for support or register for each workshop online.

January 15–18, 2013: Structure and Randomness in System Identification and Learning.

January 28–February 1, 2013: Adaptive Data Analysis and Sparsity.

February 11–15, 2013: Convex Relaxation Methods for Geometric Problems in Scientific Computing.

March 4–8, 2013: Multimodal Neuroimaging.

Long Programs. You may apply online for support to be a core participant for the entire program or to attend any of the following individual workshops.

March 11–June 14, 2013. Interactions Between Analysis and Geometry.

March 12–15, 2013: Tutorials.

March 18–22, 2013: Workshop I: Analysis on Metric Spaces.

April 8–12, 2013: Workshop II: Dynamics of Groups and Rational Maps.

April 29–May 3, 2013: Workshop III: Nonsmooth Geometry.

May 20–24, 2013: Workshop IV: Quasiconformal Geometry and Elliptic PDEs.

September 9–December 13, 2013: Materials for a Sustainable Energy Future. This program is part of the international initiative "Mathematics of Planet Earth". You may apply online for support to be a core participant for the entire program or to attend any of the following individual workshops.

September 10–13, 2013: Tutorials.

September 23–27, 2013: Workshop I: Solar Cells.

October 14–18, 2013: Workshop II: Fuels from Sunlight.

November 4–8, 2013: Workshop III: Batteries and Fuel Cells.

November 18–22, 2013: Workshop IV: Energy Conservation and Waste Heat Recovery.

—From an IPAM announcement

News from the MSRI

With funding from the National Science Foundation (NSF) and the National Security Agency (NSA), the Mathematical Sciences Research Institute (MSRI) will hold five workshops in Commutative Algebra and Noncommutative Algebraic Geometry and Representation Theory during the spring of 2013. Established researchers, postdoctoral fellows, and graduate students are invited to apply for funding. It is the policy of MSRI to actively seek to achieve diversity in its workshops. Thus a strong effort is made to remove barriers that hinder equal opportunity, particularly for those groups that have been historically underrepresented in the mathematical sciences. The workshops to be held are as follows:

January 24–25, 2013: Connections for Women: Noncommutative Algebraic Geometry and Representation Theory. `https://www.msri.org/web/msri/scientific/workshops/programmatic-workshops/show/-/event/Wm9061`.

January 28–February 1, 2013: Introductory Workshop: Noncommutative Algebraic Geometry and Representation Theory. `https://www.msri.org/web/msri/scientific/workshops/programmatic-workshops/show/-/event/Wm9062`.

February 11–17, 2013: Representation Theory, Homological Algebra, and Free Resolutions. `https://www.msri.org/web/msri/scientific/workshops/programmatic-workshops/show/-/event/Wm8999`.

April 8–12, 2013: Interactions between Noncommutative Algebra, Representation Theory, and Algebraic Geometry. `https://www.msri.org/web/msri/scientific/workshops/programmatic-workshops/show/-/event/Wm9063`.

May 6–10, 2013: The Commutative Algebra of Singularities in Birational Geometry: Multiplier Ideals, Jets, Valuations, and Positive Characteristic Methods. `https://www.msri.org/web/msri/scientific/workshops/programmatic-workshops/show/-/event/Wm9000`.

News from Institut Mittag-Leffler

Institut Mittag-Leffler in Djursholm, Sweden, announces postdoctoral fellowship grants for 2013–2014. The scientific areas are *Evolutionary Problems*, September 2 to December 13, 2013; and *Graphs, Hypergraphs, and Computing*, January 14 to April 30, 2014. The deadline to apply is **January 7, 2013**.

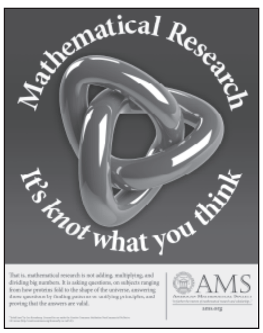
The institute also issues a call for proposals for programs in mathematical sciences for the academic year 2015–2016. The deadline to submit proposals is **February 4, 2013**.

For further information on both of these opportunities, visit the website `http://www.mittag-leffler.se`.

—Institut Mittag-Leffler announcements

Inside the AMS

From the AMS Public Awareness Office



*** "Math Research, It's *Knot* What You Think" is a new poster from the Public Awareness Office**. To request a copy, email paoffice@ams.org with subject line: Math research poster.

*** Highlights of the 2012 Mathematics Research Communities (MRC)**. See photographs and read feedback abut the 2012 MRC programs, held in Snowbird, Utah, at http://www.ams.org/programs/research-communities/mrc-12-highlights

*** Bridges 2012: Highlights of the Conference on Mathematics Connections in Art, Music, and Science**. Read about the varied program and see photographs of the 2012 conference held at Towson University in Maryland, at http://www.ams.org/meetings/bridges-2012-conf.

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

AMS Fellows Selected

A list of those who have accepted the designation of "Fellow of the AMS" will appear on the AMS website beginning November 1, 2012. The list will be located at

www.ams.org/profession/ams-fellows

—AMS Membership and Programs Department

Deaths of AMS Members

William G. Bade, of Oakland, California, died on August 10, 2012. Born on May 29, 1924, he was a member of the Society for 64 years.

Jayanthi Chidambaraswamy, of Bloomington, Illinois, died on June 25, 2006. Born on November 14, 1927, he was a member of the Society for 41 years.

Nicolaas G. de Bruijn, professor, Technical University Eindhoven, died on February 17, 2012. Born on July 9, 1918, he was a member of the Society for 57 years.

Nathan J. Divinsky of Vancouver, British Columbia, died on June 17, 2012. Born on October 29, 1925, he was a member of the Society for 63 years.

Richard L. Faber, of Newton, Massachusetts, died on August 22, 2011. Born on May 7, 1940, he was a member of the Society for 50 years.

Godfrey L. Loudner, of Mission, South Dakota, died on August 2, 2012. Born on September 30, 1942, he was a member of the Society for 22 years.

R. Duncan Luce, professor, University of California Irvine, died on August 11, 2012. Born on May 16, 1925, he was a member of the Society for 62 years.

Leo N. Orloff, of San Francisco, California, died on March 1, 2012. Born on November 9, 1916, he was a member of the Society for 53 years.

Emilio O. Roxin, of Franklin, Massachusetts, died on August 21, 2012. Born on April 6, 1922, he was a member of the Society for 51 years.

William G. Stokes, of Austin, Texas, died on September 16, 2012. Born on December 26, 1921, he was a member of the Society for 47 years.

William Paul Thurston, of Ithaca, New York, died on August 21, 2012. Born on October 30, 1946, he was a member of the Society for 44 years.

Paul A. Willis, of Altadena, California, died on April 22, 2012. Born on September 4, 1927, he was a member of the Society for 50 years.

How Many Norman Lloyd Johnsons Are There in the Mathematical Reviews Database?

Norman Richert

Do you know your MR Author ID? The proper identification of authors of scientific papers has become increasingly important in the digital era. Mathematical Reviews (MR) has been working on "author authority" since 1940. In fact, in the basement of our Ann Arbor, Michigan, office there are file cards on authors, which Otto Neugebauer, our founding editor, brought with him from Germany in the 1930s. At the founding of Mathematical Reviews in 1940, the "author database" was a file card system. That file card system was translated into an electronic database in the late 1960s and early 1970s. Our identification of authors is not simply a machine algorithm, although it begins with extensive computation. The results of that computer analysis for each author of each paper are examined by MR staff members in the Cataloging Department. As of the writing of this column, there were 634,104 distinct authors in the MR author database. By the time you read this, there will be at least 10,000 more. Keeping these authors separate involves a careful look at the published name string of an author, coauthors, institutional codes, Mathematics Subject Classifications (MSC), and sometimes direct communication.

We are hoping that your MR Author ID will become a mathematical "unique personal academic identifier", reliably identifying your published research. Beginning in 2013, AMS publications will ask for your MR Author ID and those of your coauthors when your paper is accepted for publication. Providing this information will not only improve the information associated with your published paper (i.e., by providing a link from the publisher site rather than into MathSciNet) but will also assist us in keeping up with the ever-growing volume of mathematical publications around the world.

Each distinct author in the MR database has an associated author profile page. For example, the author profile of Saunders Mac Lane can be found at `www.ams.org/mathscinet/search/author.html?mrauthid=117515`. Saunders's MR Author ID 117515 can be seen in the URL, as well as on his profile page. These profile pages can be found in various ways. The most direct approach is to select the Authors tab in MathSciNet, enter the name of the author, and select from the various options if more than one. An author profile page is a series of snapshots and tools associated with that author's publications. For example, there is a complete list of published names.

One of the most important reasons for the accurate identification of authors is that authors may publish under various names: using a first name only, using a first name and middle initial, and using a first initial only, to name just a few possibilities. Saunders Mac Lane published under both Mac Lane and MacLane, as well as Makleĭn. Sometimes authors publish under pseudonyms. **MR1507467** is a DML (Digital Mathematics Li-

Norman Richert is managing editor of Mathematical Reviews. His email address is `nrichert@ams.org`.

DOI: http://dx.doi.org/10.1090/noti922

brary) item. The article link in MathSciNet takes you to a digitization of this *American Journal of Mathematics* "Correspondence" from 1956. This "Correspondence" is signed, "Yours, etc., X.X.X." It came to our attention that the author of this correspondence is Jean-Pierre Serre, so X.X.X. is one of the "published as" names for Professor Serre. Tom Odda is a pseudonym for Ron Graham (MR Author ID: 76025) in **MR0557896**, as Professor Graham's author profile shows. A search for "Odda, Tom" in the Author field under the Publications tab shows that there is still work to be done. The search returns three papers. In addition to **MR0557896,** there are **MR1538085** and **MR1537614**. In these latter two items the author names are not links, because the author authority work has not yet been done. In fact, most of the DML items in MathSciNet have not yet had their author authority work done; that is a project for the future.

To answer the question of the title, there are two authors named Norman Lloyd Johnson in the Mathematical Reviews database. Their MR Author IDs are 193061 and 193190. Both are prolific authors. The hard work of MR staff has kept all their publications correctly identified.

Of course, mistakes can be made. Should you find a mistake in author identification (or any other error), please report it to us using the Support Mail link found on every MathSciNet page. Be sure to include as much information as possible, in particular, why you believe that it is a mistake. This can be with reference to any author in the database, not just yourself. Perhaps Tom Odda will write.

Reference and Book List

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

Contacting the *Notices*

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

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

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

Information for *Notices* Authors

The *Notices* welcomes unsolicited articles for consideration for publication, as well as proposals for such articles. The following provides general guidelines for writing *Notices* articles and preparing them for submission. Contact information for *Notices* editors and staff may be found on the *Notices* website, `http://www.ams.org/notices`.

Upcoming Deadlines

October 17, 2012: Applications for NSF Postdoctoral Research Fellowships. See `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5301`.

November 1, 2012: Proposals for AIM Workshops. See `www.aimath.org`.

November 1, 2012: Nominations for Clay Research Fellowships. See `http://www.claymath.org/research_fellows`.

November 1, 2012: Applications for National Academies Research Associateship Programs. See `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 6, 2012: Applications for AMS-AIM-NSF Math Camp Workshop. See `http://www.aimath.org/ARCC/workshops/mathcamp.html`.

November 8, 2012: Applications for NSF East Asia and Pacific Summer Institutes (EAPSI). See "Mathematics Opportunities" in this issue.

November 8, 2012: Full proposals for NSF Program ADVANCE Partnerships for Adaptation, Implementation, and Dissemination (PAID). See

Where to Find It

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

http://www.nsf.gov/pubs/2012/nsf12584/nsf12584.htm?WT.mc_id=USNSF_36&WT.mc_ev=click.

November 14, 2012: Applications for NSF Graduate Research Fellowships. See "Mathematics Opportunities" in this issue.

November 14, 2012: Applications for NRC-Ford Foundation Predoctoral Fellowships. See "Mathematics Opportunities" in this issue.

November 15, 2012: Nominations for 2013 Vasil A. Popov Prize. See http://imi.cas.sc.edu/popov-prize-call-nominations/.

November 19, 2012: Applications for NRC-Ford Foundation Dissertation and Postdoctoral Fellowships. See "Mathematics Opportunities" in this issue.

December 1, 2012: Applications for PIMS Postdoctoral Fellowships. See http://www.pims.math.ca/scientific/postdoctoral or contact: assistant.director@pims.math.ca.

December 1, 2012: Applications for AMS Centennial Fellowships. See http://www.ams.org/ams-fellowships/. For paper copies of the form, write to the Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; prof-serv@ams.org; 401-455-4105

December 3, 2012: Entries for Ferran Sunyer i Balaguer Prize. See http://ffsb.iec.cat.

December 15, 2012: Applications for AMS Epsilon Fund grants. See "Mathematics Opportunities" in this issue.

December 15, 2012: Applications for Fields Institute postdoctoral fellowships for the Thematic Program on Calabi-Yau Varieties: Arithmetic, Geometry, and Physics. See "Mathematics Opportunities" in this issue.

December 31, 2012: Nominations for IMU Prizes: Leelavati Prize, Fields Medals, Nevanlinna Prize, Gauss Prize, Chern Medal, and Noether Lectureship. See "Mathematics Opportunities" in this issue.

December 31, 2012: Nominations for Otto Neugebauer Prize of the EMS. See the website http://www.euro-math-soc.eu/otto_neugebauer_prize.html.

January 7, 2013: Applications for Institut Mittag-Leffler postdoctoral fellowship grants for 2013–2014. See "Mathematics Opportunities" in this issue.

January 13, 2013: Applications for Jefferson Science Fellows Program. See "Mathematics Opportunities" in this issue.

January 31, 2013: Entries for AWM Essay Contest. See "Mathematics Opportunities" in this issue.

February 1, 2013: Applications for AWM Travel Grants, Mathematics Education Research Travel Grants, Mathematics Mentoring Travel Grants, and Mathematics Education Research Mentoring Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; or telephone: 703-934-0163; e-mail: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

February 4, 2013: Proposals for programs in mathematical sciences for Institut Mittag-Leffler for academic year 2015–2016. See "Mathematics Opportunities" in this issue.

February 12, 2013: Applications for IPAM undergraduate program Research in Industrial Projects for Students (RIPS). See "Mathematics Opportunities" in this issue.

February 15, 2013: Applications for AMS Congressional Fellowship. See "Mathematics Opportunities" in this issue.

February 25, 2013: Applications for EDGE Summer Program. See "Mathematics Opportunities" in this issue.

March 31, 2013: Applications for IPAM graduate summer school on computer vision. See "Mathematics Opportunities" in this issue.

April 15, 2013: Applications for fall 2013 semester of Math in Moscow. See http://www.mccme.ru/mathinmoscow, or write to: Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax: +7095-291-65-01; e-mail: mim@mccme.ru. Information and application forms for the AMS scholarships are available on the AMS website at http://www.ams.org/programs/travel-grants/mimoscow, or by writing to: Math in Moscow Program, Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence RI 02904-2294; email student-serv@ams.org.

May 1, 2013: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; or telephone: 703-934-0163; e-mail: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 1, 2013: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; or telephone: 703-934-0163; e-mail: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 4, 2013: Letters of intent for NSF Program ADVANCE Institutional Transformation and Institutional Transformation Catalyst awards. See http://www.nsf.gov/pubs/2012/nsf12584/nsf12584.htm?WT.mc_id=USNSF_36&WT.mc_ev=click.

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

NSF Division of Mathematical Sciences

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

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Book List

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

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

Adventures in Group Theory: Rubik's Cube, Merlin's Machine, and Other Mathematical Toys, by David Joyner. Johns Hopkins University Press (second edition), December 2008. ISBN-13: 978-08018-9013-0.

American Mathematicians as Educators, 1893–1923: Historical Roots of the "Math Wars" by David Lindsay Roberts. Docent Press, July 2012, ISBN-13: 978-09837-004-49.

The Beginning of Infinity: Explanations That Transform the World, by David Deutsch. Viking Adult, July 2011. ISBN-13: 978-06700-227-55. (Reviewed April 2012.)

Bibliography of Raymond Clare Archibald by Scott Guthery. Docent Press, April 2012. ISBN-13: 978-0983700425.

The Big Questions: Mathematics, by Tony Crilly. Quercus, April 2011. ISBN: 978-18491-624-01.(Reviewed October 2012.)

Calculating Curves: The Mathematics, History, and Aesthetic Appeal of T. H. Gronwall's Nomographic Work, by Thomas Hakon Gronwall, with contributions by Ron Doerfler and Alan Gluchoff, translation by Paul Hamburg, and bibliography by Scott Guthery. Docent Press, April 2012. ISBN-13: 978-09837-004-32.

The Calculus of Selfishness, by Karl Sigmund. Princeton University Press, January 2010. ISBN-13: 978-06911-427-53. (Reviewed January 2012.)

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. (Reviewed March 2012.)

Classic Problems of Probability, by Prakash Gorroochurn. Wiley, May 2012. ISBN: 978-1-1180-6325-5.

The Crest of the Peacock: Non-European Roots of Mathematics, by George Gheverghese Joseph. Third edition. Princeton University Press, October 2010. ISBN-13: 978-0-691-13526-7.

The Crossing of Heaven: Memoirs of a Mathematician, by Karl Gustafson. Springer, January 2012. ISBN-13: 978-36422-255-74.

Divine Machines: Leibniz and the Sciences of Life, by Justin E. H. Smith. Princeton University Press, May 2011. ISBN-13: 978-06911-417-87.

Elliptic Tales: Curves, Counting, and Number Theory, by Avner Ash and Robert Gross. Princeton University Press, March 2012. ISBN-13: 978-06911-511-99.

Emmy Noether's Wonderful Theorem, by Dwight E. Neuenschwander. Johns Hopkins University Press, November 2010. ISBN-13: 978-08018-969-41.

Excursions in the History of Mathematics, by Israel Kleiner. Birkhäuser, 2012. ISBN-13: 978-08176-826-75.

Experimental and Computational Mathematics: Selected Writings, by Jonathan Borwein and Peter Borwein. PSIpress, 2011. ISBN-13: 978-19356-380-56.

Fascinating Mathematical People: Interviews and Memoirs, edited by Donald J. Albers and Gerald L. Alexanderson. Princeton University Press, October 2011. ISBN-13: 978-06911-482-98.

**The Foundations of Geometry And Religion From An Abstract Standpoint,* by Salilesh Mukhopadhyay. Outskirts Press, July 2012. ISBN: 978-1-4327-9424-8.

Galileo's Muse: Renaissance Mathematics and the Arts, by Mark Austin-Peterson. Harvard University Press, October 2011. ISBN-13: 978-06740-597-26. (Reviewed in this issue.)

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

Gottfried Wilhelm Leibniz: The Polymath Who Brought Us Calculus, by M. B. W. Tent. A K Peters/CRC Press, October 2011. ISBN-13: 978-14398-922-20.

**Guesstimation 2.0: Solving Today's Problems on the Back of a Napkin*, by Lawrence Weinstein. Princeton University Press, September 2012. ISBN: 978-06911-508-02.

In Pursuit of the Traveling Salesman: Mathematics at the Limits of Computation, by William J. Cook. Princeton University Press, December 2011. ISBN-13: 978-06911-527-07.

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

In Service to Mathematics: The Life and Work of Mina Rees, by Amy Shell-Gellasch. Docent Press, December 2010. ISBN-13: 978-0-9837004-1-8.

The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe, by Frank Close. Basic Books, November 2011. ISBN-13: 978-04650-214-44. (Reviewed September 2012.)

The Information: A History, a Theory, a Flood, by James Gleick. Pantheon, March 2011. ISBN-13: 978-03754-237-27.

The Irrationals: A Story of the Numbers You Can't Count On, by Julian Havil. Princeton University Press, June 2012. ISBN-13: 978-0691143422.

Knots Unravelled: From String to Mathematics, by Meike Akveld and Andrew Jobbings. Arbelos, October 2011. ISBN-13: 978-09555-477-20.

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

Lemmata: A Short Mathematical Thriller, by Sam Peng. CreateSpace, December 2011. ISBN-13: 978-14681-442-39.

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

Lost in a Cave: Applying Graph Theory to Cave Exploration, by Richard L. Breisch. National Speleological Society, January 2012. ISBN-13: 978-1-879961-43-2.

The Lost Millennium: History's Timetables Under Siege, by Florin Diacu. Johns Hopkins University Press (second edition), November 2011. ISBN-13: 978-14214-028-88.

Magical Mathematics: The Mathematical Ideas That Animate Great Magic Tricks, by Persi Diaconis and Ron Graham. Princeton University Press, November 2011. ISBN-13: 978-06911-516-49. (Reviewed August 2012.)

The Man of Numbers: Fibonacci's Arithmetic Revolution, by Keith Devlin. Walker and Company, July 2011. ISBN-13: 978-08027-781-23. (Reviewed May 2012.)

Math Girls, by Hiroshi Yuki (translated from the Japanese by Tony Gonzalez). Bento Books, November 2011. ISBN-13: 978-09839-513-15. (Reviewed August 2012.)

Math is Murder, by Robert C. Brigham and James B. Reed. Universe, March 2012. ISBN-13: 978-14697-972-81.

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

Mathematical Excursions to the World's Great Buildings, by Alexander J. Hahn. Princeton University Press, July 2012. ISBN-13: 978-06911-452-04

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

Mathematics in Popular Culture: Essays on Appearances in Film, Fiction, Games, Television and Other Media, edited by Jessica K. Sklar and Elizabeth S. Sklar. McFarland, February 2012. ISBN-13: 978-07864-497-81.

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

The Mathematics of Life, by Ian Stewart. Basic Books, June 2011. ISBN-13: 978-04650-223-80. (Reviewed December 2011.)

Mathematics, Religion and Ethics: An Epistemological Study, by Salilesh Mukhopadhyay. Feasible Solution LLC, September 2010. ISBN-13: 978-1-4507-3558-2.

The Noether Theorems: Invariance and Conservation Laws in the

Twentieth Century, by Yvette Kosmann-Schwarzbach. Springer, December 2010. ISBN-13: 978-03878-786-76.

Nine Algorithms That Changed the Future: The Ingenious Ideas That Drive Today's Computers, by John MacCormick. Princeton University Press, December 2011. ISBN-13: 978-06911-471-47.

**Number-Crunching: Taming Unruly Computational Problems from Mathematical Physics to Science Fiction,* by Paul J. Nahin. Princeton University Press, August 2011. ISBN: 978-06911-442-52.

Numbers: A Very Short Introduction, by Peter M. Higgins. Oxford University Press, February 2011. ISBN-13: 978-0-19-958405-5. (Reviewed January 2012.)

On the Formal Elements of the Absolute Algebra, by Ernst Schröder (translated and with additional material by Davide Bondoni; with German parallel text). LED Edizioni Universitarie, 2012. ISBN: 978-88-7916-516-7.

Our Days are Numbered: How Mathematics Orders Our Lives, by Jason Brown. Emblem Editions, April 2010. ISBN-13: 978-07710-169-74. (Reviewed October 2012.)

The Philosophy of Mathematical Practice, Paolo Mancosu, editor. Oxford University Press, December 2011. ISBN-13: 978-01996-401-02. (Reviewed March 2012.)

