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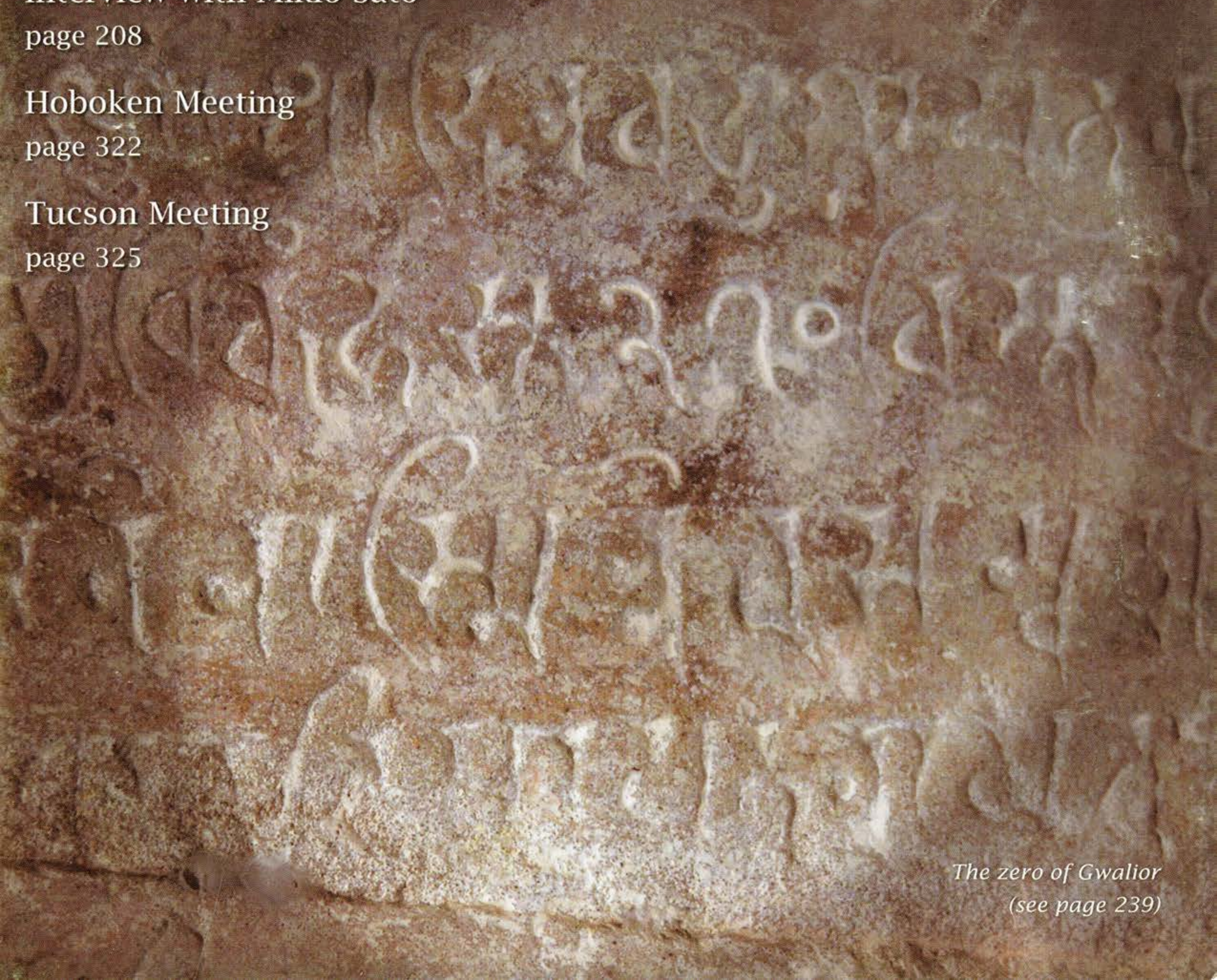

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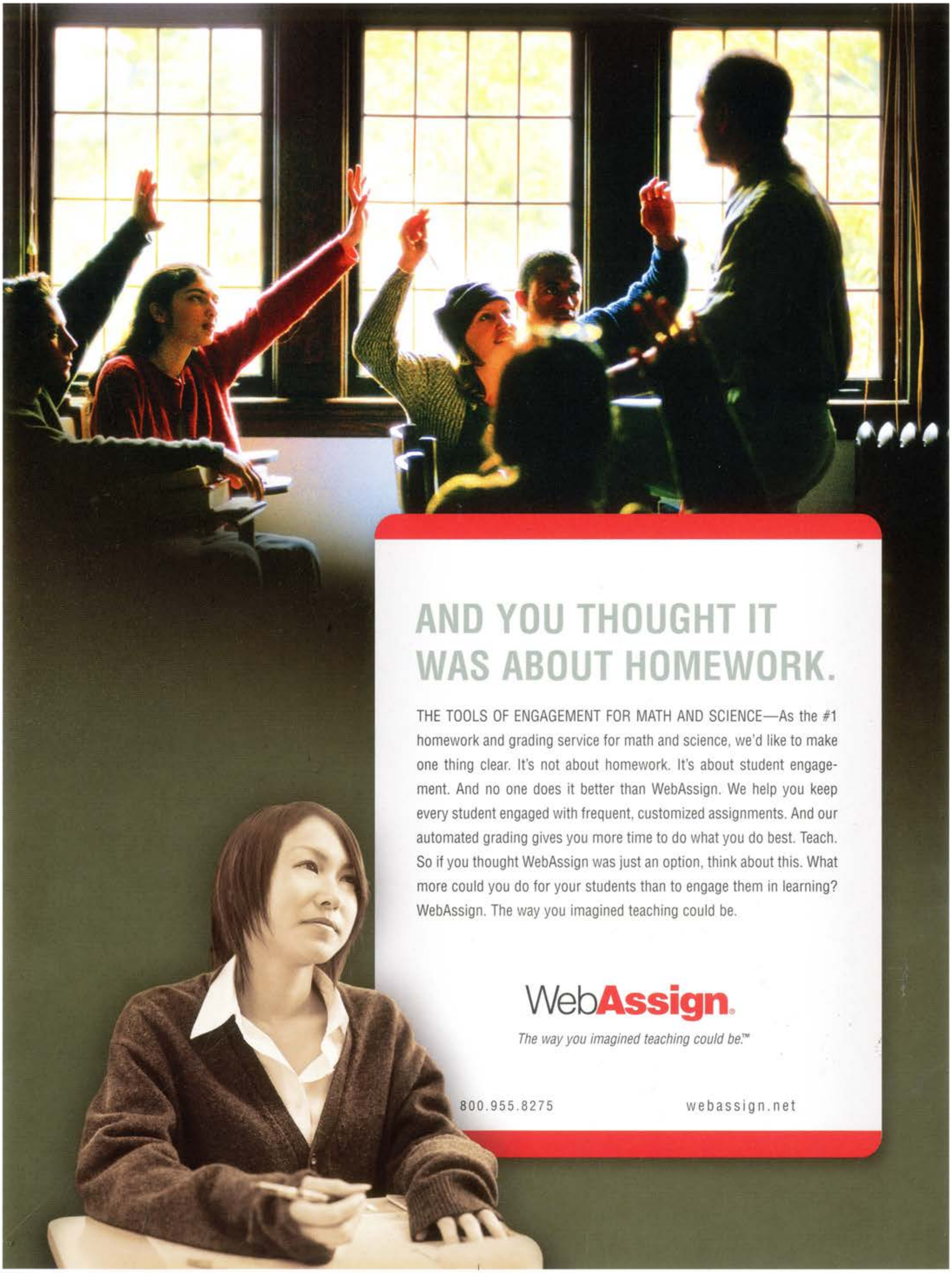
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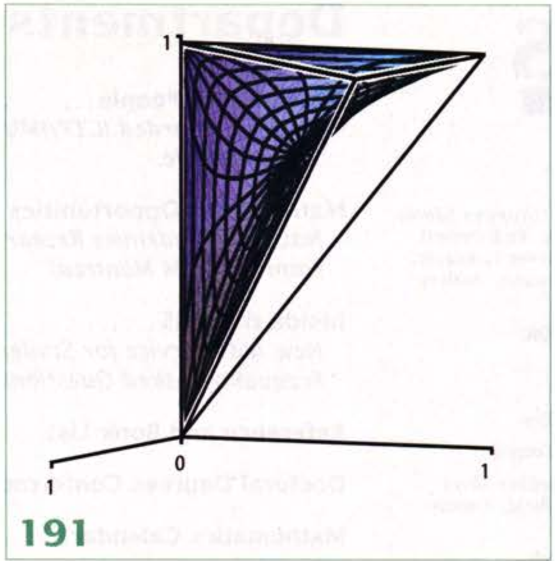
February 2007

Communications

Commentary



Features

The Four Vertex Theorem of global differential geometry says that the curvature of a simple closed plane curve, if not constant, has at least four local extrema. The converse asserts that any continuous real-valued function on the circle with at least two local maxima and two local minima is the curvature function of a simple closed curve. The authors explain the proof of both.