Pricing the Future: Finance, Physics, and the 300-Year Journey to the Black-Scholes Equation, by George G. Szpiro. Basic Books, November 2011. ISBN-13: 978-04650-224-89.

Proof and Other Dilemmas: Mathematics and Philosophy, edited by Bonnie Gold and Roger A. Simons. Mathematical Association of America, July 2008. ISBN-13: 978-08838-556-76. (Reviewed December 2011.)

The Proof Is in the Pudding: A Look at the Changing Nature of Mathematical Proof, by Steven G. Krantz. Springer, May 2011. ISBN-13: 978-03874-890-87.

Proving Darwin: Making Biology Mathematical, by Gregory Chaitin. Pantheon, May 2012. ISBN: 978-03754-231-47.

Scientific Reflections: Selected Multidisciplinary Works, by Richard Crandall. PSIpress, 2011. ISBN-13: 978-19356-380-87.

Six Gems of Geometry, by Thomas Reale. PSIpress, 2010. ISBN-13: 978-19356-380-25.

Sources in the Development of Mathematics: Series and Products from the Fifteenth to the Twenty-first Century, by Ranjan Roy. Cambridge University Press, June 2011. ISBN-13: 978-05211-147-07.

A Strange Wilderness: The Lives of the Great Mathematicians, by Amir D. Aczel. Sterling, October 2011.ISBN-13: 978-14027-858-49.

Taking Sudoku Seriously: The Math behind the World's Most Popular Pencil Puzzle, by Jason Rosenhouse and Laura Taalman. Oxford University Press, January 2012. ISBN-13: 978-01997-565-68.

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. (Reviewed May 2012.)

Top Secret Rosies: The Female Computers of World War II. Video documentary, produced and directed by LeAnn Erickson. September 2010. Website: `http://www.topsecretrosies.com`. (Reviewed February 2012.)

Transcending Tradition: Jewish Mathematicians in German Speaking Academic Culture, edited by Birgit Bergmann, Moritz Epple, and Ruti Ungar. Springer, January 2012. ISBN: 978-3642224638.

Turbulent Times in Mathematics: The Life of J.C. Fields and the History of the Fields Medal, by Elaine McKinnon Riehm and Frances Hoffman. AMS, November 2011. ISBN-13: 978-08218-691-47.

Uneducated Guesses: Using Evidence to Uncover Misguided Education Policies, by Howard Wainer. Princeton University Press, August 2011. ISBN-13: 978-06911-492-88. (Reviewed June/July 2012.)

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

Vilim Feller, istaknuti hrvatsko-americki matematicar/William Feller, Distinguished Croatian-American Mathematician, by Darko Zubrinic. Bilingual Croatian-English edition, Graphis, 2011. ISBN-13: 978-953-279-016-0.

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

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: 978-0-691-13890-9. (Reviewed February 2012.)

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

Why Beliefs Matter: Reflections on the Nature of Science, by E. Brian Davies. Oxford University Press, June 2010. ISBN-13: 978-01995-862-02. (Reviewed April 2012.)

Why Cats Land on Their Feet (and 76 Other Physical Paradoxes and Puzzles), by Mark Levi. Princeton University Press, May 2012. ISBN-13: 978-0691148540.

Backlog of Mathematics Research Journals

Journal (Print and Electronic)	Number issues per Year	Approximate Number Pages per Year	2011 Median Time (in Months) from: Submission to Final Acceptance	Acceptance to Print	Acceptance to Electronic Posting	Editor's Current Estimate of Waiting Time between Submission and Publication (in Months): Print	Electronic
Abstr. Appl. Anal.	*	4000	2	3–9**	2.1	6–9**	3.5
Acta Inform.	8	640	4	2	1	6	5
Acta Math.	4	800	11	14	13	29	28
Adv. Math. Commun.	4	800	3	2	1	5	4
Algebr. Geom. Topol.	5	3125	7.2	3	2.5	10.6	10.1
Algebra Number Theory	8	2048	8.7	9.4	8.9	18.6	18.1
Algorithmica	12	1800	4	NA	0.7	NA	4.5
Amer. J. Math.	6	1728	NA	18	17	16–18	15–17
Anal. PDE	6	1536	10.6	14.2	13.7	25.4	24.9
Ann. Appl. Probab.	6	2600	8.25	12	12	24	24
Ann. Mat. Pura Appl. (4)	4	720	8	12	1.2	20	9.2
Ann. of Math. (2)	6	3600	24	10	9	11	9
Ann. Probab.	6	2700	8.75	10.5	10.5	23.5	23.5
Ann. Statist.	6	4000	6.25	6	5	13	11
Appl. Anal.	12	1968	3	13	6	10	5.2
Arch. Hist. Exact. Sci.	6	696	3	4	2	4	2
Arch. Math. Logic	8	1040	2	5	1	7	3
Arch. Ration. Mech. Anal.	12	4200	4	6	3	4	1
Ark. Mat.	2	400	4	21	6	26	15
Balkan J. Geom. Appl.	2	300	5	5	3	8	6
Beitr. Algebra Geom.	2	600	3	3	1	6	4
Bull. Aust. Math. Soc.	6	1048	3	7	3	11	6
Bull. Lond. Math. Soc.	6	1344	8	7	3.1	15.5	10.3
Bull. Soc. Math. France	4	610	8	12	9	9	6
Calc. Var. Partial Differential Equations	12	1740	6.9	12	1.2	18	7
Canad. J. Math.	6	1440	6	17	8.4	17	9
Canad. Math. Bull.	4	896	5	30	18.2	20	8
Cent. Eur. J. Math.	6	2250	4.2	2.4	1.6	6.1	5.1
Comm. Math. Phys.	24	7000	6	4.5	1	4	1
Commun. Appl. Math. Comput. Sci.	1	225	7	2	1.5	9.5	9
Commun. Pure Appl. Anal.	6	2000	4	8	7	12	11
Complex Var. Elliptic Equ.	12	1200	3.1	13.7	8.2	11.5	5.7
Compos. Math.	6	2016	8	8	7.4	14	13

The Backlog of Research Journals is reported each year in the November issue of the *Notices*. The report covers journals of publishers who have agreed to participate and who continue to provide backlog information. Publishers whose journals are not currently included can request that their journals be added. Such requests should be made in email to Marcia Almeida, `backlogreport@ams.org`. To be eligible for inclusion in the backlog report, a journal must be on the list of journals receiving cover-to-cover treatment in *Mathematical Reviews* (`http://www.ams.org/msnhtml/serials.pdf`).

Once a publisher's journals are accepted for inclusion, the publisher must designate a contact person or persons to supply data about the journals to the AMS. While the AMS makes every effort to obtain the data from the designated contacts, if data about a journal is not supplied, then that journal will not appear in the backlog report.

Journal (Print and Electronic)	Number issues per Year	Approximate Number Pages per Year	2011 Median Time (in Months) from: Submission to Final Acceptance	Acceptance to Print	Acceptance to Electronic Posting	Editor's Current Estimate of Waiting Time between Submission and Publication (in Months) Print	Electronic
Computing	12	960	8	5	1	5	4
Constr. Approx.	6	900	8	16	5	13	10
Discrete Comput. Geom.	8	1900	8	4	2	12	10
Discrete Contin. Dyn. Syst.	12	6000	5	8	6	13	11
Discrete Contin. Dyn. Syst. Ser. B	8	4000	4	7	5	11	9
Duke Math. J.	15	3000	13	8	8	19	19
Dyn. Syst.	4	592	7.5	6.3	1.7	10	7.7
Found. Comput. Math.	6	750	14.5	6	2	18	12
Geom. Dedicata	6	1500	10.1	7	0.5	6–7	3
Geom. Topol.	4	2500	11.3	2.4	1.9	14.2	13.7
Homology Homotopy Appl.	2	700–800	5.25	5.9	3.4	10	7
Houston J. Math.	4	1300	6	26	23	30	27
Illinois J. Math.	4	1400	6	15	13	18	16
Int. J. Math. Math. Sci.	*	1500	2.3	3–9**	2.5	6–9**	4.5
Int. J. Stoch. Anal.	*	300	3.9	9–10**	1.9	7–9**	3.8
Invent. Math.	12	2740	7.5	6	1.2	13.5	8.7
Inverse Probl. Imaging	4	1000	4	3	2	7	6
Involve	4	512	9.9	4.4	3.9	14.9	14.4
Israel J. Math.	6	4000	4.5	20	14	20	12
J. Algebraic Geom.	4	800	8	12	2	18	10
J. Amer. Math. Soc.	4	1200	10.2	5.2	1.3	16.4	11.3
J. Anal. Math.	3	1180	6	13	13	17	17
J. Appl. Anal.	2	300	11	15	14	15	14
J. Appl. Math.	*	5000	3.2	9–10**	2.7	6–9**	3.6
J. Aust. Math. Soc.	6	864	10	8	15	12	10
J. Complexity	6	600	6	6	1	12	7
J. Comput. System Sci.	6	1200	12	14	12	14	12
J. Differential Geom.	9	1700	6	6	4	5	5
J. Eur. Math. Soc. (JEMS)	6	1800	6	12	11	18	17
J. Geom. Anal.	4	1200	4.8	14	3.8	12	6
J. Ind. Manag. Optim.	4	1000	4	5	4	9	8
J. Integral Equations Appl.	4	600	10	22	19	24	21
J. Lond. Math. Soc. (2)	6	1920	10	8.5	5.1	16.6	13.9
J. Math. Biol.	12	2000	9	8.5	1.5	17.5	10.5
J. Math. Phys.	12	10072	2.8	1.8	0.8	4.6	3.6
J. Mod. Dyn.	4	800	6	1	1	7	7
J. Operator Theory	4	1200	10	25	22	32	29
J. Symbolic Logic	4	1450	9	11	9	17	15
J. Topol.	4	1024	10	5	3.7	14	12.6
Kyoto J. Math.	4	900	5.8	7.2	7.2	8	7
Linear Algebra Appl.	24	8000	5	5	1.2	8	6
Linear Multilinear Algebra	12	1476	5.6	14.9	9.3	10	5.7
Lobachevskii J. Math.	4	500	3	3	2	6	5
Manuscripta Math.	12	1630	6.5	7.6	1.8	14	8.3
Math. Ann.	12	2900	9	5	4.5	14	13
Math. Comp.	4	2400	7.8	13.5	7.3	24.4	17.2
Math. Control Signals Systems	4	320	16	5	0.5	11	6.5
Math. Oper. Res.	4	800	18	5	3	16	14
Math. Program.	12	2400	9	4.5	4	13	12

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Math. Res. Lett.	6	1300	7	9	9	9	9
Math. Social Sci.	6	400	12	7	1	18	12
Math. Z.	12	3600	11.5	14	1.5	25.5	13
Mathematika	2	480	8.8	6.7	3.4	12.3	7.7
Mem. Amer. Math. Soc.	6	3200	18.2	20.8	14.2	26.2	17.5
Methods Appl. Anal.	6	500	5	3	3	5	5
Michigan Math. J.	4	796	7	16	15	12	11
Monatsh. Math.	16	2400	3	2	1	5	4
Multiscale Model. Simul.	4	1865	8.5	5.7	3.3	13.7	11.7
Nagoya Math. J.	4	800	8.8	9.3	9.3	18	18
Notre Dame J. Form. Log.	4	600	7	6	6	16	16
Numer. Math.	12	2400	13	6	4	14	13
Pacific J. Math.	10	2560	6.7	8.3	7.8	15.4	14.9
Probab. Theory Related Fields	12	2100	8.5	11	1.2	19.2	9.7
Proc. Amer. Math. Soc.	12	4200	4.8	10.7	4.4	19	11.3
Proc. Lond. Math. Soc. (3)	12	2688	9.3	9.9	2.9	17.1	11.6
Publ. Math. Inst. Hautes Etudes Sci.	2	500	12.6	4	1.5	16.6	14
Quart. Appl. Math.	4	800	3	17.1	13.6	18.7	13.7
Rocky Mountain J. Math.	6	2400	10	26	23	27	24
Semigroup Forum	6	1140	12	5	1	16	13
SIAM J. Appl. Math.	6	2360	8.5	5.2	3	13.1	11.1
SIAM J. Comput.	6	2000	16.8	5	3	21.5	19.5
SIAM J. Control Optim.	6	2630	13.2	5	3.1	18.5	16.5
SIAM J. Discrete Math.	4	1920	12.8	6.7	3	18	16
SIAM J. Math. Anal.	6	2780	8.1	6.8	3.1	12.3	11.3
SIAM J. Matrix Anal. Appl.	4	1560	11	5.2	3.2	16	14
SIAM J. Numer. Anal.	6	2640	11.2	6.3	2.8	15.5	14.5
SIAM J. Optim.	4	1740	12.3	5.3	3.3	17.3	15.3
SIAM J. Sci. Comput.	6	3565	11.1	6.2	2.9	14.3	13.3
SIAM Rev.	4	825	14.8	12	11	26.8	25.8
Theory Comput. Syst.	8	1300	4	NA	0.7	NA	4.5
Trans. Amer. Math. Soc.	12	6600	8.3	20.4	15.7	27.9	24.5

Journal (Electronic)	Number of Articles Posted in 2011	2011 Median Time (in days) from: Submission to Final Acceptance	Acceptance to Posting	Format(s)
Acta Math. Acad. Paedagog. Nyházi. (N.S.) www.emis.de/journals/AMAPN/	29	165	240	pdf, ps
Adv. Difference Equ. www.advancesindifferenceequations.com/content	68	60	0***	html, pdf
Appl. Math. E-Notes www.math.nthu.edu.tw/~amen/	34	180	180	pdf
Bound. Value Probl. www.boundaryvalueproblems.com/content	59	115	0***	html, pdf
Conform. Geom. Dyn. www.ams.org/journals/ecgd	14	153	69	pdf

Journal (Electronic)	Number of Articles Posted in 2011	2011 Median Time (in days) from: Submission to Final Acceptance	Acceptance to Posting	Format(s)
Differ. Geom. Dyn. Syst. www.mathem.pub.ro/dgds	20	100	180	pdf
Discrete Math. Theor. Comput. Sci. www.dmtcs.org	35	345	22	pdf, ps
Electron. Commun. Probab. ecp.ejpecp.org	70	168	41	pdf
Electron. J. Combin. www.combinatorics.org	265	201	12	pdf
Electron. J. Differential Equations ejde.math.txstate.edu/	169	106	8	html, pdf, tex
Electron. J. Qual. Theory Differ. Equ. www.math.u-szeged.hu/ejqtde/	99	150	10	pdf
Electron. Res. Announc. Math. Sci. eramath.s3-website-us-east-1.amazonaws.com/	13	30	10	pdf
Electron. Trans. Numer. Anal. etna.mcs.kent.edu/	20	198.5	80	html, pdf
Fixed Point Theory Appl. www.fixedpointtheoryandapplications.com/content	106	170	0***	html, pdf
Integers www.integers-ejcnt.org/	112	226	40	pdf
J. Inequal. Appl. www.journalofinequalitiesandapplications.com/content	142	95	0***	html, pdf
J. Integer Seq. www.cs.uwaterloo.ca/journals/JIS/	72	130	5	pdf, ps, dvi, tex
LMS J. Comput. Math. www.lms.ac.uk/lcm	20	318	115	pdf
Math. Biosci. Eng. aimsciences.org/journals/home.jsp?journalID=8	60	90	50	pdf
Netw. Heterog. Media aimsciences.org/journals/home.jsp?journalID=9	40	90	45	pdf
New York J. Math. nyjm.albany.edu/	35	180	14	pdf
Represent. Theory www.ams.org/journals/ert	24	282	231	pdf
Sém. Lothar. Combin. www.mat.univie.ac.at/~slc	12	156	13	pdf, ps, dvi, tex
SIAM J. Appl. Dyn. Syst. epubs.siam.org/siads.php	48	255	96	pdf, BibTex
SIAM J. Financial Math. epubs.siam.org/siims.php	39	371	87	pdf, BibTex
SIAM J. Imaging Sci. epubs.siam.org/siims.php	45	297	90	pdf, BibTex
Theory Appl. Categ. www.tac.mta.ca/tac/	22	263	7	pdf, ps, dvi
Theory Comput. dx.doi.org/10.4086/toc	13	321	28	html, pdf, ps, tex

NR means no response received. NA means not available or not applicable.
*Articles are published on an article-by-article basis.
**Print edition is printed on demand and in the form of an archival volume.
***Journal publishes provisional PDF.

Reciprocity Agreements

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

Allahabad Mathematical Society

Argentina Mathematical Society

Australian Mathematical Society

Austrian Mathematical Society

Azerbaijan Mathematical Society

Balkan Society of Geometers

Belgian Mathematical Society

Berliner Mathematische Gesellschaft e.V.

Brazilian Mathematical Society

Brazilian Society of Computational and Applied Mathematics

Calcutta Mathematical Society

Canadian Mathematical Society

Catalan Mathematical Society

Chilean Mathematical Society

Columbian Mathematical Society

Croation Mathematical Society

Cyprus Mathematical Society

Danish Mathematical Society

Dutch Mathematical Society

Ecuadorian Mathematical Society

Edinburgh Mathematical Society

Egyptian Mathematical Society

European Mathematical Society

Finnish Mathematical Society

German Mathematical Society

German Society for Applied Maths and Mechanics

Glasgow Mathematical Association

Hellenic Mathematical Society

Icelandic Mathematical Society

Indian Mathematical Society

Indonesian Mathematical Society

Iranian Mathematical Society

Irish Mathematical Society

Israel Mathematical Union

Italian Mathematical Union

János Bolyai Mathematical Society

Korean Mathematical Society

London Mathematical Society

Luxembourg Mathematical Society

Macedonian Society Association Mathematics/Computer Science

Malaysian Mathematical Science Society

Mathematical Society of France

Mathematical Society of Japan

Mathematical Society of Serbia

Mathematical Society of the Philippines

Mathematical Society of the Republic of China

Mexican Mathematical Society

Mongolian Mathematical Society

Nepal Mathematical Society

New Zealand Mathematical Society

Nigerian Mathematical Society

Norwegian Mathematical Society

Palestine Society for Mathematical Sciences

Parana's Mathematical Society

Polish Mathematical Society

Portuguese Mathematical Society

Punjab Mathematical Society

Ramanujan Mathematical Society

Romanian Mathematical Society

Romanian Society of Mathematicians

Royal Spanish Mathematical Society

Saudi Association for Mathematical Sciences

Singapore Mathematical Society

Soc. de Mathématiques Appliquées et Industrielles (SMAI)

Soc. Uruguaya de Matemática y Estadística "Rafael Laguardia"

Sociedad Matematica de la Republica Dominicana

Society of Mathematicians, Physicists, and Astronomers of Slovenia

South African Mathematical Society

Southeast Asian Mathematical Society

Spanish Society of Applied Mathematics

Swedish Mathematical Society

Swiss Mathematical Society

Tunisian Mathematical Society

Turkish Mathematical Society

Ukrainian Mathematical Society

Union of Bulgarian Mathematicians

Union of Czech Mathematicians and Physicists

Union of Slovak Mathematicians & Physicists

Vietnam Mathematical Society

Vijnana Parishad of India

Mathematics Calendar

Please submit conference information for the Mathematics Calendar through the Mathematics Calendar submission form at http://www.ams.org/cgi-bin/mathcal-submit.pl. The most comprehensive and up-to-date Mathematics Calendar information is available on the AMS website at http://www.ams.org/mathcal/.

November 2012

* 2 **Conference on Mathematical Finance and Partial Differential Equations**, Rutgers, The State University of New Jersey, New Brunswick, New Jersey.
Description: Partial differential equations, probability, and analytical methods are fundamental in the modeling and description of financial markets. The purpose of this meeting is to highlight the new methods, directions and the most recent research in partial differential equations, probability, stochastic control, numerical analysis, and their application to mathematical finance. The meeting encourages the participation of academic and industry researchers in this field and contributions on related topics are welcome.
Information: http://www.finmath.rutgers.edu/mfpde2012.

* 8 **Cahit Arf Lecture 2012 by David E. Nadler titled Traces and Loops**, Mathematics Department, Middle East Technical University, Ankara, Turkey.
Description: This talk will focus on the interplay between two basic notions originating in algebra and topology. In algebra, there is the trace of a matrix, important for its equality with the sum of the eigenvalues of the matrix. In topology, there are the loops on a space, which play a central role in the computation of homotopy groups and in the structure theory of spaces. There is a well-developed understanding of the intimate relation between traces and loops coming from non-commutative geometry and mathematical physics. We will explain how modern formulations elucidate fundamental identities in geometry and representation theory.
Information: http://www.matematikvakfi.org.tr/en/arf-lectures.

* 10–11 **The Fifth Dr. George Bachman Memorial Conference**, Manhattan Campus of St. John's University, Manhattan, New York.
Description: We welcome submissions of papers to be presented at the conference.The papers may be in any area of mathematics. Accepted articles will be published in "The Proceedings of the Fifth Dr. George Bachman Memorial Conference".
Organizers: For further information, kindly contact the organizers: Dr. Edward Beckenstein, email: Drbeckense@aol.com; Dr. Charles Traina, email: trainac@stjohns.edu.
Deadline: Abstracts should be received by October 4, 2012.

December 2012

* 7–9 **17th Annual Conference of Gwalior Academy of Mathematical Sciences and National Symposium on Computational Mathematics and Information Technology**, Department of Mathematics, Department of CSE, Jaypee University of Engineering & Technology, A. B. Road, Raghogarh Distt. Guna-M.P, India-473226.
Description: In recent years there have been exciting developments in all branches of mathematics and information technology. Rapid programs in computer related fields based on mathematical sciences have created a lot of gales in the branches. The main objective

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This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found on the last page of each issue.
An announcement will be published in the *Notices* if it contains a call for papers and specifies the place, date, subject (when applicable), and the speakers; a second announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in every third issue until it has been held and a reference will be given in parentheses to the month, year, and page of the issue in which the complete information appeared. Asterisks (*) mark those announcements containing new or revised information.
In general, announcements of meetings and conferences carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. If there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the *Notices* in care of the American Mathematical Society in Providence or electronically to notices@ams.org or mathcal@ams.org.
In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **eight months** prior to the scheduled date of the meeting.
The complete listing of the Mathematics Calendar will be published only in the September issue of the *Notices*. The March, June/July, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.
The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through the AMS website on the World Wide Web. To access the AMS website, use the URL: http://www.ams.org/.

of the conference is to bring Mathematicians, Industrialists, Computer Scientists, etc., together on one platform to interact with each other, share knowledge, exchange views, and discuss the topics of mutual interests and develop interdisciplinary groups for fruitful applications of mathematics & IT Industries. It also aims at presenting and discussing recent developments in mathematics & information technology.

Call for Papers: Original research papers, review of special topics, survey articles on recent developments in applicable mathematics & IT are invited for presentation at the conference. Intended participants are invited to send the abstracts (not exceeding 250 words) of their papers to the email: `conference.juet@yahoo.com`.

Deadline: Last date of paper submission is September 30, 2012.

Information: `http://www.juet.ac.in`.

* 9–13 **15th International Conference of International Academy of Physical Sciences (CONIAPS XV)**, Rajamangala University of Technology Thanyaburi, Pathumthani, Thailand.

Main topics: Will include a broad set of research areas such as: Physics, mathematics and statistics, chemistry, computer science, bio-informatics, bio-physics and bio-chemistry, material sciences, environmental sciences, etc.

Description: The conference will bring together scientists, engineers, technicians, educators, and students to exchange and share their experiences, new ideas, and all other aspects of their research (theory, applications and tools). The conference will include keynote address, fellowship award lectures and other plenary lectures, invited lectures, paper presentations (oral and poster).

Information: `http://www.iaps.in/coniaps`.

* 16–18 **Southeastern Lie Theory Workshop: Vertex Algebras, Conformal Field Theory, and Integrable Systems**, College of Charleston, Charleston, South Carolina.

Description: Researchers from all areas of Lie Theory (including, but not limited to, representation theory, Vertex algebras, integrable systems, and applications of Lie algebras to mathematical physics) will be presenting their research in 45 to 50 minute talks.

Support: Modest support from the conference grant may be available to graduate students, postdocs, junior faculty, women, and members of underrepresented minority groups. Please contact one of the organizers for more info. Graduate students are encouraged to share the hotel room with another participant. We will let you know after November 10 if any partial support will be available from the conference. Please let us know if you need an answer before November 10, 2012.

Information: `http://math.cofc.edu/research/selie/index.php`.

* 18–21 **5th HiPC Student Research Symposium (SRS) *** Held in conjunction with the 19th International Conference on High Performance Computing (HIPC 2012)**, Pune, India.

Call for Extended Abstracts: The Student Research Symposium (SRS) at HiPC is organized to stimulate and foster student engagement in high performance computing (HPC) research, and to provide an international forum to highlight student research accomplishments in HPC. The symposium will also expose students to the latest research and best practices in the HPC community from academia and industry.

Last year, HiPC SRS featured 21 papers and 18 posters, which were accepted from 51 submissions from seven countries. Besides presentations and poster exhibits by student authors, the one-day symposium this year will feature invited talks by leading HPC researchers/practitioners. The HiPC conference reception will provide an opportunity for students to interact with HPC researchers and practitioners (and recruiters) from academia and industry.

Important Dates: Sept. 23, 2012: Submission Deadline. Oct. 21, 2012: Accept/Reject Decision Notification. Dec. 18, 2012: Symposium.

Information: `http://www.hipc.org`.

February 2013

* 4–5 **2nd Annual International Conference on Computational Mathematics, Computational Geometry & Statistics (CMCGS 2013)**, Hotel Fort Canning, Singapore, Singapore.

Description: The objectives of this conference are to provide a forum for researchers, educators, students, contributors, users of mathematical knowledge and industries to exchange ideas and communicate and discuss research findings and new advancement in mathematics and statistics; to explore possible avenues to foster academic and student exchange, as well as scientific activities; to promote and encourage exchange of ideas on recent discoveries in the field of mathematics, statistics and mathematical education.

Information: `http://www.mathsstat.org/`.

* 11–14 **The AMSI Workshop on Graph C^*-algebras, Leavitt path algebras and symbolic dynamics**, University of Western Sydney, Australia.

Description: The workshop will bring together international experts to develop the emerging connections between the traditionally disparate fields of Leavitt path algebras and graph C^*-algebras. The workshop is also motivated by the desire to present an accessible introduction to the two theories side by side—highlighting the interplay between them—to prospective and starting Ph.D. students and early career researchers.

Main Speakers: Gene Abrams (Colorado), Pere Ara (Barcelona), Gonzalo Aranda Pino (Malaga), Anthony Bak (Bielefeld), Xiao-Wu Chen (Hefei), Astrid an Huef (Otago), Enrique Pardo (Cádiz), David Pask (Wollongong), Iain Raeburn (Otago), Mercedes Siles Molina (Malaga), S. Paul Smith (Washington).

Organizers: R. Hazrat (`r.hazrat@uws.edu.edu`) and Aidan Sims (`asims@uow.edu.au`).

Information: `http://sites.google.com/site/amsiuws2012/`.

April 2013

* 4–6 **38th Arkansas Spring Lecture Series in the Mathematical Sciences: "Extension and Interpolation of Functions"**, University of Arkansas, Fayetteville, Arkansas.

Description: The principal speaker will be Charles Fefferman (Princeton University), on the topic of "Extension and Interpolation of Functions." There will also be talks by invited speakers. Applications for contributed talks by junior mathematicians are strongly encouraged. For further information, please contact Phil Harrington; email: `psharrin@uark.edu`.

Information: `http://math.uark.edu/3742.php`.

* 12–13 **New Frontiers in Numerical Analysis and Scientific Computing**, Kent State University, Kent, Ohio.

Description: The conference will be held for the occasion of Lothar Reichel's 60th birthday and on the 20th anniversary of the journal *ETNA*.

Registration deadline: December 15, 2012.

Supporter: National Science Foundation. A number of travel supports are available to encourage participation by individuals who lack other federal support, or who are students, post-doctoral scholars, junior faculty, to enhance the breadth and diversity of the participants. The support will cover all or part of the participant's transportation and local lodging expenses. Information on application of the travel support is available on the conference website.

Information: `http://www.math.kent.edu/~li/LR60/`.

* 15–17 **Geomathematics 2013**, Hotel Haus am Weinberg, Sankt Martin, Palatinate, Germany.

Description: Geomathematics is an emerging new scientific area. Its increasing importance is due to visionary scientists such as Willi Freeden, whose 65th birthday is celebrated by this conference. This workshop is dedicated to the interdisciplinary research of mathematicians and geoscientists and contributes to the international

year "Mathematics of Planet Earth 2013". It provides a platform for scientists working in the intersection of mathematics and the geosciences to present and discuss novel solutions and open problems. Besides the invited lectures, contributed talks, in particular also by junior scientists, from all areas of the interface of mathematics and the geosciences are welcome.
Information: http://www.geomathematics2013.de.

May 2013

* 27–31 **Summer School on Topics in Space-Time Modeling and Inference**, Aalborg University, Department of Mathematical Sciences, Aalborg, Denmark.
Lecturers: Professor Peter Diggle, Lancaster University; Professor Tilmann Gneiting, University of Heidelberg; Professor Peter F. Craigmile, Ohio State University; Professor Rasmus Waagepetersen, Aalborg University.
Organizer: Professor Jesper Møller Aalborg University.
Information: http://csgb.dk/activities/2013/space-timemodeling/.

June 2013

* 10–14 **AIM Workshop: Automorphic forms and harmonic analysis on covering groups**, American Institute of Mathematics, Palo Alto, California.
Description: This workshop, sponsored by AIM and the NSF, will be devoted to discussing extensions of the Langlands program to nonlinear groups in some generality. An important example of such group is the metaplectic group: the two-fold cover the symplectic group over a local field.
Information: http://www.aimath.org/ARCC/workshops/autoformcovergp.html.

* 17–28 **Algebraic Topology**, Mathematical Sciences Research Institute, Berkeley, California.
Description: Modern algebraic topology is a broad and vibrant field which has seen recent progress on classical problems as well as exciting new interactions with applied mathematics. This summer school will consist of a series of lectures by experts on major research directions, including several lectures on applied algebraic topology. Participants will also have the opportunity to have guided interaction with the seminal texts in the field, reading and speaking about the foundational papers.
Information: http://www.msri.org/web/msri/scientific/workshops/summer-graduate-workshops/show/-/event/Wm9603.

* 26–29 **International Symposium on Symbolic and Algebraic Computation (ISSAC)**, Northeastern University, Boston, Massachussetts.
Description: ISSAC is the premier conference for research in symbolic computation and computer algebra. This includes the design, development and application of algebraic algorithms and computer algebra systems like MAPLE and MATHEMATICA. Other areas of research include computational number theory, computational group theory, exact linear algebra and (differential) algebraic geometry. The conference traditionally presents a range of invited speakers, tutorials, poster sessions and software demonstrations with a centre-piece of between 40 to 50 contributed research papers.
Deadline: For paper submission for ISSAC 2013 is mid-January, 2013.
Information: http://www.issac-conference.org/2013/.

* 27 **5th National Dyscalculia and Maths Learning Difficulties Conference, UK**, Cumberland Hotel, London, England.
Description: This unique conference, now in its fifth year, brings together the worlds of research, maths teaching and SEN expertise.
Three keynote speakers: Dr. Daniel Ansari, Dr. Derek Haylock and Dr. Ruth Trundley plus three breakout sessions, six streams, eleven workshop themes provide you with cutting edge research and opportunities to engage with leading practitioners from schools, FE and HE institutions. Early Bird prices available until December 21, 2012.
Information: http://www.dyscalculia-maths-difficulties.org.uk/.

* 30–July 20 **IAS/PCMI Summer 2013: Geometric Analysis**, Mathematical Sciences Research Institute, Berkeley, California.
Description: Please visit the PCMI workshop home page for further details on the subject and the format of the summer school. Complete information will be available on November 1, 2012.
Information: http://www.msri.org/web/msri/scientific/workshops/summer-graduate-workshops/show/-/event/Wm9754.

July 2013

* 1–5 **The 6th Pacific RIM Conference on Mathematics 2013**, Sapporo Convention Center, Sapporo City, Japan.
Description: The Pacific Rim Conference on Mathematics has been held triannually to present the latest topics in various areas of mathematics. Past meetings were held in Hong Kong (1998), Taipei (2001), Shanghai (2005), Hong Kong (2007), Stanford (2010). With several focusing sessions the conference emphasizes survey lectures by world-leading specialists on pure and applied mathematics to boost interactions and in-depth discussions among researchers in mathematics and related fields.
Organizers: Y. Giga (Univ. of Tokyo), K. Yamaguchi (Hokkaido Univ.).
Local Organizers: S. Jimbo (Hokkaido Univ.), H. Terao (Hokkaido Univ.).
Participating Institutions: City Univ. of Hong Kong, Academia Sinica (Taipei), Seoul National Univ., National Univ. of Singapore, Fudan Univ., Australian National Univ., Stanford Univ., UC Berkeley, UCLA, Pacific Institute for the Mathematical Sciences, Univ. of Auckland, Pontifical Catholic Univ. of Chile, Kyoto Univ., Tohoku Univ., Meiji Univ., Hokkaido Univ., Univ. of Tokyo.
Information: http://www.math.sci.hokudai.ac.jp/sympo/130701/.

* 1–12 **New Geometric Techniques in Number Theory**, Mathematical Sciences Research Institute, Berkeley, California.
Description: The branches of number theory most directly related to automorphic forms have seen enormous progress over the past five years. Techniques introduced since 2008 have made it possible to prove many new arithmetic applications. The purpose of the current workshop is to draw the attention of young students or researchers to new questions that have arisen in the course of bringing several chapters in the Langlands program and related algebraic number theory to a close. We will focus especially on some precise questions of a geometric nature, or whose solutions seem to require new geometric insights. A graduate level in number theory is expected. This two-week workshop will be devoted to the following subjects: Automorphy lifting theorems, p-adic local Langlands program, characters of categorical representations and Hasse-Weil zeta function.
Information: http://www.msri.org/web/msri/scientific/workshops/summer-graduate-workshops/show/-/event/Wm9460.

* 2–5 **The 4th International Conference on Matrix Analysis and Applications**, Konya, Turkey.
Description: The purpose of this conference is to stimulate research in matrix analysis and its applications, to provide an opportunity for researchers to present their newest results, and to meet for informal discussions. Scientific researchers with related work in all fields are welcome.
Keynote speaker: Steve Kirkland, Stokes Professor at Hamilton Institute, National University of Ireland.
Guest speaker: Alexander A. Klyachko, Bilkent University, Ankara, Turkey.

Scientific organizing committee (SOC): Peter Semrl (University of Ljubljana, Slovenia), Tin-Yau Tam (Auburn University, USA), Qingwen Wang (Shanghai University, China), and Fuzhen Zhang (Nova Southeastern University, USA). The meeting is endorsed by the International Linear Algebra Society (ILAS).
Information: http://icmaa2013.selcuk.edu.tr/.

* 3–5 **The 2013 International Conference of Applied and Engineering Mathematics**, Imperial College London, London, United Kingdom.
Description: The conference ICAEM'13 is held under the World Congress on Engineering 2013. The WCE 2013 is organized by the International Association of Engineers (IAENG), and serves as good platforms for the engineering community members to meet with each other and to exchange ideas. The last IAENG conferences attracted more than one thousand participants from over 30 countries. All submitted papers will be under peer review and accepted papers will be published in the conference proceeding (ISBN: 978-988-19251-0-7). The accepted papers will also be considered for publication in the special issues of the journal *Engineering Letters*, in IAENG journals and in edited books.
Information: http://www.iaeng.org/WCE2013/ICAEM2013.html.

* 29–August 9 **Introduction to the Mathematics of Seismic Imaging**, Mathematical Sciences Research Institute, Berkeley, California.
Description: In this two week program we will develop some of the mathematical foundations of seismic imaging that is a basic tool used in "Imaging the Earth Interior". This is one of the components of the Mathematics of Planet Earth year in 2013. The goal in seismic imaging is to determine the inner structure of the Earth from the crust to the inner core by using information provided by earthquakes in the case of the deep interior or by measuring the reflection of waves produced by acoustic or elastic sources on the surface of the Earth. The mathematics of seismic imaging involves solving inverse problems for the wave equation. No previous experience on inverse problems will be assumed.
Information: http://www.msri.org/web/msri/scientific/workshops/summer-graduate-workshops/show/-/event/Wm9427.

August 2013

* 12–15 **International Conference on Algebra in Honour of Patrick Smith and John Clark's 70th Birthdays**, Balikesir, Turkey.
Description: This conference is devoted to all branches of algebra.
Information: http://ica.balikesir.edu.tr/.

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.

January 2014

* 20–May 23 **Algebraic Topology Program**, Mathematical Sciences Research Institute, Berkeley, California.
Description: Algebraic topology touches almost every branch of modern mathematics. Algebra, geometry, topology, analysis, algebraic geometry, and number theory all influence and in turn are influenced by the methods of algebraic topology. The goals of this 2014 program at MSRI are: Bring together algebraic topology researchers from all subdisciplines, reconnecting the pieces of the field, identify the fundamental problems and goals in the field, uncovering the broader themes and connections, connect young researchers with the field, broadening their perspective and introducing them to the myriad approaches and techniques.
Information: http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm8964.

February 2014

* 3–7 **Introductory Workshop: Model Theory, Arithmetic Geometry and Number Theory**, Mathematical Sciences Research Institute, Berkeley, California.
Description: Model theory is a branch of mathematical logic whose structural techniques have proven to be remarkably useful in arithmetic geometry and number theory. We will introduce in this workshop some of the main themes of the programme covering such topics as Additive Combinatorics, Algebraic Dynamics, Berkovich Spaces, and the Pink-Zilber Conjectures. Tutorials will be given by both model theorists and experts in the relevant field of application. The workshop will also include "state of the art" lectures on the programme topics, indicating recent results as well as directions for future work.
Information: http://www.msri.org/web/msri/scientific/workshops/all-workshops/show/-/event/Wm9549.

August 2014

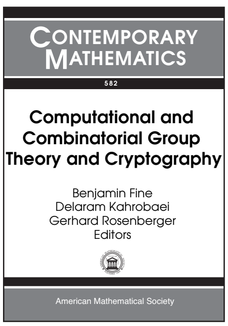
* 11–December 12 **New geometric methods in number theory and automorphic forms**, Mathematical Sciences Research Institute, Berkeley, California.
Description: The branches of number theory most directly related to the arithmetic of automorphic forms have seen much recent progress, with the resolution of many longstanding conjectures. These breakthroughs have largely been achieved by the discovery of new geometric techniques and insights. The goal of this program is to highlight new geometric structures and new questions of a geometric nature which seem most crucial for further development. In particular, the program will emphasize geometric questions arising in the study of Shimura varieties, the p-adic Langlands program, and periods of automorphic forms.
Information: http://www.msri.org/web/msri/scientific/programs/show-/event/Pm8996.

* 18–December 19 **Geometric Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California.
Description: The fundamental aims of geometric representation theory are to uncover the deeper geometric and categorical structures underlying the familiar objects of representation theory and harmonic analysis, and to apply the resulting insights to the resolution of classical problems. One of the main sources of inspiration for the field is the Langlands philosophy, a vast nonabelian generalization of the Fourier transform of classical harmonic analysis, which serves as a visionary roadmap for the subject and places it at the heart of number theory. A primary goal of the proposed MSRI program is to explore the potential impact of geometric methods and ideas in the Langlands program by bringing together researchers working in the diverse areas impacted by the Langlands philosophy, with a particular emphasis on representation theory over local fields.
Information: http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm8951.

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



Computational and Combinatorial Group Theory and Cryptography

Benjamin Fine, *Fairfield University, CT*, **Delaram Kahrobaei**, *CUNY Graduate Center, New York, NY*, and **Gerhard Rosenberger**, *University of Hamburg, Germany*, Editors

This volume contains the proceedings of the AMS Special Session on Computational Algebra, Groups, and Applications, held April 30–May 1, 2011, at the University of Nevada, Las Vegas, Nevada, and the AMS Special Session on the Mathematical Aspects of Cryptography and Cyber Security, held September 10–11, 2011, at Cornell University, Ithaca, New York.

Over the past twenty years combinatorial and infinite group theory has been energized by three developments: the emergence of geometric and asymptotic group theory, the development of algebraic geometry over groups leading to the solution of the Tarski problems, and the development of group-based cryptography. These three areas in turn have had an impact on computational algebra and complexity theory.

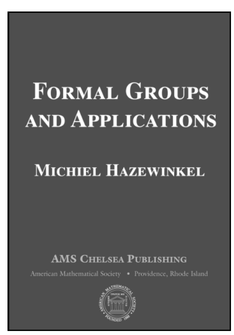
The papers in this volume, both survey and research, exhibit the tremendous vitality that is at the heart of group theory in the beginning of the twenty-first century as well as the diversity of interests in the field.

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

Contents: R. Ali and **M. Kreuzer**, Weyl Gröbner basis cryptosystems; **G. Baumslag**, **R. Mikhailov**, and **K. E. Orr**, A new look at finitely generated metabelian groups; **M. Bonanome**, **M. H. Dean**, and **M. Zyman**, IA-automorphisms of groups with almost constant upper central series; **C. S. Chum**, **B. Fine**, **G. Rosenberger**, and **X. Zhang**, A proposed alternative to the Shamir secret sharing scheme; **C. S. Chum** and **X. Zhang**, Improving Latin square based secret sharing schemes; **A. E. Clement**, A hand-computation involving surface groups, the Reidemeister-Schreier rewriting process and Kurosh subgroup theorem; **M. H. Dean**, **S. Majewicz**, and **M. Zyman**, Adjunction of roots in exponential A-groups; **V. Diekert**, **J. Kausch**, and **M. Lohrey**, Logspace computations in Coxeter groups and graph groups; **B. Eick**, Collection by polynomials in finite p-groups; **B. Fine**, **A. Hulpke**, and **G. Rosenberger**, All finite generalized tetrahedon groups II; **B. Fine** and **G. Rosenberger**, The classification of one relator limit groups and the surface group conjecture; **A. M. Gaglione**, **S. Lipschutz**, and **D. Spellman**, Discrimination and separation in the metabelian variety; **M. Habeeb**, **D. Kahrobaei**, and **V. Shpilrain**, A secret sharing scheme based on group presentations and the word problem; **S. Jarecki** and **N. Saxena**, Authenticated key agreement with key re-use in the short authenticated strings model; **D. Kahrobaei** and **E. Vidaurre**, Publicly verifiable secret sharing using non-abelian groups; **M. Neumann-Brosig**, A note on the hyperbolicity of strict Pride groups; **E. Ziliak**, An algorithm to express words as a product of conjugates of relators.

Contemporary Mathematics, Volume 582

December 2012, 199 pages, Softcover, ISBN: 978-0-8218-7563-6, LC 2012023441, 2010 *Mathematics Subject Classification:* 20-XX, 68-XX, **AMS members US$59.20**, List US$74, Order code CONM/582



Formal Groups and Applications

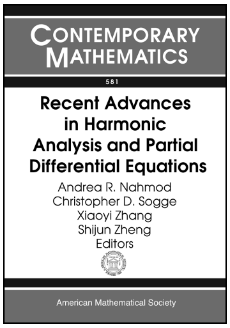
Michiel Hazewinkel

This book is a comprehensive treatment of the theory of formal groups and its numerous applications in several areas of mathematics. The seven chapters of the book present basics and main results of the theory, as well as very important applications in algebraic topology, number theory, and algebraic geometry. Each chapter ends with several pages of historical and bibliographic summary. One prerequisite for reading the book is an introductory graduate algebra course, including certain familiarity with category theory.

Contents: Methods for constructing one-dimensional formal groups; Methods for constructing higher dimensional formal group laws; Curves, p-typical formal group laws, and lots of Witt vectors; Homomorphisms, endomorphisms, and the classification of formal groups by power series methods; Cartier-Dieudonné modules; Applications of formal groups in algebraic topology, number theory, and algebraic geometry; Formal groups and bialgebras; On power series rings; Brief notes on further applications of formal group (law) theory; Bibliography; Notation; Index.

AMS Chelsea Publishing, Volume 375

December 2012, 573 pages, Hardcover, ISBN: 978-0-8218-5349-8, 2010 *Mathematics Subject Classification:* 14L05; 16Txx, 05Exx, 11Fxx, 11Sxx, 12Fxx, 13F35, 55N22, **AMS members US$64.80**, List US$72, Order code CHEL/375.H



Recent Advances in Harmonic Analysis and Partial Differential Equations

Andrea R. Nahmod, *University of Massachusetts, Amherst, MA*, **Christopher D. Sogge**, *Johns Hopkins University, Baltimore, MD*, **Xiaoyi Zhang**, *University of Iowa, Iowa City, IA*, and **Shijun Zheng**, *Georgia Southern University, Statesboro, GA*, Editors

This volume is based on the AMS Special Session on Harmonic Analysis and Partial Differential Equations and the AMS Special Session on Nonlinear Analysis of Partial Differential Equations, both held March 12–13, 2011, at Georgia Southern University, Statesboro, Georgia, as well as the JAMI Conference on Analysis of PDEs, held March 21–25, 2011, at Johns Hopkins University, Baltimore, Maryland. These conferences all concentrated on problems of current interest in harmonic analysis and PDE, with emphasis on the interaction between them.

This volume consists of invited expositions as well as research papers that address prospects of the recent significant development in the field of analysis and PDE. The central topics mainly focused on using Fourier, spectral and geometrical methods to treat wellposedness, scattering and stability problems in PDE, including dispersive type evolution equations, higher-order systems and Sobolev spaces theory that arise in aspects of mathematical physics.

The study of all these problems involves state-of-the-art techniques and approaches that have been used and developed in the last decade. The interrelationship between the theory and the tools reflects the richness and deep connections between various subjects in both classical and modern analysis.

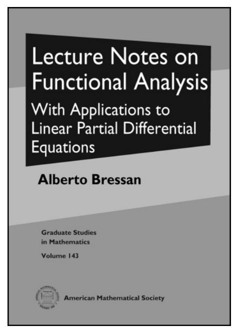
This item will also be of interest to those working in differential equations.