The late Emmanuel Andronikof talked to the distinguished mathematician about his work and life.

Notices
of the American Mathematical Society

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Departments

From the AMS Secretary

The Role of Uncle Sam—and You—in Fundamental Research

One of the most difficult problems today in Washington is addressing the challenge of a knowledge-based economy coupled with increasing competition from other nations. Federal agencies, the National Academies, and think tanks are all skilled at identifying problems and recommending policy solutions. Most everyone agrees that to remain internationally competitive we have to strengthen our science and technology talent, improve math and science education, and foster a business environment friendly to innovation. However, the stakeholders responsible for those solutions are not always delineated. At times this contributes to diffused responsibility with everyone thinking someone else will fix the problem.

Despite this confusion, it remains clear that the federal government is one of the most influential stakeholders, and one that has an important role to play in addressing these challenges. Put simply, the responsibility of the federal government is to stimulate innovative research that directly links to a healthy economy. Federal policy should lay the groundwork for fertile discovery and innovation, without setting too many parameters that might squelch the freedom necessary to produce such results.

Federal investment in science and technology has yielded life-changing payoffs. New analysis from the Bureau of Economic Analysis shows research and development accounted for a substantial share of the resurgence in U.S. economic growth in recent years. Yet even in the face of these encouraging statistics, the general public, and, indeed, many members of Congress, still fail to consider funding for fundamental research a top priority. For proof of this, we need look no further than the budget for mathematics and physical science research at the National Science Foundation (NSF), which has generally grown at a rate less than inflation and has even endured real cuts in recent years.

The question is, then, how can we increase federal funding for research? Before we can increase federal funding for research, we must first convince others of the necessity of doing so. Fortunately, there are signs that this is already beginning to happen. In Congress the discussion on this topic has gone from virtually nonexistent to a modest din. In fact, President Bush spoke eloquently in his 2006 State of the Union address on the connection between science and technology and U.S. economic competitiveness. More importantly, his words were backed up with significant funding increases requested for the National Science Foundation, the Office of Science at the Department of Energy, and the laboratories of the National Institute of Science and Technology.

But many of my colleagues in Congress are still not among the converted. Every member of Congress is in favor of science and technology in the abstract, but when it comes to distributing federal dollars, science is often crowded out by other concerns. In light of these challenges, I have found it to be an extremely tough job being a "missionary" for science and math.

What of the other stakeholders? What roles do they play? The federal government is not alone in its responsibility for research and development funding. While higher education has always been a federal priority, it is primarily the responsibility of the states to maintain educational institutions that become the breeding ground for seminal research. Universities are able to identify promising faculty members with both research and teaching strengths. But for new faculty, finding initial funding can be tough, especially when federal agency budgets are tight. Recent legislative proposals have attempted to address this through establishing grants targeted at early investigators.

The private sector also plays an important role in maintaining the science and technology enterprise. All stakeholders share the challenge of leaping over the so-called "valley of death" that often plagues institution-level research discoveries that do not have a pathway into the marketplace. The process of translating foundational research into fully realized technologies has improved, but tech transfer programs at universities need the support of the private sector to fully realize academic entrepreneurship.

State and local entities share the responsibility of educating our youngest children. In order to compete globally, we need a constant stream of innovative ideas originating from U.S. scientists. This starts in our K–12 institutions, where children are introduced to math and science. To do this, we must improve our curricula, equip our teachers with the knowledge of quality content and pedagogy, and support educational research to expand our knowledge of how children best learn math and science.

The final group of stakeholders includes science, technology, engineering and math (STEM) professionals, those who are perhaps in the best position to act as advocates for STEM in communities. There are many ways to be involved in this process, from raising awareness among students, parents, and teachers at all levels, to personally encouraging members of Congress to make research funding a priority. I hope you will consider speaking with your local, state, and federal governmental leaders about the importance of research funding and STEM education.

It is only when all stakeholders are doing their part that we will be able to move past waiting for someone else to fix the problem and toward working together to create solutions.

—Congressman Vernon J. Ehlers (MI-03)
Congressman Ehlers taught physics at Calvin College for sixteen years. He represents the third district of Michigan.

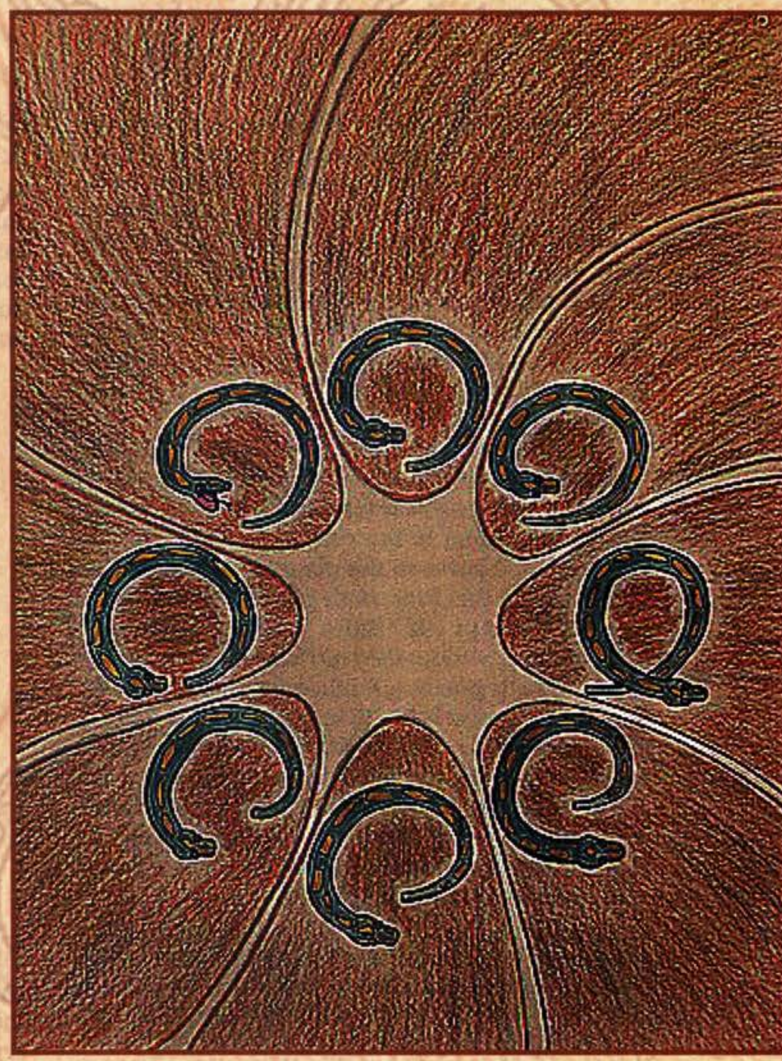
“A snake searches unsuccessfully for his tail”

This drawing represents one of the core arguments in proving the converse to the Four Vertex Theorem (see the article on the following pages).

The drawing shows eight pictures of a snake, who is searching unsuccessfully for his tail. The figures are arranged so that the head of the eastern snake is to the east of his tail, the head of the northeastern snake is to the northeast of his tail, and so on.

The snake is following a hidden loop of instructions, from which the eight pictures are but a sample. An invisible “error vector”, which extends from the snake’s tail to his head, turns once around the origin as you go once around the loop.

The loop of instructions is contractible in a larger space of instructions, and it follows by the usual winding number argument that some instruction in that larger space will tell the snake how to find his tail.



Thanks to Monroe Tenner for his help in creating and coloring this drawing.

The Four Vertex Theorem and Its Converse

Dennis DeTurck, Herman Gluck, Daniel Pomerleano, and David Shea Vick

DEDICATED TO THE MEMORY OF BJÖRN DAHLBERG.

The ***Four Vertex Theorem***, one of the earliest results in global differential geometry, says that a simple closed curve in the plane, other than a circle, must have at least four "vertices", that is, at least four points where the curvature has a local maximum or local minimum. In 1909 Syamadas Mukhopadhyaya proved this for strictly convex curves in the plane, and in 1912 Adolf Kneser proved it for all simple closed curves in the plane, not just the strictly convex ones.