Contents: A. Bulut, The defocusing cubic nonlinear wave equation in the energy-supercritical regime; **K. Brewster**, **I. Mitrea**, and **M. Mitrea**, Stein's extension operator on weighted Sobolev spaces on Lipschitz domains and applications to interpolation; **T. Chen**, **N. Pavlović**, and **N. Tzirakis**, Multilinear Morawetz identities for the Gross-Pitaevskii hierarchy; **X. Chen**, Elementary proofs for Kato smoothing estimates of Schrödinger-like dispersive equations; **H. Dong** and **D. Kim**, The conormal derivative problem for higher order elliptic systems with irregular coefficients; **M. Filoche**, **S. Mayboroda**, and **B. Patterson**, Localization of eigenfunctions of a one-dimensional elliptic operator; **C. Guevara** and **F. Carreon**, Scattering and blow up for the two dimensional focusing quintic nonlinear Schrödinger equation; **C. Klein** and **C. Sparber**, Transverse stability of periodic traveling waves in Kadomtsev-Petviashvili equations: A numerical study; **J.-E. Lin**, Time decay for the solutions of a fourth-order nonlinear Schrödinger equation; **O. Milatovic**, Self-adjoint realizations of Schrödinger operators on vector bundles over Riemannian manifolds; **I. Mitrea**, **K. Ott**, and **E. Stachura**, Spectral properties of the reflection operator in two dimensions; **N. Pennington**, Recent local and global solutions to the Lagrangian averaged Navier-Stokes equation; **C. Wang** and **X. Yu**, Recent works on the Strauss conjecture; **D. Li** and **X. Zhang**, Wave operators for nonlinear wave equations with null structures; **S. Zheng**, Fractional regularity for nonlinear Schrödinger equations with magnetic fields.

Contemporary Mathematics, Volume 581

December 2012, 285 pages, Softcover, ISBN: 978-0-8218-6921-5, LC 2012023439, 2010 *Mathematics Subject Classification:* 42B37, 35J10, 35K52, 35Q55, 35L70, 58J45; 74J30, 76D05, **AMS members US$77.60**, List US$97, Order code CONM/581

Analysis



Lecture Notes on Functional Analysis

With Applications to Linear Partial Differential Equations

Alberto Bressan, *Pennsylvania State University, University Park, PA*

This textbook is addressed to graduate students in mathematics or other disciplines who wish to understand the essential concepts of functional analysis and their applications to partial differential equations.

The book is intentionally concise, presenting all the fundamental concepts and results but omitting the more specialized topics. Enough of the theory of Sobolev spaces and semigroups of linear operators is included as needed to develop significant applications to elliptic, parabolic, and hyperbolic PDEs. Throughout the book, care has been taken to explain the connections between theorems in functional analysis and familiar results of finite-dimensional linear algebra.

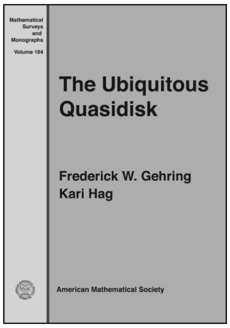
The main concepts and ideas used in the proofs are illustrated with a large number of figures. A rich collection of homework problems is included at the end of most chapters. The book is suitable as a text for a one-semester graduate course.

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

Contents: Introduction; Banach spaces; Spaces of continuous functions; Bounded linear operators; Hilbert spaces; Compact operators on a Hilbert space; Semigroups of linear operators; Sobolev spaces; Linear partial differential equations; Background material; Summary of notation; Bibliography; Index.

Graduate Studies in Mathematics, Volume 143

January 2013, approximately 250 pages, Hardcover, ISBN: 978-0-8218-8771-4, 2010 *Mathematics Subject Classification:* 46-01; 35-01, **AMS members US$51.20**, List US$64, Order code GSM/143



The Ubiquitous Quasidisk

Frederick W. Gehring, and **Kari Hag**, *Norwegian University of Science and Technology, Trondheim, Norway*

This book focuses on gathering the numerous properties and many different connections with various topics in geometric function theory that quasidisks possess. A quasidisk is the image of a disk under a quasiconformal mapping of the Riemann sphere. In 1981 Frederick W. Gehring gave a short course of six lectures on this topic in Montreal and his lecture notes "Characteristic Properties of Quasidisks" were published by the University Press of the University of Montreal. The notes became quite popular and within the next decade the number of characterizing properties of quasidisks and their ramifications increased tremendously. In the late 1990s Gehring and Hag decided to write an expanded version of the Montreal notes. At three times the size of the original notes, it turned into much more than just an extended version. New topics include two-sided criteria. The text will be a valuable resource for current and future researchers in various branches of analysis and geometry, and with its clear and elegant exposition the book can also serve as a text for a graduate course on selected topics in function theory.

Frederick W. Gehring (1925–2012) was a leading figure in the theory of quasiconformal mappings for over fifty years. He received numerous awards and shared his passion for mathematics generously by mentoring twenty-nine Ph.D. students and more than forty postdoctoral fellows.

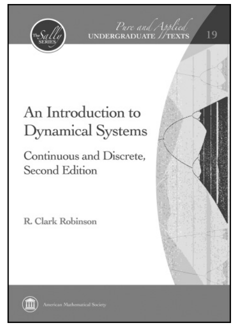
Kari Hag received her Ph.D. under Gehring's direction in 1972 and worked with him on the present text for more than a decade.

Contents: *Properties of quasidisks:* Preliminaries; Geometric properties; Conformal invariants; Injectivity criteria; Criteria for extension; Two-sided criteria; Miscellaneous properties; *Some proofs of these properties:* First series of implications; Second series of implications; Third series of implications; Fourth series of implications; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 184

December 2012, approximately 169 pages, Hardcover, ISBN: 978-0-8218-9086-8, 2010 *Mathematics Subject Classification:* 30C62; 30C20, 30C45, 30C65, 30F45, **AMS members US$59.20**, List US$74, Order code SURV/184

Differential Equations



An Introduction to Dynamical Systems

Continuous and Discrete, Second Edition

R. Clark Robinson, *Northwestern University, Evanston, IL*

This book gives a mathematical treatment of the introduction to qualitative differential equations and discrete dynamical systems. The treatment includes theoretical proofs, methods of calculation, and applications. The two parts of the book, continuous time of differential equations and discrete time of dynamical systems, can be covered independently in one semester each or combined together into a year-long course.

The material on differential equations introduces the qualitative or geometric approach through a treatment of linear systems in any dimensions. There follows chapters where equilibria are the most important feature, where scalar (energy) functions is the principal tool, where periodic orbits appear, and finally chaotic systems of differential equations. The many different approaches are systematically introduced through examples and theorems.

The material on discrete dynamical systems starts with maps of one variable and proceeds to systems in higher dimensions. The treatment starts with examples where the periodic points can be found explicitly and then introduces symbolic dynamics to analyze where they can be shown to exist but not given in explicit form. Chaotic systems are presented both mathematically and more computationally using Lyapunov exponents. With the one-dimensional maps as models, the multidimensional maps cover the same material in higher dimensions. This higher dimensional material is less computational and more conceptual and theoretical. The final chapter on fractals introduces various dimensions which is another computational tool for measuring the complexity of a system. It also treats iterated function systems which give examples of complicated sets.

In the second edition of the book, much of the material has been rewritten to clarify the presentation. Also, some new material has been included in both parts of the book.

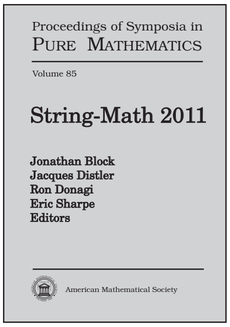
This book can be used as a textbook for an advanced undergraduate course on ordinary differential equations and/or dynamical systems. Prerequisites are standard courses in calculus (single variable and multivariable), linear algebra, and introductory differential equations.

Contents: *Systems of nonlinear differential equations:* Geometric approach to differential equations; Linear systems; The flow: Solutions of nonlinear equations; Phase portraits with emphasis on fixed points; Phase portraits using Scalar functions; Periodic orbits; Chaotic attractors; *Iteration of functions:* Iteration of functions as dynamics; Periodic points of one-dimensional maps; Itineraries for one-dimensional maps; Invariant sets for one-dimensional maps; Periodic points of higher dimensional maps; Invariant sets for higher dimensional maps; Fractals; Background and terminology; Generic properties; Bibliography; Index.

Pure and Applied Undergraduate Texts, Volume 19

January 2013, 760 pages, Hardcover, ISBN: 978-0-8218-9135-3, LC 2012025520, 2010 *Mathematics Subject Classification:* 34Cxx, 37Cxx, 37Dxx, 37Exx, 37Nxx, 70Kxx, **AMS members US$74.40**, List US$93, Order code AMSTEXT/19

Mathematical Physics



String-Math 2011

Jonathan Block, *University of Pennsylvania, Philadelphia, PA*, **Jacques Distler**, *University of Texas at Austin, TX*, **Ron Donagi**, *University of Pennsylvania, Philadelphia, PA*, and **Eric Sharpe**, *Virginia Polytech Institute & State University, Blacksburg, VA*, Editors

The nature of interactions between mathematicians and physicists has been thoroughly transformed in recent years. String theory and quantum field theory have contributed a series of profound ideas that gave rise to entirely new mathematical fields and revitalized older ones. The influence flows in both directions, with mathematical techniques and ideas contributing crucially to major advances in string theory. A large and rapidly growing number of both mathematicians and physicists are working at the string-theoretic interface between the two academic fields.

The String-Math conference series aims to bring together leading mathematicians and mathematically minded physicists working in this interface.

This volume contains the proceedings of the inaugural conference in this series, String-Math 2011, which was held June 6–11, 2011, at the University of Pennsylvania.

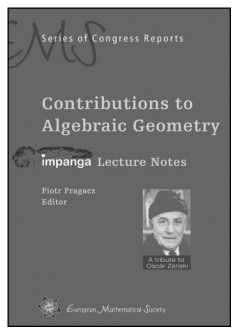
Contents: *Plenary talks:* **M. Aganagic** and **S. Shakirov**, Refined Chern-Simons theory and knot homology; **P. S. Aspinwall** and **M. R. Plesser**, Elusive worldsheet instantons in heterotic string compactifications; **M. C. N. Cheng** and **J. F. R. Duncan**, The largest Mathieu group and (mock) automorphic forms; **R. Donagi**, **J. Guffin**, **S. Katz**, and **E. Sharpe**, (0,2) quantum cohomology; **M. R. Douglas**, Foundations of quantum field theory; **S. Gukov** and **M. Stošić**, Homological algebra of knots and BPS states; **M. Marcolli**, Motivic structures in quantum field theory; **G. W. Moore** and **Y. Tachikawa**, On 2d TQFTs whose values are holomorphic symplectic varieties; **Y. Ruan**, The Witten equation and the geometry of the Landau-Ginzburg model; **L.-S. Tseng** and **S.-T. Yau**, Non-Kähler Calabi-Yau manifolds; **S. Schäfer-Nameki**, F-theory GUTs: Global aspects and phenomenology; **M. Wijnholt**, Higgs bundles and string phenomenology; *Contributed talks:* **D. Baraglia**, Topological T-duality with monodromy; **N. Behr** and **S. Fredenhagen**, Variable transformation defects; **E. A. Bergshoeff** and **F. Riccioni**, The D-brane U-scan; **N. Carqueville** and **M. M. Kay**, An invitation to algebraic topological string theory; **A. Francis**, **T. Jarvis**, **D. Johnson**, and **R. Suggs**, Landau-Ginzburg mirror symmetry for orbifolded Frobenius algebras; **J. Fullwood** and **M. van Hoeij**, On Hirzebruch invariants of elliptic fibrations; **S. Grigorian**, G_2-structure deformations and warped products; **M. Hamanaka**, Non-commutative solitons and quasi-determinants; **B. Jurke**, Computing cohomology on toric varieties; **T. Kragh**, Fibrancy of symplectic homology in cotangent bundles; **D. Pomerleano**, Curved string topology and tangential Fukaya categories; **T. Rahn**, Target space dualities of heterotic grand unified theories; **F. F. Ruffino**, Freed-Witten anomaly and D-brane gauge theories; **J. Seo**, Singularity structure and massless dyons of pure Seiberg-Witten theories with SU and Sp gauge groups; **A. Sheshmani**, An introduction to the theory of higher rank stable pairs and virtual localization; **N. Sibilla**, HMS for punctured tori and categorical mapping class group actions; **J. Yagi**, Vanishing chiral algebras and Höhn-Stolz conjecture.

Proceedings of Symposia in Pure Mathematics, Volume 85

November 2012, approximately 479 pages, Hardcover, ISBN: 978-0-8218-7295-6, 2010 *Mathematics Subject Classification:* 14-XX, 18-XX, 19-XX, 22-XX, 53-XX, 58-XX, 81-XX, 81Txx, 83-XX, 83Exx, 83E30, **AMS members US$90.40**, List US$113, Order code PSPUM/85

New AMS-Distributed Publications

Number Theory



Contributions to Algebraic Geometry

Impanga Lecture Notes

Piotr Pragacz, *Polish Academy of Sciences, Warsaw, Poland*, Editor

The articles in this volume are the outcome of the Impanga Conference on Algebraic Geometry in 2010 at the Banach Center in Będlewo. The following spectrum of topics is covered:

- K3 surfaces and Enriques surfaces
- Prym varieties and their moduli
- invariants of singularities in birational geometry
- differential forms on singular spaces
- Minimal Model Program
- linear systems
- toric varieties
- Seshadri and packing constants
- equivariant cohomology
- Thom polynomials
- arithmetic questions

The main purpose of the volume is to give comprehensive introductions to the above topics, starting from an elementary level and ending with a discussion of current research.

The first four topics are represented by the notes from the mini courses held during the conference. In the articles, the reader will find classical results and methods, as well as modern ones.

This book is addressed to researchers and graduate students in algebraic geometry, singularity theory, and algebraic topology. Most of the material in this volume has not yet appeared in book form.

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

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: P. Blass, The influence of Oscar Zariski on algebraic geometry; **K. Altmann**, **N. O. Ilten**, **L. Petersen**, **H. Süß**, and

R. Vollmert, The geometry of T-varieties; **D. Anderson**, Introduction to equivariant cohomology in algebraic geometry; **T. Bauer**, **C. Bocci**, **S. Cooper**, **S. Di Rocco**, **M. Dumnicki**, **B. Harbourne**, **K. Jabbusch**, **A. L. Knutsen**, **A. Küronya**, **R. Miranda**, **J. Roé**, **H. Schenck**, **T. Szemberg**, and **Z. Teitler**, Recent developments and open problems in linear series; **G. Bérczi**, Moduli of map germs, Thom polynomials and the Green–Griffiths conjecture; **P. Cascini** and **V. Lazić**, The Minimal Model Program revisited; **S. Cynk** and **S. Rams**, Invariants of hypersurfaces and logarithmic differential forms; **G. Farkas**, Prym varieties and their moduli; **L. Gatto** and **I. Scherbak**, On generalized Wrońskians; **K. Hutchinson** and **M. Vlasenko**, Lines crossing a tetrahedron and the Bloch group; **A. Hochenegger** and **F. Witt**, On complex and symplectic toric stacks; **C. Jörder** and **S. Kebekus**, Deformation along subsheaves, II; **M. Kapustka**, Some degenerations of G_2 and Calabi–Yau varieties; **M. Michałek**, Notes on Kebekus' lectures on differential forms on singular spaces; **S. Mukai**, Lecture notes on $K3$ and Enriques surfaces; **M. Mustaţă**, IMPANGA lecture notes on log canonical thresholds; **O. Öztürk** and **P. Pragacz**, On Schur function expansions of Thom polynomials; **M. Szyjewski**, A note on the kernel of the norm map; **H. Tutaj-Gasińska**, Seshadri and packing constants; List of contributors.

EMS Series of Congress Reports, Volume 6

August 2012, 516 pages, Hardcover, ISBN: 978-3-03719-114-9, 2010 *Mathematics Subject Classification:* 14-06, **AMS members US$102.40**, List US$128, Order code EMSSCR/6

Classified Advertisements

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

CALIFORNIA

CALIFORNIA INSTITUTE OF TECHNOLOGY
Harry Bateman Research Instructorships in Mathematics

Description: Appointments are for two years. The academic year runs from approximately October 1 to June 1. Instructors are expected to teach one course per term for the full academic year and to devote the rest of their time to research. During the summer months there are no duties except research.

Eligibility: Open to persons who have recently received their doctorates in mathematics.

Deadline: January 1, 2013.

Application information: Please apply online at `mathjobs.org`. To avoid duplication of paperwork, your application may also be considered for an Olga Taussky and John Todd Instructorship.

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CALIFORNIA INSTITUTE OF TECHNOLOGY
Scott Russell Johnson Senior Postdoctoral Scholar in Mathematics

Description: There are three terms in the Caltech academic year. The fellow is expected to teach one course in two terms each year, and is expected to be in residence even during terms when not teaching. The initial appointment is for three years with an additional three-year terminal extension expected.

Eligibility: Offered to a candidate within six years of having received the Ph.D. who shows strong research promise in one of the areas in which Caltech's mathematics faculty is currently active

Deadline: January 1, 2013.

Application information: Please apply online at `mathjobs.org`. To avoid duplication of paperwork, your application will also be considered for an Olga Taussky and John Todd Instructorship and a Harry Bateman Research Instructorship.

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CALIFORNIA INSTITUTE OF TECHNOLOGY
Olga Taussky and John Todd Instructorships in Mathematics

Description: Appointments are for three years. There are three terms in the Caltech academic year, and instructors are expected to teach one course in all but two terms of the total appointment. These two terms will be devoted to research. During the summer months there are no duties except research.

Eligibility: Offered to persons within three years of having received the Ph.D. who show strong research promise in one of the areas in which Caltech's mathematics faculty is currently active.

Deadline: January 1, 2013.

Application information: Please apply online at `mathjobs.org`. To avoid duplication of paperwork, your application will also be considered for a Harry Bateman Research Instructorship.

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CALIFORNIA INSTITUTE OF TECHNOLOGY
The Division of Physics, Mathematics, and Astronomy

The Division of Physics, Mathematics, and Astronomy at the California Institute of Technology invites applications for a possible tenure-track position in mathematics at the assistant professor level. We are particularly interested in the following research areas: Algebraic Geometry/Number Theory, Analysis/Dynamics, Combinatorics, Finite and Algebraic Groups, Geometry/Topology, Logic/Set Theory, and Mathematical Physics, but other fields may be considered. The term of the initial appointment is normally four years for a tenure-track assistant professor (with a possible extension to as much as seven years). Appointment is contingent upon completion of the Ph.D. Exceptional candidates may also be considered at the associate or full professor level. We are seeking highly qualified applicants who are committed to a career in research and

Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 2012 rate is \$3.50 per word with a minimum two-line headline. No discounts for multiple ads or the same ad in consecutive issues. For an additional \$10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

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

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

Upcoming deadlines for classified advertising are as follows: December 2012 issue–October 1, 2012; January 2013 issue–October 29, 2012; February 2013 issue–November 28, 2012; March 2013 issue–January 2, 2013; April 2013 issue–January 30, 2013; May 2013–February 28, 2013.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 1373 (vol. 44).

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

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940; or via fax: 401-331-3842; or send email to `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 20904. Advertisers will be billed upon publication.

teaching. Applicants should apply online at mathjobs.org.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women and minorities are encouraged to apply.

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UNIVERSITY OF CALIFORNIA, DAVIS
Faculty Position in Mathematics

The Department of Mathematics at the University of California, Davis, invites applications for a tenure-track or tenured faculty position starting July 1, 2013. Outstanding candidates in all areas of mathematics may be considered. Minimum qualifications for these positions include a Ph.D. degree or its equivalent in the Mathematical Sciences and great promise in research and teaching. Duties include mathematical research, undergraduate and graduate teaching, and departmental and university service. Additional information about the department may be found at: http://math.ucdavis.edu/. Applications will be accepted until the position is filled. To guarantee full consideration, the application should be received by November 30, 2012. To apply: submit the AMS Cover Sheet and supporting documentation electronically through http://www.mathjobs.org/. The University of California is an Affirmative Action/Equal Opportunity Employer.

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UNIVERSITY OF CALIFORNIA, DAVIS
Arthur J. Krener Assistant Professor Positions in Mathematics

The Department of Mathematics at the University of California, Davis, is soliciting applications for one or more Arthur J. Krener positions starting July 1, 2013. The department seeks applicants with excellent research potential in areas of faculty interest and effective teaching skills. Applicants are required to have completed their Ph.D. by the time of their appointment, but no earlier than July 1, 2009. The annual salary is $58,100. The teaching load is 3 to 4 quarter-long courses. Krener appointments are renewable for a total of up to three years, assuming satisfactory performance in research and teaching. Additional information about the department may be found at: http://math.ucdavis.edu/. Our postal address is Department of Mathematics, University of California, One Shields Avenue, Davis, CA 95616-8633. Applications will be accepted until the positions are filled. For full consideration, the application should be received by November 30, 2012. To apply: submit the AMS Cover Sheet and supporting documentation electronically through http://www.mathjobs.org/. The University of California is an Affirmative Action/Equal Opportunity Employer.

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UNIVERSITY OF CALIFORNIA, SAN DIEGO
Stefan E. Warschawski Assistant Professorship

The Department of Mathematics at the University of California, San Diego, is committed to academic excellence and diversity within the faculty, staff, and student body. We are seeking an outstanding candidate for a special three-year assistant professorship, the S. E. Warschawski Assistant Professorship, pending funding approval. We encourage applications in any area of pure mathematics, applied mathematics, or statistics. The nine-month salary is $58,100. This is a three-year nonrenewable appointment.

Applicants should possess a recent Ph.D. degree (received no earlier than 2009) in Mathematics. Candidates should have excellent teaching skills and excellent research potential. Candidates with teaching and research interests compatible with current faculty are sought. The successful candidate will have demonstrated a commitment to excellence through leadership in teaching, research, or service towards building an equitable and diverse scholarly environment.

For full consideration, applications should be submitted by December 1, 2012 to: http://www.mathjobs.org. For instructions on the application procedure, see http://www.math.ucsd.edu/about/employment/faculty.

UCSD is an Equal Opportunity/Affirmative Action Employer with a strong institutional commitment to the achievement of diversity among its faculty and staff.

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UCLA
Department of Mathematics

The Department of Mathematics invites applications for temporary and visiting appointments in the categories 1-4 below. Depending on the level, candidates must give evidence of potential or demonstrated distinction in scholarship and teaching.

Temporary Positions:

(1) E.R. Hedrick Assistant Professorships. Salary is $63,000 and appointments are for three years. The teaching load is four one-quarter courses per year.

(2) Computational and Applied Mathematics (CAM) Assistant Professorships. Salary is $63,000, and appointments are for three years. The teaching load is normally reduced by research funding to two quarter courses per year.

(3) Program in Computing (PIC) Assistant Adjunct Professorships. Salary is $67,500. Applicants for these positions must show very strong promise in teaching and research in an area related to computing. The teaching load is four one-quarter programming courses each year and one additional course every two years. Initial appointments are for one year and possibly longer, up to a maximum service of four years.

(4) Assistant Adjunct Professorships and Research Postdocs. Normally appointments are for one year, with the possibility of renewal. Strong research and teaching background required. The salary range is $54,800-$61,300. The teaching load for Adjuncts is six one-quarter courses per year.

Applications and supporting documentation must be submitted electronically via www.mathjobs.org. All letters of evaluation are subject to UCLA campus policies on confidentiality. Refer potential reviewers to the UCLA Statement of Confidentiality at: http://www.math.ucla.edu/people/confidentiality.pdf.

For fullest consideration, all application materials should be submitted on or before December 7, 2012. A Ph.D. is required for all positions.

The University is an Equal Opportunity/Affirmative Action Employer. UCLA and the Department of Mathematics have a strong commitment to the achievement of excellence in teaching and research and diversity among its faculty and staff. The University of California asks that applicants complete the Equal Opportunity Employer survey for Letters and Science at the following URL: http://cis.ucla.edu/facultysurvey. Under Federal law, the University of California may employ only individuals who are legally authorized to work in the United States as established by providing documents specified in the Immigration Reform and Control Act of 1986.

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COLORADO

UNIVERSITY OF DENVER
Department of Mathematics
Assistant Professor

We invite applications for three tenure-track faculty positions in mathematics at the Assistant Professor level to begin September 2013. Candidates must have a Ph.D. in mathematics by September 2013 and show a commitment to excellence in both research and teaching. The University of Denver offers bachelor's, master's and Ph.D. degrees in mathematics. Active areas of research in the department include combinatorics, functional analysis, logic, non-associative algebra, operator theory, ordered algebra, set theory, topological dynamics and ergodic theory. Applications received by December 1, 2012, will be given full consideration. The search will continue until the position is filled. Applications should apply electronically at http://www.mathjobs.org. The University of Denver is committed to enhancing the diversity of its faculty and staff and encourages applications from women, minorities, people with disabilities, and veterans. DU is an EEO/AA Employer.

000088

ILLINOIS

UNIVERSITY OF CHICAGO
Department of Mathematics

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

1. L.E. Dickson Instructor: This is open to mathematicians who have recently completed or will soon complete a doctorate in mathematics or a closely related field, and whose work shows remarkable promise in mathematical research and teaching. The appointment typically is for two years, with the possibility of renewal for a third year. The teaching obligation is up to four one-quarter courses per year.

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

Applicants will be considered for any of the positions above which seem appropriate. Complete applications consist of (a) a cover letter, (b) a curriculum vitae, (c) three or more letters of reference, at least one of which addresses teaching ability, and (d) a description of previous research and plans for future mathematical research. Applicants are strongly encouraged to include information related to their teaching experience, such as a teaching statement or evaluations from courses previously taught, as well as an AMS cover sheet. If you have applied for an NSF Mathematical Sciences Postdoctoral Fellowship, please include that information in your application, and let us know how you plan to use it if awarded. Applications must be submitted online through `www.mathjobs.org`. Questions may be directed to: `apptsec@math.uchicago.edu`. We will begin screening applications on November 1, 2012. Screening will continue until all available positions are filled. The University of Chicago is an Affirmative Action/Equal Opportunity Employer.

000085

INDIANA

INDIANA UNIVERSITY BLOOMINGTON
Department of Mathematics
Zorn Research Postdoctoral Fellowships

The Department of Mathematics seeks applications for two Zorn Research Postdoctoral Fellowships beginning in the fall of 2013. These are three-year, non-tenure-track positions with reduced teaching loads. Outstanding candidates with a recent Ph.D. in any area of pure or applied mathematics are encouraged to apply; a minimum requirement is a Ph.D. in Mathematics. Zorn fellows are paired with mentors with whom they have compatible research interests. The department maintains strong research groups in all of the principal fields of mathematics. Bloomington is located in the forested hills of southern Indiana and offers a rich variety of musical and cultural attractions.

Applicants should submit an AMS cover sheet, a curriculum vitae, a research statement, and a teaching statement using the online service provided by the AMS at: `http://www.mathjobs.org`. If unable to do so, you may send application materials to the address below. Applicants should arrange for four letters of recommendation, including one evaluating teaching experience. Please ask reference writers to submit their letters electronically through `http://www.mathjobs.org`. If they are unable to do so, they may also send their letters to the following address: Zorn Postdoctoral Fellowships Search Committee, Department of Mathematics, Indiana University, 831 East 3rd Street, Rawles Hall, Bloomington, IN 47405-7106. Applications should be received by December 15, 2012. Indiana University is an Equal Opportunity/Affirmative Action Employer.

000071

INDIANA UNIVERSITY BLOOMINGTON
Department of Mathematics
Assistant Professor

The Department of Mathematics seeks applications for a tenure-track position, with appointment beginning in the fall of 2013. Exceptionally well qualified applicants may be considered also at the tenured level. Outstanding candidates with a Ph.D. in any area of pure or applied mathematics and with postdoctoral or faculty-level experience are encouraged to apply, with particular emphasis in the areas of Algebra and Pure and Applied Analysis. A minimum requirement is a Ph.D. in Mathematics. Salary will be commensurate with qualifications and the level at which the position is filled. The base teaching load for research-active faculty is three courses per year. The department maintains strong research groups in all of the principal fields of mathematics. Bloomington is located in the forested hills of southern Indiana and offers a rich variety of musical and cultural attractions.

Applicants should submit an AMS cover sheet, curriculum vitae, a research statement, and a teaching statement using the online service provided by the AMS at: `http://www.mathjobs.org`. Applicants should arrange for four letters of recommendation, including one evaluating teaching experience. Where applicable, please ask reference writers to submit their letters electronically through `http://www.mathjobs.org`. If applicants or letter writers are unable to submit materials online, they may submit them alternatively to the following address: Search Committee, Department of Mathematics, Indiana University, 831 East 3rd Street, Rawles Hall, Bloomington, IN 47405-7106. Applications should be received by November 1, 2012, but will continue to be accepted until the search is filled.

Indiana University is supportive of the needs of dual career couples and is an Equal Opportunity/Affirmative Action Employer.

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MARYLAND

JOHNS HOPKINS UNIVERSITY
Department of Mathematics
J. J. Sylvester Assistant Professor

Subject to availability of resources and administrative approval, the Department of Mathematics invites applications for non-tenure-track two-year Assistant Professor positions beginning July 1, 2013. The J.J. Sylvester Assistant Professorship is a position offered to recent Ph.D.'s with outstanding research potential. Candidates in all areas of pure mathematics are encouraged to apply. The teaching load is three courses per academic year. To submit your application, go to `http://www.mathjobs.org/jobs/jhu`. Submit the AMS cover sheet, your curriculum vitae, and research and teaching statements, and ensure that at least four letters of recommendation, one of which addresses teaching, are submitted by the reference writers. If you are unable to apply online, you may send application materials to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. If you have questions concerning this position, please write to: `cpoole@jhu.edu`. Preference will be given to applications received by December 1, 2012. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply.

000050

JOHNS HOPKINS UNIVERSITY
Department of Mathematics
Tenure-Track Assistant Professor

The Department of Mathematics invites applications for two positions at the tenure-track Assistant Professor level beginning July 1, 2013. A Ph.D. degree or its equivalent and demonstrated promise in research and commitment to teaching are required. Candidates in all areas of pure mathematics are encouraged to apply. To submit your application, go to: www.mathjobs.org/jobs/jhu. Submit the AMS cover sheet, your curriculum vitae, list of publications, and research and teaching statements, and ensure that at least four letters of recommendation, one of which addresses teaching, are submitted by the reference writers. If you are unable to apply online or do not wish to do so, you may send application materials to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. If you have questions concerning this position, please write to: cpoole@jhu.edu. Preference will be given to applications received by October 15, 2012. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply.

000051

MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics

The Mathematics Department at MIT is seeking to fill positions in Pure and Applied Mathematics, and Statistics at the level of Instructor, Assistant Professor or higher beginning September 2013. The department also seeks candidates for the Schramm Postdoctoral Fellowship. Appointments are based primarily on exceptional research qualifications. Appointees will be expected to fulfill teaching duties and to pursue their own research program. Ph.D. required by employment start date.

For more information and to apply, please visit www.mathjobs.org. To receive full consideration, submit applications by December 1, 2012. MIT is an Equal Opportunity, Affirmative Action Employer.

000060

WILLIAMS COLLEGE
Department of Mathematics and Statistics

Williams College invites applications for one tenure-track position in mathematics, beginning fall 2013, at the rank of assistant professor (in an exceptional case, a more advanced appointment may be considered). We are seeking a highly qualified candidate who has demonstrated excellence in teaching, who will establish an active and successful research program, and who will have a Ph.D. by the time of appointment. Williams College is a private, coeducational, residential, highly selective liberal arts college with an undergraduate enrollment of approximately 2,000 students. The teaching load is two courses per 12-week semester and a winter term course every other January. Applicants are encouraged to apply electronically at: http://mathjobs.org or send a vita and have three letters of recommendation on teaching and research sent to Satyan Devadoss, Chair of the Hiring Committee, Department of Mathematics and Statistics, Williams College, 18 Hoxsey Street, Williamstown, MA 01267. Teaching and research statements are also welcome. Evaluations of applications will begin on or after November 15 and will continue until the position is filled. All offers of employment are contingent upon completion of a background check. Further information is available upon request. For more information on the Department of Mathematics and Statistics, visit: http://math.williams.edu/. Williams College is a coeducational liberal arts institution located in the Berkshire Hills of western Massachusetts with easy access to the culturally rich cities of Albany, Boston, and New York City. The college is committed to building and supporting a diverse population of students, and to fostering an inclusive faculty, staff, and curriculum. Williams has built its reputation on outstanding teaching and scholarship and on the academic excellence of its students. Please visit the Williams College website http://www.williams.edu/. Beyond meeting fully its legal obligations for non-discrimination, Williams College is committed to building a diverse and inclusive community where members from all backgrounds can live, learn, and thrive.

000041

WILLIAMS COLLEGE
Department of Mathematics and Statistics

The Williams College Department of Mathematics and Statistics invites applications for a visiting position in mathematics for the 2013-2014 year, at the rank of assistant professor. Preference will be given to candidates who will have a Ph.D. in mathematics by September 2013. Applicants are encouraged to apply electronically at http://mathjobs.org or please send a vita and have three letters of recommendation on teaching and research sent to the Visitor Hiring Committee, Department of Mathematics and Statistics, Williams College, 18 Hoxsey Street, Williamstown, MA 01267. Teaching and research statements are also welcome. Evaluations of applications will begin on or after November 15, 2012, and will continue until the position is filled. All offers of employment are contingent upon completion of a background check. Further information is available upon request. For more information on the Department of Mathematics and Statistics, visit http://math.williams.edu/. Williams College is a coeducational liberal arts institution located in the Berkshire Hills of western Massachusetts with easy access to the culturally rich cities of Albany, Boston, and New York City. The college is committed to building and supporting a diverse population of students, and to fostering an inclusive faculty, staff, and curriculum. Williams has built its reputation on outstanding teaching and scholarship and on the academic excellence of its students. Please visit the Williams College website http://www.williams.edu/. Beyond meeting fully its legal obligations for non-discrimination, Williams College is committed to building a diverse and inclusive community where members from all backgrounds can live, learn, and thrive.

000079

MONTANA

MONTANA STATE UNIVERSITY
Department of Mathematical Sciences

The Department of Mathematical Sciences at Montana State University invites applications for a tenure-track position in Mathematics at the Assistant Professor level to begin in August 2013. For more information visit: http://www.montana.edu/jobs/faculty/12221-2. Submit applications at www.mathjobs.org. Screening begins 01/02/2013. Montana State University is ADA/AA/EO/Veteran Preference Employer.

000091

NEBRASKA

UNIVERSITY OF NEBRASKA-LINCOLN
Department of Mathematics

The UNL Department of Mathematics invites applications for the following positions: 1) One open rank (Assistant, Associate, or Full Professor) tenure-track position with emphasis in Mathematics Education. 2) One tenure-track Assistant Professor position in Scientific Computing/Computational Mathematics. Both positions begin August 2013. Review of applications will begin November 30, 2012, and continue until a suitable candidate is found. For more information about these positions and information on how to apply for them please go to: http://www.math.unl.edu/department/jobs/. The University of Nebraska has an active National Science Foundation ADVANCE gender equity program, and is committed to a pluralistic campus community through affirmative action, equal opportunity, work-life balance, and dual careers.

000081

NEW HAMPSHIRE

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics anticipates a tenure-track opening with initial appointment as an Assistant Professor in the 2013-2014 academic year. The successful applicant will have a research profile with a concentration in computational or applied mathematics. Applicants should apply online at www.mathjobs.org. Position ID: APACM #3874. Applications received by December 15, 2012, will receive first consideration. For more information about this position, please visit our website: http://www.math.dartmouth.edu/activities/recruiting/. Dartmouth is committed to diversity and encourages applications from women and minorities.

000076

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics anticipates a senior opening with initial appointment in the 2013-2014 academic year. The successful applicant will have a research profile with a concentration in computational or applied mathematics, will be appointed at the level of Full Professor and is expected to have an overall record of achievement and leadership consonant with such an appointment. Applicants should apply online at www.mathjobs.org. Position ID: PACM #3873. Applications received by December 15, 2012, will receive first consideration. For more information about this position, please visit our website: http://www.math.dartmouth.edu/activities/recruiting/. Dartmouth is committed to diversity and encourages applications from women and minorities.

000077

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics anticipates a tenure-track opening with initial appointment in the 2013-2014 academic year, for a mathematician working in either topology or number theory. The appointment is for candidates at any rank. Applicants should apply online at www.mathjobs.org. Position ID: TTPTNT #3875. Applications received by December 15, 2012, will receive first consideration. For more information about this position, please visit our website: http://www.math.dartmouth.edu/activities/recruiting/. Dartmouth is committed to diversity and encourages applications from women and minorities.

000078

NEW JERSEY

INSTITUTE FOR ADVANCED STUDY
School of Mathematics

The School of Mathematics has a limited number of memberships with financial support for research in mathematics and computer science at the Institute during the 2013-14 academic year.

The school frequently sponsors special programs. However, these programs comprise no more than one-third of the membership so that each year a wide range of mathematics is supported.

"Non-equilibrium Dynamics and Random Matrices" will be the topic of the special program during 2013-14. Horng-Tzer Yau of Harvard and Thomas Spencer of the Institute will lead the program. Juerg Froehlich of ETH and Herbert Spohn of Zentrum Mathematik will be among the senior participants attending.

For more information about the special program for the year, please see the school's homepage.

Several years ago the school established the von Neumann Fellowships. Up to eight of these fellowships will be available for each academic year. To be eligible for the von Neumann Fellowships, applicants should be at least five, but no more than fifteen, years following the receipt of their Ph.D.

The Veblen Research Instructorship is a three-year position which was established in partnership with the Department of Mathematics at Princeton University in 1998. Three-year instructorships will be offered each year to candidates in pure and applied mathematics who have received their Ph.D. within the last three years. Usually the first and third year of the instructorship will be spent at Princeton University and will carry regular teaching responsibilities. The second year is spent at the Institute and dedicated to independent research of the instructor's choice.

Candidates must have given evidence of ability in research comparable at least with that expected for the Ph.D. degree.

Application materials may be requested from Applications, School of Mathematics, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540; email: applications@math.ias.edu.

Postdoctoral computer science and discrete mathematics applicants may be interested in applying for a joint (2-year) position with one of the following: The Department of Computer Science at Princeton University, http://www.cs.princeton.edu; DIMACS at Rutgers, The State University of New Jersey, http://www.dimacs.rutgers.edu; http://intractability.princeton.edu; or the Intractability Center. For a joint appointment, applicants should apply to the School of Mathematics as well as to the above noting their interest in a joint appointment.

Applications may be found online at: https://applications.ias.edu.

The deadline for all applications is December 1.

The Institute for Advanced Study is committed to diversity and strongly encourages applications from women and minorities.

000049

PRINCETON UNIVERSITY
Program in Applied and Computational Mathematics
Postdoctoral Research Associate

The Program in Applied and Computational Mathematics invites applications for Postdoctoral Research Associates to join in research efforts of interest to its faculty. Domains of interest include nonlinear partial differential equations, computational fluid dynamics and material science, dynamical systems, numerical analysis, stochastic problems and stochastic analysis, graph theory and applications, mathematical biology, financial mathematics and mathematical approaches to signal analysis, information theory and graphics, and structural biology and image processing. Applicants should have a recently-completed or soon-to-be completed doctorate. Appointments are for one year and may be renewed if funding is available and performance is satisfactory. For details on specific faculty members and their research interests, please go to: http://www.pacm.princeton.edu/index.shtml. Applicants should apply online at https://jobs.princeton.edu and submit a cover letter, CV, bibliography/publications list, statement of research and contact information for three references. Princeton University is an Equal Opportunity Employer and complies with applicable EEO and Affirmative Action Regulations.

000084

RUTGERS UNIVERSITY-NEW BRUNSWICK
Mathematics Department

The Mathematics Department of Rutgers University-New Brunswick invites applications for the following positions which may be available September 2013.

TENURE-TRACK ASSISTANT PROFESSORSHIPS: Subject to availability of funding, the department expects two or more openings at the level of Tenure-Track Assistant Professor. In exceptional cases there may be the possibility of appointment at a higher level. Candidates must have the Ph.D. and show a strong record of research accomplishments in pure or applied mathematics, and concern for teaching. The department has hiring priorities in Algebra (including Algebraic Geometry/Algebraic Topology), Probability/Stochastic Analysis and Numerical Analysis/Scientific Computation, but outstanding candidates in any field of pure or applied mathematics will be considered. The normal annual teaching load for research-active faculty is 2-1, that is, two courses for one semester, plus one course for the other semester. Review of applications begins immediately.

HILL ASSISTANT PROFESSORSHIPS and NON-TENURE-TRACK ASSISTANT PROFESSORSHIPS: These are both three-year nonrenewable positions. Subject to availability of funding, the department expects several open positions of these types. The Hill Assistant Professorship carries a reduced teaching load of 2-1 for research; candidates for it should have received the Ph.D., show outstanding promise of research ability in pure or applied mathematics, and have concern for teaching. The Non-Tenure-Track Assistant Professorship carries a teaching load of 2-2; candidates for it should have received the Ph.D., show evidence of superior teaching accomplishments, and promise of research ability. Review of applications begins January 1, 2013.

Applicants for the above position(s) should submit a curriculum vitae (including a publication list) and arrange for four letters of reference to be submitted, one of which evaluates teaching. Applicants should first go to the website `https://www.mathjobs.org/jobs` and fill out the AMS Cover Sheet electronically. It is essential to fill out the cover sheet completely, including naming the positions being applied for (TTAP, HILL, NTTAP, respectively) giving the AMS Subject Classification number(s) of area(s) of specialization, and answering the question about how materials are being submitted. The strongly preferred way to submit the CV, references, and any other application materials is online at: `https://www.mathjobs.org/jobs`. If necessary, however, application materials may instead be mailed to: Search Committee, Dept. of Math., Hill Center, Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. Review of applications will begin on the dates indicated above, and will continue until openings are filled. Updates on these positions will appear on the Rutgers Mathematics Department webpage at: `http://www.math.rutgers.edu`.

Rutgers is an Affirmative Action/Equal Opportunity Employer and encourages applications from women and minority-group members.

000094

NEW YORK

CLARKSON UNIVERSITY
Department of Mathematics

Clarkson University Department of Mathematics (`http://www.clarkson.edu/math`) invites applications for a tenure-track Assistant Professor position in applied mathematics starting in August 2013.

We are especially interested in candidates with expertise in computational areas of applied mathematics, including statistics or dynamical systems, but all areas of applied mathematics will be considered. Responsibilities will include teaching undergraduate and graduate level mathematics courses, and directing graduate students. Minimum requirements are a Ph.D. in mathematics by the date of appointment, demonstrated excellence in both research potential and teaching ability, and fluency in English. In addition, the candidate should be able to interact with other faculty in the department and the university.

Applications including vita and three reference letters should be submitted to `https://clarkson.peopleadmin.com/`. Completed applications will be reviewed starting immediately. Women and minorities are urged to apply. Clarkson University is an AA/EOE Employer.

000096

CORNELL UNIVERSITY
Tenure or Tenure-Track Positions

The Department of Mathematics at Cornell University invites applications for three tenure-track Assistant Professor positions, or higher rank, pending administrative approval, starting July 1, 2013. The searches are open to all areas of mathematics with an emphasis on the areas of probability; algebra, in particular, number theory; analysis, in particular, PDE; and topology. 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/positions.html`. Applicants will be automatically considered for all eligible positions. Deadline November 1, 2012. Early applications will be regarded favorably. Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

000054

CORNELL UNIVERSITY
Department of Mathematics
H.C. Wang Assistant Professor

The Department of Mathematics at Cornell University invites applications for one H.C. Wang Assistant Professor, non-renewable, 3-year position beginning July 1, 2013. Successful candidates are expected to pursue independent research at Cornell and teach three courses per year. A Ph.D. in mathematics is required. The department actively encourages applications from women and minority candidates.

Applicants must apply electronically at: `http://www.mathjobs.org`.

For information about our positions and application instructions, see: `http://www.math.cornell.edu/Positions/positions.html`.

Applicants will be automatically considered for all eligible positions. Deadline December 1, 2012. Early applications will be regarded favorably. Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

000055

NORTH CAROLINA

NORTH CAROLINA STATE UNIVERSITY
Chancellor's Faculty Excellence Program

As one of the leading land-grant institutions in the nation, North Carolina State University is proud to announce its Chancellor's Faculty Excellence Program; a cluster hire program that marks the first major initiative of the university's 2011-2020 strategic plan "The Pathway to the Future". Starting in 2012, NC State will hire thirty-eight faculty in twelve research areas or "clusters" to promote interdisciplinary scholarship and the development of innovative curricula in emerging areas of strategic strength; see `http://www.ncsu.edu/workthatmatters`. The research cluster in Personalized Medicine (`http://www.ncsu.edu/projects/personalmed`) invites applications for a position in the Mathematics Department. The Personalized Medicine Cluster is a collaboration of the Department of Mathematics with the Edward P. Fitts Department of Industrial and Systems Engineering (ISE) and the Department of Statistics in which each department will recruit relevant faculty. The North Carolina Research Triangle, home of NC State, has a vast health and medical care environment. The Department of Mathematics has cutting edge research programs in both pure and applied mathematics. Many members of the Department participate in interdisciplinary programs and research groups on campus and in the broader scientific community. More than 10 faculty members have been elected as Fellows of Professional Societies (AAAS, IoP, ACM, ASA, IEEE and SIAM) in recent years, and for the last 10 years the department has ranked in the top five nationally for federally financed R&D expenditures in the mathematical sciences. The department has been recognized nationally for its excellence in graduate and undergraduate education with two successive awards: the 2010 American Mathematical Society Award for an Exemplary Program or Achievement in a Mathematics Department and the 2011 American Mathematical Society Award for Mathematics

Programs that Make a Difference. The latter award cited the department for distinction in its extraordinary record in serving students who have traditionally been underrepresented in mathematics, especially African-Americans. The department is housed in the new state-of-the-art SAS Hall, and it is one of the few mathematics departments in the world with a physical/biological laboratory where students can conduct laboratory experiments for data collection and analysis. To fill its commitment to the Personalized Medicine Cluster, the department is seeking qualified applicants for a full-time faculty position, starting as early as August 2013. Strong preference will be given to candidates with a proven record of research achievements and a record of research support in related areas of interest in the cluster. A record of contributions in related disciplines as applied to personalized medicine, mathematical modeling, medical decision making and/or health care systems analysis is essential. Applicants with strong methodological research interests are particularly encouraged to apply. The successful candidate will be expected to carry out innovative research in mathematical modeling and health systems analysis within the Personalized Medicine Cluster and to pursue relevant research funding. In addition, the candidate is expected to be active in the Ph.D. program and to teach at the graduate and undergraduate levels. To submit your application materials, go to `http://www.mathjobs.org/jobs/ncsu`. Applicants should submit a cover letter with a complete curriculum vitae, detailing educational background, research and professional experience, teaching experience and publications, along with the names of three references familiar with their work. A one page description of past, current and future research activities and interests should also be submitted. Review of applications will begin immediately. Applications will be accepted until suitable candidates are found.