The ***Converse to the Four Vertex Theorem*** says that any continuous real-valued function on the circle that has at least two local maxima and two local minima is the curvature function of a simple closed curve in the plane. In 1971 Herman Gluck proved this for strictly positive preassigned curvature, and in 1997 Björn Dahlberg proved the full converse, without the restriction that the curvature be strictly positive. Publication was delayed by Dahlberg's untimely death in January 1998, but his paper was edited afterwards by Vilhelm Adolfsson and Peter Kumlin, and finally appeared in 2005.

The work of Dahlberg completes the almost hundred-year-long thread of ideas begun by Mukhopadhyaya, and we take this opportunity to provide a self-contained exposition.

The authors of this article are all affiliated with the University of Pennsylvania. Dennis DeTurck is the Evan C. Thompson Professor in the department of mathematics. His email addresss is `deturck@math.upenn.edu`. *Herman Gluck is professor of mathematics. His email address is* `gluck@math.upenn.edu`. *Daniel Pomerleano and David Shea Vick are graduate students in the department of mathematics. Their email addresses are* `dpomerle@math.upenn.edu` *and* `dvick@math.upenn.edu`.

Why Is the Four Vertex Theorem True?

A Simple Construction

A counterexample would be a simple closed curve in the plane whose curvature is nonconstant, has one minimum and one maximum, and is weakly monotonic on the two arcs between them. We will try to build such a curve from a few arcs of circles, fail, and see why.

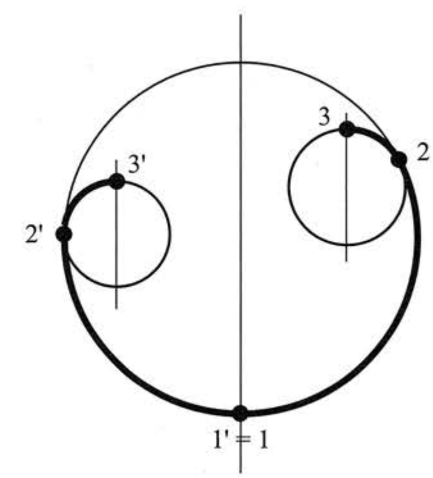


Figure 1: A failed counterexample.

Think of the circles in Figure 1 as train tracks. Our curve will be traced out by a train that travels along these circular tracks, switching from one to another at the labeled junction points.

Let the train start at point 1 on the bottom of the largest circle, giving the minimum curvature there. It then moves off to the right along this large circle, comes to the point 2, and switches there to a smaller circle, increasing its curvature.

The important thing to note is that the vertical diameter of this smaller circle is displaced to the right of the vertical diameter of the original circle.

To keep things brief, we let the train stay on this second circle until it comes to the top at the point 3, which is to the right of the vertical diameter of the original circle.

Then we go back to the beginning, start the train once again at the bottom of the original circle, relabel this point 1′, and now let the train move off to the left. It switches to a smaller circle at point 2′, and comes to the top of this circle at 3′, which is now to the left of the vertical diameter of the original circle.

If the curved path of the train is to form a convex simple closed curve, then the top points 3 and 3′ should coincide...but they don't. So the curve does not exist.

No matter how many circles we use, we get the same contradiction: the curve cannot close up while staying simple, and therefore does not exist.

But if we permit a self-intersection, then it's easy to get just one maximum and one minimum for the curvature.

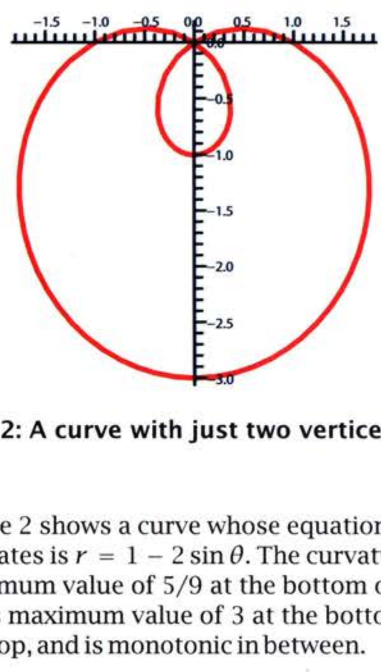


Figure 2: A curve with just two vertices.