To be considered for this position, please also go to `http://jobs.ncsu.edu/postings/12683` and complete a Faculty Profile for this position. Write to `math-jobs@math.ncsu.edu` for questions concerning this position.

Individuals with disabilities desiring accommodations in the application process should contact Frankie Stephenson, Executive Assistant at: `Frankie_stephenson@ncsu.edu` (email), (919) 513-2294 (voice) or (919) 515-0657 (fax).

NCSU is an Equal Opportunity And Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, national origin, religion, sex, age, veteran status, or disability. In addition, NC State University welcomes all persons without regard to sexual orientation. Applications from women, minorities, and persons with disabilities are encouraged. The College of Physical and Mathematical Sciences welcomes the opportunity to work with candidates to identify suitable employment opportunities for spouses or partners.

000092

OREGON

PORTLAND STATE UNIVERSITY, Fariborz Maseeh Department of Mathematics & Statistics Tenure-Track Position in Mathematical Sciences

The Fariborz Maseeh Department of Mathematics and Statistics at Portland State University invites applications for a tenure-track position in mathematical sciences, to begin in fall 2013. The intent is to fill this faculty position at the Assistant Professor level in an area compatible with those currently represented in the department (`http://www.pdx.edu/math/`). Applicants must have a Ph.D. in mathematical sciences, or equivalent. We are seeking applicants who can demonstrate the potential for conducting high quality independent research, contributing to our Ph.D. programs, and securing external funding.

The successful candidate will be required to teach graduate and undergraduate courses, and actively participate in supervising graduate students, as well as to conduct research. It is expected that the new hire will contribute to our novel mathematical sciences Ph.D. program (`http://www.pdx.edu/math/ph-d-mathematical-sciences`) by offering new courses and attracting outstanding students.

Qualified applicants are requested to submit curriculum vitae, a statement of research interest that details what the candidate brings to this position, a description of teaching philosophy, and at least three letters of recommendation. The required material (in PDF format) is to be sent to the Mathematical Sciences Search Committee at: `mathposition@pdx.edu`.

Consideration of applications will begin January 2, 2013, and will continue until the position is filled.

Portland is consistently ranked as one of the world's most livable cities, and Portland State University has established a record of excellence in research, teaching, community outreach, and sustainability. Please see `http://www.pdx.edu` for more details.

Portland State University is an Affirmative Action, Equal Opportunity institution and welcomes applications from diverse candidates and candidates who support diversity.

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PENNSYLVANIA

DREXEL UNIVERSITY Department of Mathematics

The Department of Mathematics at Drexel University invites applications for a tenure-track/tenure position, effective September 2013. We are especially interested in candidates in Numerical Analysis, Algebraic Combinatorics, Approximation Theory, Compressed Sensing, and Genomic Mathematics.

Applicants must possess a doctoral degree in mathematics or equivalent and show a strong record and commitment to research and teaching.

Applicants for senior positions should demonstrate an outstanding record of achievement commensurate with the level of appointment, including a track record of external support and research group leadership.

Drexel University is a private, urban university, with over 11,000 full-time undergraduates and is well-known for its co-operative education program. The Mathematics Department offers undergraduate, master's and Ph.D. degrees.

To apply for this position please visit `http://www.mathjobs.org` to submit all relevant materials online. These include: AMS cover sheet, letter of application, vita, statement of research program and evidence of teaching effectiveness, and at least three letters of reference.

Review of applications will begin December 1, 2012, and continue until the positions are filled. Drexel University is an Equal Opportunity/Affirmative Action Employer.

000074

SOUTH CAROLINA

UNIVERSITY OF SOUTH CAROLINA Department of Mathematics Tenure-track and Tenured Positions

Algebraic Geometry Tenure-track Assistant Professor

Applications are invited for a tenure-track Assistant Professor position in the area of algebraic geometry. Areas of particular interest include algebraic geometry and allied fields, such as algebraic and geometric combinatorics, algebraic number theory, algebraic topology, commutative algebra, non-commutative algebra, representation theory, and symbolic computation.

Candidates must have a Ph.D. in Mathematics, an outstanding research program, a commitment to effective teaching at the undergraduate and graduate levels, and a demonstrated potential for excellence in both research and teaching.

The beginning date for the position will be August 16, 2013. Review of applications will begin on December 1, 2012, and continue until the position is filled. To ensure consideration, applications should be received by January 8, 2013.

Tenure-track or Tenured Positions Biomathematics

Applications are invited for an open rank tenure-track or tenured position in Bio-mathematics for research related to modeling and computation of tissue and organ fabrication. Candidates should have a Ph.D. in Mathematics or a related field, and have sufficient background in mathematical modeling, mathematical/numerical analysis, simulation, and/or visualization of biological systems to direct a vigorous interdisciplinary research program in mathematical biology. The successful candidate is expected to interact effectively with researchers in the College of Engineering and Computing and the College of Medicine at the University of South Carolina, and at the Medical University of South Carolina.

The beginning date for the position will be August 16, 2013. Review of applications will begin on November 15, 2012, and continue until the position is filled. To ensure consideration, applications should be received by December 15, 2012.

How to apply

Applicants for either position must apply electronically at: `http://www.mathjobs.org`. A complete application should contain a cover letter, standard AMS cover sheet, curriculum vitae, description of research plans, statement of teaching philosophy, and four letters of recommendation. One of the letters should appraise the candidate's teaching ability. Please address inquiries to `hiring@math.sc.edu`.

The Mathematics Department, located in the heart of the historic campus, currently has 32 tenured and tenure-track faculty, 5 instructors, 48 graduate students, over 250 majors, and 40 minors. Faculty research interests include algebra, analysis, applied and computational math, biomath, discrete math, geometry, logic, and number theory.

The University of South Carolina's main campus is located in the state capital, close to mountains and coast. The Carnegie Foundation for the Advancement of Teaching has designated the University of South Carolina as one of only 73 public and 32 private academic institutions with "very high research activity". The Carnegie Foundation also lists USC as having strong community engagement. The university has over 29,500 students on the main campus (and over 44,500 students system-wide), more than 350 degree programs, and a nationally-ranked library system that includes one of the nation's largest public film archives. Columbia, the capital of South Carolina, is the center of an increasingly sophisticated greater metropolitan area with a population over 750,000.

The University of South Carolina is an Affirmative Action, Equal Opportunity Employer. Minorities and women are encouraged to apply. The University of South Carolina does not discriminate in educational or employment opportunities or decisions for qualified persons on the basis of race, color, religion, sex, national origin, age, disability, sexual orientation, or veteran status.

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TENNESSEE

UNIVERSITY OF TENNESSEE
Position Advertisement

The Department of Mathematics at the University of Tennessee seeks to fill a tenure-track position in Computational and Applied Mathematics. Preference will be given to candidates who will enhance existing strengths of the group, including numerical PDEs (analysis, adaptive methods, and fast solvers) and modelling and computation applied to problems from fluid dynamics, material science, biology, and other fields of science. A Ph.D. or equivalent degree is required. Outstanding research promise and dedication to excellent teaching are paramount. Some postdoctoral experience is desirable though not required. Employment begins August 1, 2013.

Applicants should arrange to have submitted a curriculum vita, at least three letters of recommendation, a research statement (including future plans and abstracts of finished papers), and evidence of quality teaching. These documents can be submitted any of the following ways: (1) electronically at: `http://www.mathjobs.org/jobs` (preferred), (2) by e-mail to: `cam@math.utk.edu` (3) by mail to Computational Applied Mathematics Search, Department of Mathematics, The University of Tennessee, Knoxville, TN 37996-0612. Review of applications will begin December 1, 2012, and will continue until the position is filled.

The Knoxville campus of the University of Tennessee is seeking candidates who have the ability to contribute in meaningful ways to the diversity and intercultural goals of the university. For more information about the university and Department of Mathematics please see our websites at: `http://www.utk.edu` and `http://www.math.utk.edu`.

The University of Tennessee is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services. All qualified applicants will receive equal consideration for employment without regard to race, color, national origin, religion, sex, pregnancy, marital status, sexual orientation, gender identity, age, physical or mental disability, or covered veteran status.

000080

VANDERBILT UNIVERSITY,
Non-Tenure-Track Assistant Professor Positions

We invite applications for several visiting and non-tenure-track assistant professor positions in the research areas of the Mathematics Department beginning fall 2013. These positions will have variable terms and teaching loads but most will be three-year appointments with a 2-2 teaching load. We anticipate that some of these appointments will carry a 1-1 teaching load and provide a stipend to support research.

We are looking for individuals with outstanding research potential and a strong commitment to excellence in teaching. Preference will be given to recent doctorates. Submit your application and supporting materials electronically through the AMS website Mathjobs.org via the link `https://www.mathjobs.org/jobs/jobs/3896`. Alternatively, application materials may be sent to: NTT Appointments Committee, Vanderbilt University, Department of Mathematics, 1326 Stevenson Center, Nashville, TN 37240. These materials should include a letter of application, a curriculum vitae, a publication list, a research statement, four letters of recommendation and the AMS Cover Sheet. One of the letters must discuss the applicant's teaching qualifications. Reference letter writers should be asked to submit their letters online through `Mathjobs.org`. Evaluation of the applications will commence on December 1, 2012, and continue until the positions are filled. For information about the Department of Mathematics at Vanderbilt University, please consult the Web at: `http://www.vanderbilt.edu/math`.

Vanderbilt is an Equal Employment Opportunity/Affirmative Action Employer. Women and minorities are especially invited to apply.

000082

VANDERBILT UNIVERSITY
Nashville, Tennessee
Department of Mathematics
Tenure-Track Assistant Professor Position

The Department of Mathematics at Vanderbilt University invites applications for a tenure-track position (Assistant Professor) beginning fall 2013. Exceptional candidates from any area of pure or applied mathematics are encouraged to apply, but priority will be given to applicants in applied analysis or one of the research areas of the department. The department especially encourages applications from women and minorities.

We are looking for individuals with an outstanding record in research and demonstrated excellence in teaching. A Ph.D. degree is required. Qualified candidates should submit their application materials electronically through the AMS website Mathjobs.org via the URL https://www.mathjobs.org/jobs/jobs/3963. Alternatively, application materials may be sent to:

Faculty Hiring Committee
Vanderbilt University
Department of Mathematics
1326 Stevenson Center
Nashville, TN 37240

These materials should include a letter of application, a curriculum vitae, a publication list, a description of current and planned research, a teaching statement, at least four letters of recommendation, and the AMS Cover Sheet. One of the letters must discuss the applicant's teaching qualifications. Reference letter writers should be asked to submit their letters online through MathJobs.org. Evaluation of the applications will commence on November 15, 2012, and continue until the position is filled. For information about the Department of Mathematics at Vanderbilt University, please consult the web at http://www.vanderbilt.edu/math/.

Vanderbilt is an Equal Employment Opportunity/Affirmative Action Employer.

000098

TEXAS

RICE UNIVERSITY
Tenure-Track Position

The Department of Mathematics of Rice University anticipates filling one position at the rank of tenure-track Assistant Professor, contingent on budgetary approval. Candidates who could make an extraordinary contribution may be considered at other ranks. Applicants should have extremely strong research potential and provide evidence of success in teaching. All application materials, including at least three letters of reference, should be submitted via http://www.mathjobs.org/jobs. For more information, see http://www.math.rice.edu/. Applications should be received by November 15, 2012, to receive full consideration; early application is advisable. Rice University is an Equal Opportunity/Affirmative Action Employer and strongly encourages applications from women and members of under-represented minority groups.

000075

TEXAS A&M UNIVERSITY
Department of Mathematics

The Department of Mathematics anticipates several openings for tenured, tenure-eligible, and visiting faculty positions beginning fall 2013. One position at either the Associate or Assistant Professor level is in Noncommutative Geometry and Topology. For the others, the field is open, but we particularly seek applications from individuals whose mathematical interests would augment and build upon existing strengths both within the Mathematics Department as well as other departments in the university. We also have several visiting positions available. Research and teaching are duties expected of all positions. Salary, and start-up funds are competitive. For a tenured position the applicant should have an outstanding research record. An established research program, including success in attracting external funding, and a demonstrated ability and interest in teaching are required. Informal inquiries are welcome. For an Assistant Professorship, we seek very strong research potential and evidence of excellence in teaching. Research productivity beyond the doctoral dissertation will normally be expected. 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. Senior Visiting Positions may be for a semester or one year period. A complete dossier should be received by December 15, 2012. Early applications are encouraged since the department will start the review process in October 2012. 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: http://www.mathjobs.org. 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.

000070

TEXAS TECH UNIVERSITY
Department of Mathematics and Statistics

The Department of Mathematics and Statistics at Texas Tech University (M&S) invites applications for three tenure-track assistant professor positions beginning fall 2013. A Ph.D. degree at the time of appointment is required. M&S has active research groups in both pure and applied mathematics (see http://www.math.ttu.edu/FacultyStaff/research.shtml). The department fosters a spirit of interdisciplinary collaboration across areas of mathematics as well as with engineering and the physical and biological sciences. M&S is seeking candidates who will be engaged in nationally visible scholarship, establish externally-funded research programs, interact with the existing research groups in the department, involve graduate students in their research, and show excellence in teaching at the undergraduate and graduate levels.

It is anticipated that one of the positions will be in statistics, one in numerical analysis, and one in another area compatible with the department's existing research programs. Candidates with very strong records who will bring externally sponsored research to Texas Tech will be considered for associate or full professor ranks.

Please apply for position numbers T96800 for Statistics, T96232 for Numerical Analysis, and T96376 for all other areas, at http://jobs.texastech.edu. Include a completed AMS standard cover sheet and a vita.

Three letters of reference plus any material in addition to that completed online should be sent to:

Alex Wang, Hiring Committee Chair,
Department of Mathematics and Statistics, Texas Tech University,
Lubbock, TX 79409-1042.

Review of applications will begin immediately.

Texas Tech University is committed to diversity among its faculty. We strongly encourage applications from women, minorities, persons with disabilities, and veterans, and we consider the needs of dual career couples.

Texas Tech University is an Affirmative Action/Equal Opportunity Employer.

000048

UTAH

UNIVERSITY OF UTAH
Department of Mathematics

The Department of Mathematics at the University of Utah invites applications for the following faculty positions:

· Three-year Wylie and Burgess Assistant Professor Lecturer positions

· Postdoctoral positions are available for the NSF-sponsored RTG (Research Training Group) in Mathematical Biology. See our website http://www.math.utah.edu/research/mathbio/RTG_overview.html for a description of these postdoctoral positions.

· Full-time tenure-track or tenured appointments at the level of assistant, associate, or full professor in all areas of mathematics and statistics.

· Full-time tenure-track or tenured appointment as assistant, associate, or full professor in the Department of Mathematics and as the Associate Director of the Center for Science and Mathematics Education (CSME). Successful applicants should have experience, interest, and a demonstrated excellence in mathematics education, in conducting outreach programs, broadly interpreted, and in mathematics research.

The successful candidate will develop and maintain a balance of education, outreach, and research activities, including directing existing teacher preparation and mathematics education grants. Preferred starting date is August 2013. Applications must be completed through the website: http://www.mathjobs.org/jobs/Utah, and will be accepted until the position(s) have been filled. All applications will be reviewed when they are complete. The University of Utah is an Equal Opportunity/Affirmative Action Employer and Educator. Minorities, women, and persons with disabilities are strongly encouraged to apply. Veterans preference. Reasonable accommodations provided. For additional information: http://www.regulations.utah.edu/humanResources/5-106.html. The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and possess a strong commitment to improving access to higher education for historically underrepresented students. The department is one of 25 Group I Mathematics Departments in public institutions nationwide, and its faculty have received many honors including Clay, Guggenheim, Packard, and Sloan Fellowships. For more information see: http://www.math.utah.edu or email hiring@math.utah.edu.

000093

VIRGINIA

UNIVERSITY OF VIRGINIA
Department of Mathematics
Tenure-Track/Tenured Positions

The Department of Mathematics at the University of Virginia, Charlottesville, VA, invites applications for two full time positions, either tenure-track or tenured open rank, to begin in the fall semester of 2013. Applicants must present evidence of outstanding accomplishments and promise in both research and teaching. Candidates whose research interests complement the strengths of the department's current faculty are encouraged to apply, with priority given to applicants in algebra and algebraic geometry for one position and analysis for the other. Applicants are required to have a Ph.D. by the time of appointment.

Information about the department may be found at http://artsandsciences.virginia.edu/mathematics/index.html.

Review of applications will begin on November 15, 2012; however, the positions will remain open until filled.

To apply, please submit the following required documents electronically through http://www.MathJobs.org: A cover letter, an AMS Standard Cover Sheet, a curriculum vitae, a publication list, a description of research, and a statement about teaching interests and experience. The applicant must also have at least four letters of recommendation submitted, of which one must support the applicant's effectiveness as a teacher.

In addition, all candidates are required to complete a Candidate Profile through the University of Virginia's employment system, which is Jobs@UVA (https://jobs.virginia.edu). Search for posting number 0610625 and follow the directions for applying to this posting to submit CV with a publication list, statement of research interest, and statement of teaching philosophy.

Questions regarding the application process for Jobs@UVa should be directed to: zk4g@virginia.edu.

For additional information about the position contact: mathematics-hiring@Virginia.EDU.

The university will perform background checks on all new faculty hires prior to making a final offer of employment.

The University of Virginia is an Equal Opportunity/Affirmative Action Employer. Women, minorities, veterans and persons with disabilities are encouraged to apply.

000086

UNIVERSITY OF VIRGINIA
Department of Mathematics
Whyburn Instructorship

The Department of Mathematics at the University of Virginia invites applications for a Whyburn Instructorship in commutative algebra beginning August 25, 2013. This position carries a three-year appointment. Preference will be given to candidates who have received their Ph.D. within the last three years. Candidates must have a Ph.D. by the time of appointment, an outstanding research record, and demonstrated teaching success. Information about the department may be found at http://artsandsciences.virginia.edu/mathematics/index.html.

Review of applications will begin on November 15, 2012; however, the position will remain open until filled.

To apply, submit the following required documents electronically through http://www.MathJobs.org: A cover letter, an AMS Standard Cover Sheet, a curriculum vitae, a publication list, a description of research, and a statement about teaching interests and experience. The applicant must also have four letters of recommendation submitted, of which one must support the applicant's effectiveness as a teacher.

In addition, all candidates are required to complete a Candidate Profile through the University of Virginia's employment system, which is Jobs@UVA (https://jobs.virginia.edu). Search for posting number 0610670 and follow the directions for applying to this posting to submit CV with a publication list, statement of research interest, and statement of teaching philosophy.

Questions regarding the application process for Jobs@UVa should be directed to: zk4g@virginia.edu.

For additional information about the position contact: huneke@Virginia.EDU.

The university will perform background checks on all new faculty hires prior to making a final offer of employment.

The University of Virginia is an Equal Opportunity/Affirmative Action Employer. Women, minorities, veterans and persons with disabilities are encouraged to apply.

000087

HONG KONG

THE UNIVERSITY OF HONG KONG
Tenure-Track Associate Professor/ Assistant Professor in the Department of Mathematics (Ref.: 201200445)

Applications are invited for a tenure-track appointment as Associate Professor/Assistant Professor in the Department of Mathematics, from July 1, 2013, or as soon as possible thereafter. The position will initially be made on a three-year term basis, with the possibility of renewal and with consideration for tenure during the second three-year contract.

The position is to be held by an academic in Pure Mathematics. Special consideration will be given to candidates whose expertise overlaps with Algebraic Geometry, Arithmetic Geometry and/or Complex Geometry, but applications from candidates in any area of Pure Mathematics will also be considered. The appointee, who will be a regular professoriate member of the department, will be associated with the Institute of Mathematical Research (IMR) (http://www.hku.hk/math/imr), a centre of the University of Hong Kong attached to the department. He/She is expected to actively participate in research activities of the IMR and to take part in the organization of these activities such as research seminars, workshops, and conferences. The appointee will share teaching duties as other regular professoriate members of the department, but efforts will be made by the department so that part of those duties will be fulfilled through the teaching of graduate level and advanced undergraduate level courses. For enquiries about the existing research activities and the specific job requirements, please write to Professor J. Lu, Head of the Department of Mathematics (email: jhlu@maths.hku.hk).

A globally competitive remuneration package commensurate with the appointee's qualifications and experience will be offered. At current rates, salaries tax does not exceed 15% of gross income. The appointment will attract a contract-end gratuity and university contribution to a retirement benefits scheme, totalling up to 15% of basic salary, as well as leave, and medical benefits. Housing benefits will be provided as applicable.

Applicants should send a completed application form, together with a C.V. containing information on educational experience, professional experience, a complete list of publications, a survey of past research and teaching experience, a research plan for the next few years, and a statement on teaching philosophy by email to: `scmath@hku.hk`. They should also arrange for submission, to the same email address as stated above, three reference letters from senior academics. One of these senior academics should be asked to comment on the applicant's ability in teaching, or the applicant should arrange to have an additional reference letter on his/her teaching sent to the same email address as stated above. Please indicate clearly "Ref.: 201200445" and which level the candidate is being considered for (Tenure-Track Associate Professor/ Assistant Professor in the Department of Mathematics) in the subject of the email. Application forms (341/1111) can be obtained at: `http://www.hku.hk/apptunit/form-ext.doc`. Further particulars can be obtained at `http://jobs.hku.hk/`. Closes November 30, 2012.

The university thanks applicants for their interest, but advises that only shortlisted applicants will be notified of the application result.

The university is an Equal Opportunity Employer and is committed to a No-Smoking policy.

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SINGAPORE

NATIONAL UNIVERSITY OF SINGAPORE (NUS)
Department of Mathematics

The Department of Mathematics at the National University of Singapore (NUS) invites applications for tenured, tenure-track and visiting positions at all levels, beginning in August 2013.

NUS is a research intensive university that provides quality undergraduate and graduate education. The Department of Mathematics has about 65 faculty members and teaching staff whose expertise covers major areas of contemporary mathematical research.

We seek promising scholars and established mathematicians with outstanding track records in any field of pure and applied mathematics. The department, housed in a newly renovated building equipped with state-of-the-art facilities, offers internationally competitive salary with start-up research grants, as well as an environment conducive to active research, with ample opportunities for career development. The teaching load for junior faculty is kept especially light.