Figure 2 shows a curve whose equation in polar coordinates is $r = 1 - 2\sin\theta$. The curvature takes its minimum value of 5/9 at the bottom of the big loop, its maximum value of 3 at the bottom of the small loop, and is monotonic in between.

Osserman's Proof of the Four Vertex Theorem

Consider the Circumscribed Circle

In 1985, Robert Osserman gave a simple proof of the Four Vertex Theorem in which all cases, strictly positive or mixed positive and negative curvature, are treated on an equal footing. At the beginning of his paper, Osserman says,

> *The essence of the proof may be distilled in a single phrase: consider the circumscribed circle.*

Let E be a fixed nonempty compact set in the plane. Among all circles C that enclose E, there is a unique smallest one, the ***circumscribed circle***, as in Figure 3.

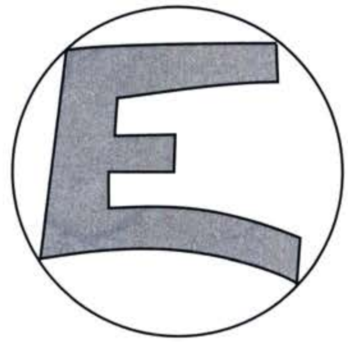


Figure 3: The compact set E and its circumscribed circle.

What can $C \cap E$ look like?

(1) C must meet E, otherwise C could be made smaller and still enclose E.

(2) $C \cap E$ cannot lie in an open semi-circle. Otherwise we could shift C a bit, without changing its size, so that the new C still encloses E but does not meet it. But this would contradict (1).

(3) Thus $C \cap E$ has at least two points, and if only these, then they must be antipodal. This happens when E is an ellipse.

An Overview of Osserman's Proof

Osserman's Theorem. *Let α be a simple closed curve of class C^2 in the plane and C the circumscribed circle. If $\alpha \cap C$ has at least n components, then α has at least $2n$ vertices.*

Here are the major steps in the proof.

(1) Let R be the radius of the circumscribed circle C, and $K = 1/R$ its curvature. If $\alpha \cap C$ has at least n components, then α has at least n vertices where the curvature satisfies $\kappa \geq K$, and at least n more vertices where $\kappa < K$.

Caution. We do not claim that the six points shown in Figure 4 are vertices. But if you find six consecutive points on the curve α where the curvature goes up and down as shown, then you can replace them by six vertices of α, three of them local maxima and three local minima. We leave it to the reader to check this simple assertion.

It is clear from Figure 4 how we get the n points where $\kappa \geq K$.

To get the ones in between, where $\kappa < K$, we proceed as follows.

Let $P_1, P_2, \ldots, P_n$ be n points in counterclockwise order on the circle C, one from each component of $C \cap \alpha$. Since $C \cap \alpha$ cannot lie in an open semi-circle, we can choose these points so that the arc of C from each point to the next is no larger than a semi-circle.

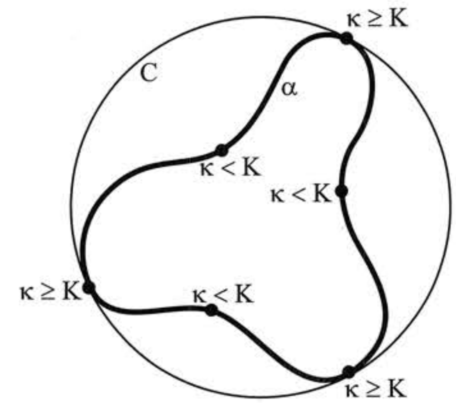


Figure 4: The curve α and its circumscribed circle.

Now focus on the arc C_1 of C from P_1 to P_2, and on the corresponding arc α_1 of the curve α. We have arranged for the convenience of description that the line connecting P_1 and P_2 is vertical.

The arc α_1 of α is tangent to C at P_1 and P_2 and does not lie entirely along C. It therefore contains a point Q that is not on C_1, yet lies to the right of the vertical line connecting P_1 and P_2. Consider the circle C' through P_1, Q and P_2, as shown in Figure 5.