The department is particularly interested in, but not restricted to, considering applicants specializing in any of the following areas:

· Analysis and Ergodic Theory
· Number Theory, Arithmetic Geometry
· Computational Science, especially Biomedical Imaging and Computational Material Sciences
· Probability, Stochastic Processes, and Financial Mathematics
· Combinatorics and Discrete Mathematics Application materials should be sent to the Search Committee via email (as PDF files): `search@math.nus.edu.sg`.

Please include the following supporting documentation in the application:

1. an American Mathematical Society Standard Cover Sheet;
2. a detailed CV including publications list;
3. a statement (max. of 3 pages) of research accomplishments and plan;
4. a statement (max. of 2 pages) of teaching philosophy and methodology. Please attach evaluation on teaching from faculty members or students of your current institution, where applicable;
5. at least three letters of recommendation including one which indicates the candidate's effectiveness and commitment in teaching. Please ask your referees to send their letters directly to `search@math.nus.edu.sg`.

Enquiries may also be sent to this email address. Review process will begin on 15 October, and will continue until positions are filled.

For further information about the department, please visit `http://www.math.nus.edu.sg`.

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POSTDOCTORAL FELLOWSHIPS

ALLIANCE FOR BUILDING FACULTY DIVERSITY IN THE MATHEMATICAL SCIENCES POSTDOCTORAL FELLOWSHIPS
NSF-funded Postdoctoral Fellowships

The Alliance for Building Faculty Diversity in the Mathematical Sciences aims to increase the access of U.S. underrepresented minority groups to academic tenure-track positions. The Alliance offers four NSF funded Postdoctoral Fellowships beginning fall 2013 targeted at new or recent minority Ph.D.'s. The Alliance is comprised of NSF Mathematical Sciences Institutes and seven major research universities with a good record of mentoring underrepresented mathematics graduate students. Successful applicants will show strong research potential and be interested in continuing in a career at a research university.

The postdoctoral fellowships are for three years. A typical 3-year postdoctoral fellow will spend 2 years at one of the Alliance universities and up to a year at a national institute if there is a suitable program. Each postdoc will be matched with a research mentor at the host university. The Fellowship salary will be $60,000 per year plus benefits. In addition the fellows will receive a travel and research allowance. For more information see `http://www.math.ncsu.edu/alliance`.

Eligibility. Applicants must be U.S. citizens or permanent residents who have obtained a Ph.D. in mathematics within the last 5 years. Particular attention will be given to U.S. underrepresented minority (U.S. URM) candidates.

The Alliance universities are (listed alphabetically): Arizona State University, Howard University, Iowa State University, North Carolina State University, University of Arizona, University of Iowa and University of Nebraska. The Alliance NSF Mathematical Sciences Institutes are (listed alphabetically): American Institute of Mathematics (AIM), Institute for Computational and Experimental Research in Mathematics (ICERM), Institute for Mathematics and its Applications (IMA), Institute For Pure and Applied Mathematics (IPAM), Mathematical Biosciences Institute (MBI), Mathematical Sciences Research Institute (MSRI), National Institute for Mathematical and Biological Synthesis (NIMBioS), Park City Mathematics Institute (PCMI/IAS), and Statistical and Applied Mathematical Sciences Institute (SAMSI).

To submit your application materials, go to `http://www.mathjobs.org/jobs/alliance`. Include a vita, at least three letters of recommendation, and a description of current and planned research. Please also include a short statement to address how your plans fit with the priorities of this program. Applicants are encouraged to consult the Alliance website `http://www.math.ncsu.edu/alliance` and provide a list of potential mentors and preferred institutions.

Write to `alliance@math.ncsu.edu` for questions concerning this position. Applications received by December 15, 2012. will be given priority.

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Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See `http://www.ams.org/meetings/`. Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL and in an electronic issue of the *Notices* as noted below for each meeting.

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: 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

T. J. Christiansen, University of Missouri, *Resonances and Schrödinger operators*.

Tim Cochran, Rice University, *Title to be announced*.

Ronald Mark Solomon, Ohio State University, *Finite Groups and Beyond*.

Ben Weinkove, University of California, San Diego, *Parabolic flows in complex geometry*.

Special Sessions

A Survey of Lattice-Valued Mathematics and its Applications, **Austin Melton**, Kent State University, and **Stephen E. Rodabaugh**, Youngstown State University.

Additive and Combinatorial Number Theory, **Tsz Ho Chan**, University of Memphis, **Kevin O'Bryant**, City University of New York, and **Gang Yu**, Kent State University.

Applied Topology, **Peter Bubenik**, Cleveland State University, and **Matthew Kahle**, Ohio State University.

Cayley Graph Computations and Challenges for Permutation Puzzle Groups, **Morley Davidson**, Kent State University, and **Tomas Rokicki**, Radical Eye Software.

Commutative Algebra, **Livia Hummel**, University of Indianapolis, and **Sean Sather-Wagstaff**, North Dakota State University.

Complex Analysis and its Broader Impacts, **Mehmet Celik**, University of North Texas, Dallas, **Alexander Izzo**, Bowling Green State University, and **Sonmez Sahutoglu**, University of Toledo.

Complex Geometry and Partial Differential Equations, **Gabor Szekelyhidi**, University of Notre Dame, **Valentino Tosatti**, Columbia University, and **Ben Weinkove**, University of California San Diego.

Extremal Graph Theory, **Arthur Busch**, University of Dayton, and **Michael Ferrara**, University of Colorado Denver.

Geometry of Algebraic Varieties, **Ana-Marie Castravet**, **Emanuele Macrí**, and **Hsian-Hua Tseng**, The Ohio State University.

Graphs and Polytopes in Algebraic Combinatorics, **Stefan Forcey**, University of Akron, and **Forest Fisher**, NOVA-Manassas.

Groups, Representations, and Characters, **Mark Lewis**, Kent State University, **Adriana Nenciu**, Otterbein University, and **Ronald Solomon**, Ohio State University.

Harmonic Analysis and Convexity, **Benjamin Jaye**, **Dmitry Ryabogin**, and **Artem Zvavitch**, Kent State University.

Interactions Between Geometry and Topology, **Dan Farley**, Miami University, **Jean-Francois Lafont**, Ohio State University, and **Ivonne J. Ortiz**, Miami University.

Issues in the Preparation of Secondary Teachers of Mathematics, **Laurie A. Dunlap** and **Antonio R. Quesada**, University of Akron.

Knot Theory and 4-Manifolds, **Tim Cochran** and **Christopher Davis**, Rice University, and **Kent Orr**, Indiana University.

Noncommutative Ring Theory, **S. K. Jain**, Ohio University, and **Greg Marks** and **Ashish Srivastava**, St. Louis University.

Nonlinear Partial Differential Equations and Harmonic Analysis, **Diego Maldonado**, Kansas State University,

Truyen Nguyen, University of Akron, and **Nguyen Cong Phuc**, Louisiana State University.

Nonlinear Waves and Patterns, **Anna Ghazaryan** and **Vahagn Manukian**, Miami University.

Separate versus Joint Continuity—A Tribute to I. Namioka, **Zbigniew Piotrowski** and **Eric J. Wingler**, Youngstown State University.

Spectral, Scattering, and Inverse Scattering Theory, **Tanya Christiansen**, University of Missouri, and **Peter Hislop** and **Peter Perry**, University of Kentucky.

Statistical Genetics and Applications, **Omar De La Cruz**, Case Western Reserve University.

Stochastic Processes and Applications, **Oana Mocioalca**, Kent State University.

Toric Algebraic Geometry and Beyond, **Kiumars Kaveh**, University of Pittsburgh, **Benjamin Nill**, Case Western Reserve University, and **Ivan Soprunov**, Cleveland State University.

Tucson, Arizona

University of Arizona

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: 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

Michael Hutchings, University of California Berkeley, *Quantitative invariants in four-dimensional symplectic geometry*.

Kenneth McLaughlin, University of Arizona, Tucson, *Random matrices, integrable systems, asymptotic analysis, combinatorics*.

Ken Ono, Emory University, *Adding and counting* (Erdős Memorial Lecture).

Jacob Sterbenz, University of California San Diego, *Regularity of hypberbolic gauge field equations*.

Goufang Wei, University of California Santa Barbara, *Comparison results for Ricci curvature*.

Special Sessions

Analytical and Numerical Approaches in Nonlinear Systems: Collapses, Turbulence, Nonlinear Waves in Mathematics, Physics, and Biology, **Alexander Korotkevich** and **Pavel Lushnikov**, University of New Mexico.

Asymptotic Analysis of Random Matrices, Integrable Systems, and Applications, **Ken McLaughlin** and **Nick Ercolani**, University of Arizona.

Biomathematics, **Jim M. Cushing** and **Joseph Watkins**, University of Arizona.

Differential Equations and Biological Systems, **Patrick Shipman**, Colorado State University, and **Zoi Rapti**, University of Illinois at Urbana-Champaign.

Dispersion in Heterogeneous and/or Random Environments, **Rabi Bhattacharya**, University of Arizona, and **Edward Waymire**, Oregon State University, Corvallis.

Geometric Analysis and Riemannian Geometry, **David Glickenstein**, University of Arizona, **Guofang Wei**, University of California Santa Barbara, and **Andrea Young**, Ripon College.

Geometrical Methods in Mechanical and Dynamical Systems, **Akif Ibragimov**, Texas Tech University, **Vakhtang Putkaradze**, Colorado State University, and **Magdalena Toda**, Texas Tech University.

Harmonic Maass Forms and q-Series, **Ken Ono**, Emory University, **Amanda Folsom**, Yale University, and **Zachary Kent**, Emory University.

Hyperbolic Geometry, **Julien Paupert**, Arizona State University, and **Domingo Toledo**, University of Utah.

Inverse Problems and Wave Propagation, **Leonid Kunyansky**, University of Arizona.

Mathematical Fluid Dynamics and its Application in Geosciences, **Bin Cheng**, Arizona State University, and **Nathan Glatt-Holtz**, Indiana University.

Mathematical Physics: Spectral and Dynamical Properties of Quantum Systems, **Bruno Nachtergaele**, University of California Davis, **Robert Sims**, University of Arizona, and **Günter Stolz**, University of Alabama, Birmingham.

Mathematics of Optical Pulse Propagation: Modeling, Analysis, and Simulations, **Jason Fleischer**, Princeton University, and **Moysey Brio**, **Karl Glasner**, and **Shankar Venkataramani**, University of Arizona.

Motives, Algebraic Cycles, and K-theory, **Deepam Patel**, Indiana University, Bloomington, and **Ravindra Girivaru**, University of Missouri, St. Louis.

Representations of Groups and Algebras, **Klaus Lux** and **Pham Huu Tiep**, University of Arizona.

Special Functions, Combinatorics, and Analysis, **Diego Dominici**, SUNY New Paltz, **Tim Huber**, University of Texas-Pan American, and **Robert Maier**, University of Arizona.

Spectral Theory and Global Analysis, **Lennie Friedlander**, University of Arizona, and **Klaus Kirsten**, Baylor University.

The B.S. Degree in Mathematics in Industry, **William Velez**, University of Arizona.

The Ubiquitous Laplacian: Theory, Applications, and Computations, **Bin Dong** and **Lotfi Hermi**, University of Arizona.

Topics in Commutative Algebra, **Kristen Beck** and **Silvia Saccon**, The University of Arizona.

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: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Program Updates

Genevieve Madeleine Knight, Coppin College, will give NAM's Cox-Talbot Address on *The rest of the story*, after the banquet on Friday evening.

Rudy Lee Horne, Morehouse College, will give NAMS's Claytor-Woodward Lecture on *Stability and dynamics of solitary waves in AlGaAs waveguide arrays and BEC spinor lattices,* on Saturday afternoon.

Oxford, Mississippi

University of Mississippi

March 1–3, 2013

Friday – Sunday

Meeting #1087

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: December 2012
Program first available on AMS website: December 13, 2012
Program issue of electronic *Notices*: March 2013
Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: December 4, 2012

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Patricia Hersh, North Carolina State University, *Title to be announced.*

Daniel Krashen, University of Georgia, *Title to be announced.*

Washington Mio, Florida State University, *Taming shapes and understanding their variation.*

Slawomir Solecki, University of Illinois at Urbana-Champaign, *Title to be announced.*

Special Sessions

Algebraic Combinatorics (Code: SS 1A), **Patricia Hersh**, North Carolina State University, and **Dennis Stanton**, University of Minnesota.

Approximation Theory and Orthogonal Polynomials (Code: SS 5A), **David Benko**, University of South Alabama, **Erwin Mina-Diaz**, University of Mississippi, and **Edward Saff**, Vanderbilt University.

Banach Spaces and Operators on Them (Code: SS 4A), **Qingying Bu** and **Gerard Buskes**, University of Mississippi, and **William B. Johnson** and **Thomas Schlumprecht**, Texas A&M University.

Commutative Algebra (Code: SS 3A), **Sean Sather-Wagstaff**, North Dakota State University, and **Sandra M. Spiroff**, University of Mississippi.

Connections between Matroids, Graphs, and Geometry (Code: SS 10A), **Stan Dziobiak**, **Talmage James Reid**, and **Haidong Wu**, University of Mississippi.

Dynamical Systems (Code: SS 8A), **Alexander Grigo**, University of Oklahoma, and **Saša Kocić**, University of Mississippi.

Fractal Geometry and Ergodic Theory (Code: SS 2A), **Manav Das**, University of Louisville, and **Mrinal Kanti Roychowdhury**, University of Texas-Pan American.

Graph Theory (Code: SS 7A), **Laura Sheppardson** and **Bing Wei**, University of Mississippi, and **Hehui Wu**, McGill University.

Homology and Cohomology of Arithmetic Groups (Code: SS 11A), **Avner Ash**, Boston College, **Darrin Doud**, Brigham Young University, and **David Pollack**, Wesleyan University.

Modern Methods in Analytic Number Theory (Code: SS 6A), **Nathan Jones** and **Micah B. Milinovich**, University of Mississippi, and **Frank Thorne**, University of South Carolina.

Set Theory and Its Applications (Code: SS 9A), **Christian Rosendal**, University of Illinois at Chicago, and **Slawomir Solecki**, University of Illinois at Urbana-Champaign.

Chestnut Hill, Massachusetts

Boston College

April 6–7, 2013

Saturday – Sunday

Meeting #1088

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2013
Program first available on AMS website: February 21, 2013
Program issue of electronic *Notices*: April 2013
Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 18, 2012
For abstracts: February 12, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Roman Bezrukavnikov, Massachusetts Institute of Technology, *Title to be announced.*

Marston Conder, University of Auckland, *Title to be announced.*

Alice Guionnet, Ecole Normale Supérieure de Lyon, *Title to be announced.*

Yanir Rubinstein, Stanford University, *Title to be announced.*

Special Sessions

Algebraic and Geometric Structures of 3-manifolds (Code: SS 3A), **Ian Biringer**, Yale University, and **Tao Li** and **Robert Meyerhoff**, Boston College.

Arithmetic Dynamics and Galois Thoery (Code: SS 6A), **John Cullinan**, Bard College, and **Farshid Hajir** and **Siman Wong**, University of Massachusetts, Amherst.

Complex Geometry and Microlocal Analysis (Code: SS 2A), **Victor W. Guillemin** and **Richard B. Melrose**, Massachusetts Institute of Technology, and **Yanir A. Rubinstein**, Stanford University.

Counting and Equidistribution on Symmetric Spaces (Code: SS 5A), **Dubi Kelmer**, Boston College, and **Alex Kontorovich**, Yale University.

History and Philosophy of Mathematics (Code: SS 7A), **James J. Tattersall**, Providence College, and **V. Frederick Rickey**, United States Military Academy.

Homological Invariants in Low-dimensional Topology. (Code: SS 1A), **John Baldwin**, **Joshua Greene**, and **Eli Grigsby**, Boston College.

Hopf Algebras and their Applications (Code: SS 9A), **Timothy Kohl**, Boston University, and **Robert Underwood**, Auburn University Montgomery.

Moduli Spaces in Algebraic Geometry (Code: SS 4A), **Dawei Chen** and **Maksym Fedorchuk**, Boston College, and **Joe Harris** and **Yu-Jong Tzeng**, Harvard University.

Research by Undergraduates and Students in Post-Baccalaureate Programs (Code: SS 8A), **Chi-Keung Cheung**, Boston College, **David Damiano**, College of the Holy Cross, **Steven J. Miller**, Williams College, and **Suzanne L. Weekes**, Worcester Polytechnic Institute.

Boulder, Colorado

University of Colorado Boulder

April 13–14, 2013

Saturday – Sunday

Meeting #1089

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: January 2013
Program first available on AMS website: February 28, 2013
Program issue of electronic *Notices*: April 2013
Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 26, 2012
For abstracts: February 19, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Gunnar Carlsson, Stanford University, *Title to be announced.*

Jesus A. De Loera, University of California, Davis, *Title to be announced.*

Brendan Hassett, Rice University, *Title to be announced.*

Raphael Rouquier, University of California Los Angeles, *Title to be announced.*

Special Sessions

Algebras, Lattices and Varieties (Code: SS 5A), **Keith A. Kearnes** and **Ágnes Szendrei**, University of Colorado, Boulder.

Associative Rings and Their Modules (Code: SS 1A), **Greg Oman** and **Zak Mesyan**, University of Colorado, Colorado Springs.

Cluster Algebras and Related Combinatorics (Code: SS 6A), **Gregg Musiker**, University of Minnesota, **Kyungyong Lee**, Wayne State University, and **Li Li**, Oakland University.

Combinatorial and Computational Commutative Algebra and Algebraic Geometry (Code: SS 7A), **Hirotachi Abo**, University of Idaho, **Zach Teitler**, Boise State University, and **Alexander Woo**, University of Idaho.

Dynamical Systems: Thermodynamic Formalism and Connections with Geometry (Code: SS 10A), **Keith Burns**, Northwestern University, and **Dan Thompson**, The Ohio State University.

Dynamics and Arithmetic Geometry (Code: SS 2A), **Su-ion Ih**, University of Colorado at Boulder, and **Thomas J. Tucker**, University of Rochester.

Extremal Graph Theory (Code: SS 3A), **Michael Ferrara**, University of Colorado Denver, **Stephen Hartke**, University of Nebraska-Lincoln, and **Michael Jacobson**, University of Colorado Denver.

Harmonic Analysis of Frames, Wavelets, and Tilings (Code: SS 12A), **Veronika Furst**, Fort Lewis College, **Keri Kornelson**, University of Oklahoma, and **Eric Weber**, Iowa State University.

Nonlinear Waves and Integrable Systems (Code: SS 9A), **Christopher W. Curtis**, University of Colorado, Boulder, **Anton Dzhamay**, University of Northern Colorado, **Willy Hereman**, Colorado School of Mines, and **Barbara Prinari**, University of Colorado, Colorado Springs.

Number Theory with a Focus on Diophantine Equations and Recurrence Sequences (Code: SS 8A), **Patrick Ingram**, Colorado State University, and **Katherine E. Stange**, University of Colorado, Boulder.

Singular Spaces in Geometry, Topology, and Algebra (Code: SS 11A), **Greg Friedman**, Texas Christian University, and **Laurentiu Maxim**, University of Wisconsin, Madison.

Themes in Applied Mathematics: From Data Analysis through Fluid Flows and Biology to Topology (Code: SS 4A), **Hanna Makaruk**, Los Alamos National Laboratory, and **Robert Owczarek**, University of New Mexico, and Enfitek, Inc.

Ames, Iowa

Iowa State University

April 27–28, 2013

Saturday – Sunday

Meeting #1090

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: February 2013
Program first available on AMS website: March 14, 2013
Program issue of electronic *Notices*: April 2013
Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: January 18, 2013
For abstracts: March 5, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Kevin Costello, Northwestern University, *Title to be announced*.

Marianne Csornyei, University of Chicago, *Title to be announced*.

Vladimir Markovic, California Institute of Technology, *Title to be announced*.

Eitan Tadmor, University of Maryland, *Title to be announced*.

Special Sessions

Algebraic and Geometric Combinatorics (Code: SS 4A), **Sung Y. Song**, Iowa State University, and **Paul Terwilliger**, University of Wisconsin-Madison.

Commutative Algebra and its Environs (Code: SS 6A), **Olgur Celikbas** and **Greg Piepmeyer**, University of Missouri, Columbia.

Commutative Ring Theory (Code: SS 8A), **Michael Axtell**, University of St. Thomas, and **Joe Stickles**, Millikin University.

Computability and Complexity in Discrete and Continuous Worlds (Code: SS 11A), **Jack Lutz** and **Tim McNicholl**, Iowa State University.

Extremal Combinatorics (Code: SS 7A), **Steve Butler** and **Ryan Martin**, Iowa State University.

Generalizations of Nonnegative Matrices and Their Sign Patterns (Code: SS 3A), **Minerva Catral**, Xavier University, **Shaun Fallat**, University of Regina, and **Pauline van den Driessche**, University of Victoria.

Logic and Algebraic Logic (Code: SS 9A), **Jeremy Alm**, Illinois College, and **Andrew Ylvisaker**, Iowa State University.

Operator Algebras and Topological Dynamics (Code: SS 1A), **Benton L. Duncan**, North Dakota State University, and **Justin R. Peters**, Iowa State University.

Stochastic Processes with Applications to Physics and Control (Code: SS 10A), **Jim Evans** and **Arka Ghosh**, Iowa State University, **Jon Peterson**, Purdue University, and **Alexander Roitershtein**, Iowa State University.

Zero Forcing, Maximum Nullity/Minimum Rank, and Colin de Verdiere Graph Parameters (Code: SS 2A), **Leslie Hogben**, Iowa State University and American Institute of Mathematics, and **Bryan Shader**, University of Wyoming.

Alba Iulia, Romania

June 27–30, 2013

Thursday – Sunday

Meeting #1091

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*: January 2013
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

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/internmtgs.html`.

Invited Addresses

Viorel Barbu, Universitatea Cuza, *Title to be announced.*

Sergiu Klainerman, Princeton University, *Title to be announced.*

George Lusztig, Massachusetts Institute of Technology, *Title to be announced.*

Stefan Papadima, Institute of Mathematicsof the Romanian Academy of Sciences, *Title to be announced.*

Dan Timotin, Institute of Mathematics of the Romanian Academy of Sciences, *Title to be announced.*

Srinivasa Varadhan, New York University, *Title to be announced.*

Louisville, Kentucky

University of Louisville

October 5–6, 2013

Saturday – Sunday

Meeting #1092

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: June 2013
Program first available on AMS website: August 22, 2013
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 33, Issue 3

Deadlines

For organizers: March 5, 2013
For consideration of contributed papers in Special Sessions: June 18, 2013
For abstracts: August 13, 2013

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Michael Hill, University of Virginia, *Title to be announced.*

Suzanne Lenhart, University of Tennessee, *Title to be announced.*

Ralph McKenzie, Vanderbilt University, *Title to be announced.*

Victor Moll, Tulane University, *Title to be announced.*

Special Sessions

Set Theory and Its Applications (Code: SS 1A), **Paul Larson**, Miami University, **Justin Moore**, Cornell University, and **Grigor Sargsyan**, Rutgers University.