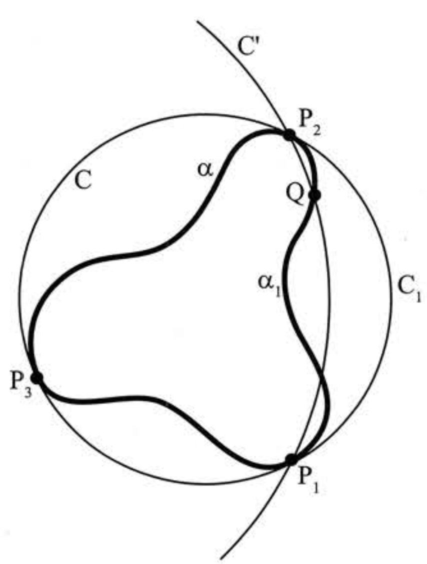


Figure 5: The circle C'.

Since Q is in the interior of C, and since C_1 is no larger than a semicircle, it follows that the circle C' is larger than C. Hence its curvature $K' < K$.

Now gradually translate the circle C' to the left, until it last touches α_1 at the point Q_1, as shown in Figure 6.

At Q_1, the curvature κ of α must satisfy $\kappa(Q_1) \leq K' < K$, which is exactly what we wanted to show.

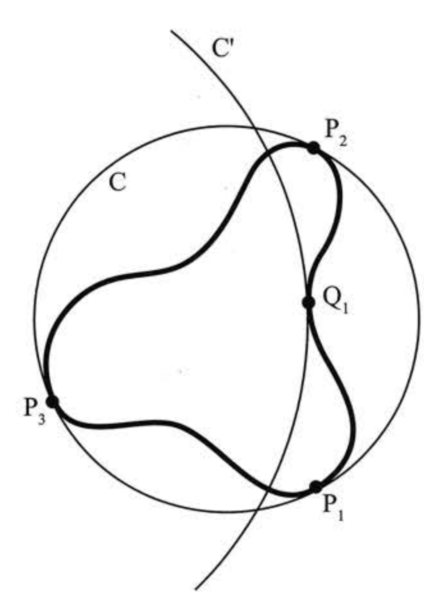


Figure 6: C' translated to the left.

(2) **Bonus clause.** The components of $\alpha \cap C$ are either single points or closed arcs. For each component that is an arc rather than a single point, we can get two extra vertices, over and above the $2n$ vertices promised by Osserman's theorem.

The picture of α in Figure 7 is roughly the same as before, but we have distorted it so that an entire arc of α about the point P_2 coincides with an arc of the circle C. The curvature of α at P_2 is now exactly κ. But in addition, there must be points of α to either side of this arc, arbitrarily close to it, where the curvature κ of α is $> K$. Two such points are shown in Figure 7 and marked R_2 and R_2'. As a result, the point P_2, where the curvature of α used to be larger than the curvature at the two neighboring marked points, has been demoted, and the curvature of α at P_2 is now less than that at the two neighboring marked points. In this way, we have gained two extra vertices for α.

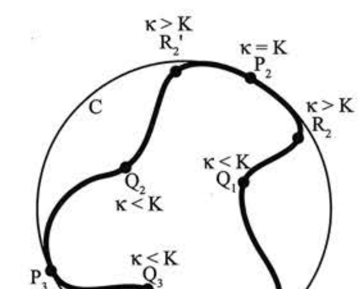


Figure 7: The bonus clause.

(3) It can happen that $\alpha \cap C$ has only one component, which must then be a closed arc on C greater than or equal to a semi-circle. Osserman's theorem promises that α has at least two vertices, and the bonus clause promises two more.

(4) Thus Osserman's theorem, together with the bonus clause, yields the Four Vertex Theorem.

The Converse in the Case of Strictly Positive Curvature

Full Converse to the Four Vertex Theorem. *Let $\kappa : S^1 \to \mathbb{R}$ be a continuous function that is either a nonzero constant or else has at least two local maxima and two local minima. Then there is an embedding $\alpha : S^1 \to \mathbb{R}^2$ whose curvature at the point $\alpha(t)$ is $\kappa(t)$ for all $t \in S^1$.*

Basic Idea of the Proof for Strictly Positive Curvature

We use a winding number argument in the group of diffeomorphisms of the circle, as follows.

Let $\kappa : S^1 \to \mathbb{R}$ be any continuous strictly positive curvature function, and for the moment think of the parameter along S^1 as the angle of inclination θ of the desired curve. Since this curve will usually not close up, it is better to cut S^1 open into the interval $[0, 2\pi]$.