Philadelphia, Pennsylvania

Temple University

October 12–13, 2013

Saturday – Sunday

Meeting #1093

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: June 2013
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 33, Issue 3

Deadlines

For organizers: March 12, 2013
For consideration of contributed papers in Special Sessions: June 25, 2013
For abstracts: August 20, 2013

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Patrick Brosnan, University of Maryland, *Title to be announced.*

Xiaojung Huang, Rutgers University, *Title to be announced.*

Barry Mazur, Harvard University, *Title to be announced* (Erdős Memorial Lecture).

Robert Strain, University of Pennsylvania, *Title to be announced.*

Special Sessions

Contact and Symplectic Topology (Code: SS 5A), **Joshua M. Sabloff**, Haverford College, and **Lisa Traynor**, Bryn Mawr College.

Geometric and Spectral Analysis (Code: SS 3A), **Thomas Krainer**, Pennsylvania State Altoona, and **Gerardo A. Mendoza**, Temple University.

Higher Structures in Algebra, Geometry and Physics (Code: SS 2A), **Jonathan Block**, University of Pennsylvania, **Vasily Dolgushev**, Temple University, and **Tony Pantev**, University of Pennsylvania.

History of Mathematics in America (Code: SS 4A), **Thomas L. Bartlow**, Villanova University, **Paul R. Wolfson**, West Chester University, and **David E. Zitarelli**, Temple University.

Recent Advances in Harmonic Analysis and Partial Differential Equations (Code: SS 1A), **Cristian Gutiérrez** and **Irina Mitrea**, Temple University.

St. Louis, Missouri

Washington University

October 18–20, 2013

Friday – Sunday

Meeting #1094

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: August 2013
Program first available on AMS website: September 5, 2013
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 33, Issue 4

Deadlines

For organizers: March 20, 2013
For consideration of contributed papers in Special Sessions: July 2, 2013
For abstracts: August 27, 2013
The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Ronny Hadani, University of Texas at Austin, *Title to be announced*.

Effie Kalfagianni, Michigan State University, *Title to be announced*.

Jon Kleinberg, Cornell University, *Title to be announced*.

Vladimir Sverak, University of Minnesota, *Title to be announced*.

Special Sessions

Algebraic and Combinatorial Invariants of Knots (Code: SS 1A), **Heather Dye**, McKendree University, **Allison Henrich**, Seattle University, and **Louis Kauffman**, University of Illinois.

Computability Across Mathematics (Code: SS 2A), **Wesley Calvert**, Southern Illinois University, and **Johanna Franklin**, University of Connecticut.

Riverside, California

University of California Riverside

November 2–3, 2013

Saturday – Sunday

Meeting #1095

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2013
Program first available on AMS website: September 19, 2013
Program issue of electronic *Notices*: November 2013
Issue of *Abstracts*: Volume 33, Issue 4

Deadlines

For organizers: April 2, 2013
For consideration of contributed papers in Special Sessions: July 15, 2013
For abstracts: September 10, 2013

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Michael Christ, University of California, Berkeley, *Title to be announced*.

Mark Gross, University of California, San Diego, *Title to be announced*.

Matilde Marcolli, California Institute of Technology, *Title to be announced*.

Paul Vojta, California Institute of Technology, *Title to be announced*.

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel at Camden Y

January 15–18, 2014

Wednesday – Saturday

Meeting #1096

Joint Mathematics Meetings, including the 120th Annual Meeting of the AMS, 97th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2013
Program first available on AMS website: November 1, 2013
Program issue of electronic *Notices*: January 2013
Issue of *Abstracts*: Volume 35, Issue 1

Deadlines

For organizers: April 1, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Knoxville, Tennessee

University of Tennessee, Knoxville

March 21–23, 2014

Friday – Sunday
Southeastern Section
Associate secretary: Robert J. Daverman
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 21, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Albuquerque, New Mexico

University of New Mexico

April 5–6, 2014

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*: April 2014
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 5, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: February 11, 2014

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Special Sessions

The Inverse Problem and Other Mathematical Methods Applied in Physics and Related Sciences (Code: SS 1A), **Hanna Makaruk**, Los Alamos National Laboratory (LANL), Los Alamos, NM, and **Robert Owczarek**, University of New Mexico, and Enfitek Inc.

Lubbock, Texas

Texas Tech University

April 11–13, 2014

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: September 18, 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

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/internmtgs.html.

Special Sessions

Mirror Symmetry and Representation Theory, **David Kazhdan**, Hebrew University, and **Roman Bezrukavnikov**, Massachusetts Institute of Technology.

Nonlinear Analysis and Optimization, **Boris Mordukhovich**, Wayne State University, and **Simeon Reich** and **Alexander Zaslavski**, The Technion-Israel Institute of Technology.

Qualitative and Analytic Theory of ODE's, **Yosef Yomdin**, Weizmann Institute.

Eau Claire, Wisconsin

University of Wisconsin-Eau Claire

September 20–21, 2014

Saturday – Sunday
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: February 20, 2014
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: August 5, 2014

San Francisco, California

San Francisco State University

October 25–26, 2014

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2014
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 25, 2014
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: September 3, 2014

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 (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: October 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2015
Issue of *Abstracts*: Volume 36, Issue 1

Deadlines

For organizers: April 1, 2014
For 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
First Joint International Meeting between the AMA and the Sociedade Portuguesa de Matemática.
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 (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 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 (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: 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

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel at Camden Y

January 16–19, 2019

Wednesday – Saturday

Joint Mathematics Meetings, including the 125th Annual Meeting of the AMS, 102nd 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 2018
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 2, 2018
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

2013 Joint Mathematics Meetings Advance Registration/Housing Form

JOINT MATHEMATICS MEETINGS
SAN DIEGO • JAN 9-12, 2013
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

Name ______________________
(please write name as you would like it to appear on your badge)

Mailing Address ______________________

____

Telephone ______________________ Fax: ______________________

In case of emergency (for you) at the meeting, call: Day # ______________ Evening #: ______________

Email Address ______________________

Acknowledgment of this registration and any hotel reservations will be sent to the email address given here, unless you check this box: *Send by U.S. Mail* ☐

Affiliation for badge ______________________ (company/university) Nonmathematician guest badge name: ______________ (Note fee of US$15)

☐ **I DO NOT want my program and badge to be mailed to me on 12/07/12. (Materials will be mailed to the address listed above unless you check this box.)**

Registration Fees

Membership please ✓ that apply. First row is eligible to register as a JMM member.

☐ AMS ☐ MAA ☐ ASL ☐ CMS ☐ SIAM
☐ ASA ☐ AWM ☐ NAM ☐ YMN

Joint Meetings	**by Dec 17**	**at mtg**	**Subtotal**
☐ Member AMS, MAA, ASL, CMS, SIAM	US$ 235	US$ 309	
☐ Nonmember	US$ 367	US$ 476	
☐ Graduate Student (Mem. of AMS or MAA)	US$ 52	US$ 62	
☐ Graduate Student (Nonmember)	US$ 80	US$ 91	
☐ Undergraduate Student	US$ 52	US$ 62	
☐ High School Student	US$ 5	US$ 10	
☐ Unemployed	US$ 52	US$ 62	
☐ Temporarily Employed	US$ 191	US$ 220	
☐ Developing Countries Special Rate	US$ 52	US$ 62	
☐ Emeritus Member of AMS or MAA	US$ 52	US$ 62	
☐ High School Teacher	US$ 52	US$ 62	
☐ Librarian	US$ 52	US$ 62	
☐ Press	US$ 0	US$ 0	
☐ Nonmathematician Guest	US$ 15	US$ 15	
			$________

AMS Short Course: *Random Matrices (1/7–1/8)*

☐ Member of AMS or MAA	US$ 104	US$ 138	
☐ Nonmember	US$ 150	US$ 180	
☐ Student, Unemployed, Emeritus	US$ 52	US$ 73	
			$________

MAA Short Course: *Conceptual Climate Models (1/7–1/8)*

☐ Member of MAA or AMS	US$ 156	US$ 166	
☐ Nonmember	US$ 225	US$ 235	
☐ Student, Unemployed, Emeritus	US$ 78	US$ 88	
			$________

MAA Minicourses (see listing in text)

I would like to attend: ☐ One Minicourse ☐ Two Minicourses
Please enroll me in MAA Minicourse(s) #______ and/or #______
In order of preference, my alternatives are: #______ and/or #______
Price: US$80 for each minicourse.
(For more than 2 minicourses call or email the MMSB.) $________

Graduate School Fair

☐ Graduate Program Table US$ 70 US$ 70
(includes table, posterboard & electricity)
$________

Employment Center *Please go to http://ams.org/profession/employment-services/employment-center/employment-center to register.*
For further information, contact Steve Ferrucci at emp-info@ams.org.

Events with Tickets

☐ Graduate Student/First Time Attendee Reception (1/9) (no charge)
☐ MER/IME Banquet (1/10) US$ 65 #___Chicken #___Fish
#___Kosher #___Vegan
☐ NAM Banquet (1/11) US$ 62 #___Chicken #___Fish
#___Kosher #___Vegan
☐ AMS 125th Anniversary Gala (1/12) US$ 62 #____

(Additional fees may apply for Kosher meals.) $________

Total for Registrations and Events $________

Registration for the Joint Meetings is not required for the short courses but it is required for the minicourses and the Employment Center.

Payment

Registration & Event Total (total from column on left) $ ____________
Hotel Deposit (only if paying by check) $ ____________

Total Amount To Be Paid **$** ____________
(Note: A US$5 processing fee will be charged for each returned check or invalid credit card. Debit cards cannot be accepted.)

Method of Payment

☐ **Check**. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates. For all check payments, please keep a copy of this form for your records.

☐ **Credit Card**. All major credit cards accepted. For your security, we do not accept credit card numbers by postal mail, email or fax. If the MMSB receives your registration form by fax or postal mail, we will contact you at the phone number provided on this form. For questions, contact the MMSB at mmsb@ams.org.

Signature: ______________________

☐ **Purchase Order #** ______________ (please enclose copy)

Other Information

Mathematical Reviews field of interest # ______________
How did you hear about this meeting? Check one:
☐ Colleague(s) ☐ Internet ☐ *Notices* ☐ *Focus* ☐ Other ________
☐ This is my first Joint Mathematics Meetings.
☐ I am a mathematics department chair.
☐ For planning purposes for the MAA Two-year College Reception, please check if you are a faculty member at a two-year college.
☐ I would like to receive promotions for future JMM meetings.
☐ Please do not include my name on any promotional mailing lists.
☐ Please do not include my name on any list of participants distributed or displayed at the meeting.
☐ Please ✓ this box if you have a disability requiring special services.

Mailing Address/Contact:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887 **Fax**: 401-455-4004; **Email:** mmsb@ams.org
Telephone: 401-455-4143 or 1-800-321-4267 x4143 or x4144

Deadlines

To be eligible for the complimentary room drawing:	**Nov. 5, 2012**
For housing reservations, badges/programs mailed:	**Nov. 19, 2012**
For housing changes/cancellations through MMSB:	**Dec. 10, 2012**
For advance registration for the Joint Meetings, short courses, minicourses, and tickets:	**Dec. 17, 2012**
For 50% refund on banquets, cancel by:	**Dec. 27, 2012***
For 50% refund on advance registration, minicourses & short courses, cancel by:	**Jan. 04, 2013***

***no refunds issued after this date**

2013 Joint Mathematics Meetings Hotel Reservations – San Diego, CA

(Please see the hotel page in the announcement or on the web for detailed information on each hotel.) To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc. in the column on the left and by circling the requested room type and rate. If the rate or the hotel requested is no longer available, you will be assigned a room at the next available comparable rate. Please call the MMSB for details on suite configurations, sizes, availability, etc. All reservations, including suite reservations, must be made through the MMSB to receive the JMM rates. Reservations made directly with the hotels before **December 19** may be changed to a higher rate. All rates are subject to a 12.5% sales/occupancy tax. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

☐ **Deposit enclosed (see front of form)** ☐ **Hold with my credit card**. **For your security, we do not accept credit card numbers by postal mail, email or fax.** If the MMSB receives your registration form by postal mail or fax, we will contact you at the phone number provided on the reverse of this form.

Date and Time of Arrival ______________ **Date and Time of Departure** ______________

Name of Other Room Occupant ______________ **Arrival Date** __________ **Departure Date** __________ **Child (give age(s)** ______

Order of choice	Hotel	Single	Double 1 bed	Double 2 beds	Triple 2 beds	Triple 2 beds w/cot	Triple - king or queen w/cot	Quad 2 beds	Quad 2 beds w/cot	Suites Starting rates
	San Diego Marriott Hotel & Marina (hdqtrs)									
	City View	US$ 184	US$ 184	US$ 184	US$ 204	US$204*	US$ 204*	US$ 224	US$ 224*	US$ 750
	Bay View	US$ 199	US$ 199	US$ 199	US$ 219	US$219*	US$ 219*	US$ 239	US$ 239*	N/A
	Student Rate (City View)	US$ 147	US$ 147	US$ 147	US$ 167	US$167*	US$ 167*	US$ 187	US$ 187*	N/A
	Omni San Diego	US$ 171	US$ 194	US$ 194	US$ 214	N/A	N/A	US$ 234	N/A	US$ 350
	Student Rate	US$ 154	US$ 174	US$ 174	US$ 194	N/A	N/A	US$ 214	N/A	N/A
	Embassy Suites San Diego Bay	US$ 155	US$ 155	US$ 155	US$ 175	N/A	N/A	US$ 195	N/A	(all suites)
	Student Rate	US$ 135	US$ 135	US$ 135	US $145	N/A	N/A	US$ 155	N/A	(all suites)
	Horton Grand Hotel	US$ 155	US$ 155	US$ 155	N/A	N/A	N/A	N/A	N/A	US$ 259
	Student Rate	US$ 145	US$ 145	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Residence Inn by Marriott Gaslamp District	US$ 152	US$ 152	US$ 152	N/A	N/A	N/A	N/A	N/A	(all suites)
	Student Rate	US$ 145	US$ 145	US$ 145	N/A	N/A	N/A	N/A	N/A	N/A
	Hard Rock Hotel San Diego	US$ 149	US$ 149	US$ 149	US$169	N/A	N/A	US$189	N/A	US$ 199
	Student Rate	US$ 129	US$ 129	US$ 129	US$149	N/A	N/A	US$ 169	N/A	N/A
	Best Western Plus Bayside Inn	US$ 129	US$ 129	US$ 129	US$ 139	US$ 149	US$ 149	US$ 139	US$ 149	N/A
	Student Rate	US$ 119	US$ 119	US$ 119	US$ 129	US$ 139	US$ 139	US$ 129	US$ 139	N/A
	Residence Inn by Marriott Downtown (1-bedroom studio suites. Bedroom has 1 queen bed. Living room has a single sofa sleeper)	US$ 129	US$ 129	US$ 129 **	N/A	N/A	US$144 **	N/A	N/A	(all suites)
	Student Rate (1 bed. studio suite)	US$ 119	US$ 119	US$ 119 **	N/A	N/A	US$134 **	N/A	N/A	(all suites)
	Residence Inn by Marriott Downtown (2-bedroom suites. Each bedroom has 1 queen bed. Living room has a single sofa sleeper.) Limited quantity.	N/A	N/A	US $239	US$ 254	US$ 254 **	N/A	US$ 269	US$ 269 **	(all suites)
	Four Points by Sheraton Downtown	US$ 125	US$ 125	US$ 125	US$ 135	N/A	US$ 145	US$ 145	N/A	N/A
	Student Rate	US$ 115	US$ 115	US$ 115	US$ 125	N/A	US$ 135	US$ 135	N/A	N/A
	Holiday Inn on the Bay	US$ 124	US$ 124	US$ 124	US$ 139	N/A	US$ 149	US$ 154	N/A	US$ 274
	Student Rate	US$ 114	US$ 114	US$ 114	US$ 129	N/A	US$ 139	US$ 144	N/A	N/A
	Hampton Inn San Diego Downtown	US$ 109	US$ 109	US$ 109	US$ 119	N/A	N/A	US $139	N/A	N/A
	Student Rate	US$ 99	US$ 99	US$ 99	US$ 119	N/A	N/A	US $129	N/A	N/A

* The San Diego Marriott has a one-time fee of US$ 20 for a rollaway cot. Rooms with 2 beds are limited. A king with a sleeper sofa may be substituted for the second bed.

** The sleeper sofa is the additional bed. Rollaway cots are not available.

Special Housing Requests:.

☐ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are: ______________

☐ Other requests: ______________

☐ I am a member of a hotel frequent-travel club and would like to receive appropriate credit.

The hotel chain and card number are: ______________

Only email confirmations will be sent by the hotels, if an email address is provided.

If you are not making a reservation, please check one of the following:

☐ I plan to make a reservation at a later date.

☐ I will be making my own reservations at a hotel not listed. Name of hotel: ______________

☐ I live in the area or will be staying privately with family or friends.

☐ I plan to share a room with ______________, who is making the reservations.

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.

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Southeastern Section: Robert J. Daverman, Department of Mathematics, University of Tennessee, Knoxville, TN 37996-6900, e-mail: `daverman@math.utk.edu`; telephone: 865-974-6900.

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 111 in the the January 2012 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset in LaTeX. Visit `http://www.ams.org/cgi-bin/abstracts/abstract.pl`. Questions about abstracts may be sent to `abs-info@ams.org`. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences in Cooperation with the AMS: (see `http://www.ams.org/meetings/` for the most up-to-date information on these conferences.)

July 22–26, 2013: Samuel Eilenberg Centenary Conference (E100), Warsaw, Poland.


Photo by David Eisenbud


Photo by E. David Luria

AMERICAN MATHEMATICAL SOCIETY

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PUBLISHER'S DISCOUNT sale

Algebra and Algebraic Geometry

The Algebraic and Geometric Theory of Quadratic Forms

Richard Elman, Nikita Karpenko, and **Alexander Merkurjev**

Colloquium Publications, Volume 56; 2008; 435 pp.; hardcover; ISBN: 978-0-8218-4329-1; List US$81; SALE US$20.25; Order code: COLL/56

Growth of Algebras and Gelfand-Kirillov Dimension

Revised Edition

Günter R. Krause and **Thomas H. Lenagan**

Graduate Studies in Mathematics, Volume 22; 2000; 212 pp.; hardcover; ISBN: 978-0-8218-0859-7; List US$45; SALE US$22.50; Order code: GSM/22

Noncommutative Noetherian Rings

J. C. McConnell and **J. C. Robson**

Graduate Studies in Mathematics, Volume 30; 1987; 636 pp.; hardcover; ISBN: 978-0-8218-2169-5; List US$84; SALE US$21.00; Order code: GSM/30

Graduate Algebra: Noncommutative View

Louis Halle Rowen

Graduate Studies in Mathematics, Volume 91; 2008; 648 pp.; hardcover; ISBN: 978-0-8218-4153-2; List US$88; SALE US$22.00; Order code: GSM/91

Extension Theory

Hermann Grassmann

Co-published with the London Mathematical Society beginning with Volume 4.

History of Mathematics, Volume 19; 2000; 411 pp.; softcover; ISBN: 978-0-8218-2031-5; List US$87; SALE US$21.75; Order code: HMATH/19

Lectures on Tensor Categories and Modular Functors

Bojko Bakalov and **Alexander Kirillov, Jr.**

University Lecture Series, Volume 21; 2001; 221 pp.; softcover; ISBN: 978-0-8218-2686-7; List US$34; SALE US$17.00; Order code: ULECT/21

Analysis

D-modules and Microlocal Calculus

Masaki Kashiwara

Translations of Mathematical Monographs (*Iwanami Series in Modern Mathematics*), Volume 217; 2003; 254 pp.; softcover; ISBN: 978-0-8218-2766-6; List US$62; SALE US$21.70; Order code: MMONO/217

Applications

Mathematical Biology

Mark A. Lewis, Mark A. J. Chaplain, James P. Keener, and **Philip K. Maini**, Editors

Titles in this series are co-published with the Institute for Advanced Study/Park City Mathematics Institute.

IAS/Park City Mathematics Series, Volume 14; 2009; 398 pp.; hardcover; ISBN: 978-0-8218-4765-7; List US$79; SALE US$19.75; Order code: PCMS/14

The Radon Transform, Inverse Problems, and Tomography

Gestur Ólafsson and **Eric Todd Quinto**, Editors

Proceedings of Symposia in Applied Mathematics, Volume 63; 2006; 158 pp.; hardcover; ISBN: 978-0-8218-3930-0; List US$40; SALE US$20.00; Order code: PSAPM/63

Differential Equations

Lectures on Analytic Differential Equations

Yulij Ilyashenko and **Sergei Yakovenko**

Graduate Studies in Mathematics, Volume 86; 2008; 625 pp.; hardcover; ISBN: 978-0-8218-3667-5; List US$81; SALE US$20.25; Order code: GSM/86

General Interest

The Coxeter Legacy

Reflections and Projections

Chandler Davis and **Erich W. Ellers**, Editors

A co-publication of the AMS and The Fields Institute for Research in Mathematical Sciences (Toronto, Ontario, Canada).

2006; 320 pp.; hardcover; ISBN: 978-0-8218-3722-1; List US$71; SALE US$24.85; Order code: COXETER

Mathematics 2: Japanese Grade 11

Kunihiko Kodaira, Editor

Mathematical World, Volume 9; 1997; 262 pp.; softcover; ISBN: 978-0-8218-0582-4; List US$36; SALE US$18.00; Order code: MAWRLD/9

Geometry and Topology

Low Dimensional Topology

Tomasz S. Mrowka and **Peter S. Ozsváth**, Editors

Titles in this series are co-published with the Institute for Advanced Study/Park City Mathematics Institute.

IAS/Park City Mathematics Series, Volume 15; 2009; 315 pp.; hardcover; ISBN: 978-0-8218-4766-4; List US$69; SALE US$24.15; Order code: PCMS/15

Logic and Foundations

Computable Functions

A. Shen and **N. K. Vereshchagin**

Student Mathematical Library, Volume 19; 2003; 166 pp.; softcover; ISBN: 978-0-8218-2732-1; List US$34; SALE US$17.00; Order code: STML/19

Descriptive Set Theory

Second Edition

Yiannis N. Moschovakis

Mathematical Surveys and Monographs, Volume 155; 2009; 502 pp.; hardcover; ISBN: 978-0-8218-4813-5; List US$115; SALE US$28.75; Order code: SURV/155

Mathematical Physics

Frobenius Manifolds, Quantum Cohomology, and Moduli Spaces

Yuri I. Manin

Colloquium Publications, Volume 47; 1999; 303 pp.; hardcover; ISBN: 978-0-8218-1917-3; List US$64; SALE US$22.40; Order code: COLL/47

Supersymmetry for Mathematicians: An Introduction

V. S. Varadarajan

Titles in this series are co-published with the Courant Institute of Mathematical Sciences at New York University.

Courant Lecture Notes, Volume 11; 2004; 300 pp.; softcover; ISBN: 978-0-8218-3574-6; List US$43; SALE US$21.50; Order code: CLN/11

Probability and Statistics

Lectures on Monte Carlo Methods

Neal Madras

Titles in this series are co-published with The Fields Institute for Research in Mathematical Sciences (Toronto, Ontario, Canada).

Fields Institute Monographs, Volume 16; 2002; 103 pp.; hardcover; ISBN: 978-0-8218-2978-3; List US$36; SALE US$18.00; Order code: FIM/16

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