There is a unique map $\alpha : [0, 2\pi] \to \mathbb{R}^2$ that begins at the origin and has unit tangent vector $(\cos\theta, \sin\theta)$ and curvature $\kappa(\theta)$ at the point $\alpha(\theta)$. In fact, if s is arc length along this curve, then the equations

$$\frac{d\alpha}{ds} = (\cos\theta, \sin\theta) \quad \text{and} \quad \frac{d\theta}{ds} = \kappa(\theta)$$

quickly lead to the explicit formula

$$\alpha(\theta) = \int_0^\theta \frac{(\cos\theta, \sin\theta)}{\kappa(\theta)}\, d\theta.$$

The ***error vector*** $E = \alpha(2\pi) - \alpha(0)$ measures the failure of our curve to close up.

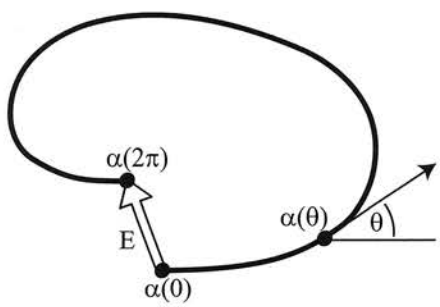


Figure 8: The error vector E.

If the curvature function κ has at least two local maxima and two local minima, we will show how to find a loop of diffeomorphisms h of the circle so that when we construct, as above, curves $\alpha_h : [0, 2\pi] \to \mathbb{R}^2$ whose curvature at the point $\alpha_h(\theta)$ is $\kappa \circ h(\theta)$, the corresponding error vectors $E(h)$ will wind once around the origin. Furthermore, we will do this so that the loop is contractible in the group $\mathrm{Diff}(S^1)$ of diffeomorphisms of the circle and conclude that for some h "inside" this loop, the curve α_h will have error vector $E(h) = 0$ and hence close up to form a smooth simple closed curve.

Its curvature at the point $\alpha_h(\theta)$ is $\kappa \circ h(\theta)$, so if we write $\alpha_h(\theta) = \alpha_h \circ h^{-1} \circ h(\theta)$, and let $h(\theta) = t$, then its curvature at the point $\alpha_h \circ h^{-1}(t)$ is $\kappa(t)$. Therefore $\alpha = \alpha_h \circ h^{-1}$ is a reparametrization of the same curve, whose curvature at the point $\alpha(t)$ is $\kappa(t)$.

How Do We Find Such a Loop of Diffeomorphisms?

The first step is to replace κ by a simpler curvature function.

Using the hypothesis that κ has at least two local maxima and two local minima, we find positive numbers $0 < a < b$ such that κ takes the values a, b, a, b at four points in order around the circle. We then find a preliminary diffeomorphism h_1 of the circle so that the function $\kappa \circ h_1$ is ***ϵ-close in measure*** to a step function κ_0 with values a, b, a, b on four successive arcs of length $\pi/2$ each, in the sense that $\kappa \circ h_1$ is within ϵ of κ_0 on almost all of S^1, except on a set of measure $< \epsilon$.

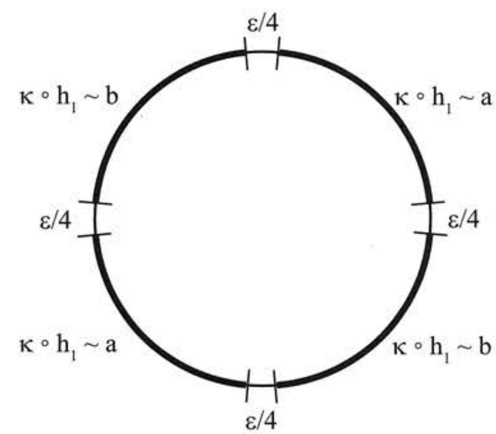


Figure 9: $\kappa \circ h_1$ is ϵ-close in measure to the step function κ_0.

If the curvature functions $\kappa \circ h_1$ and κ_0 are ϵ-close in measure, then the corresponding curves are easily seen to be C^1-close. With this in mind, we will focus attention on the curvature step function κ_0 and ignore the original curvature function κ until almost the end of the argument.

Given this shift of attention, we next find a contractible loop of diffeomorphisms h of the circle so that the error vectors $E(h)$ for the curvature step functions $\kappa_0 \circ h$ wind once around the origin, as in Figure 10.

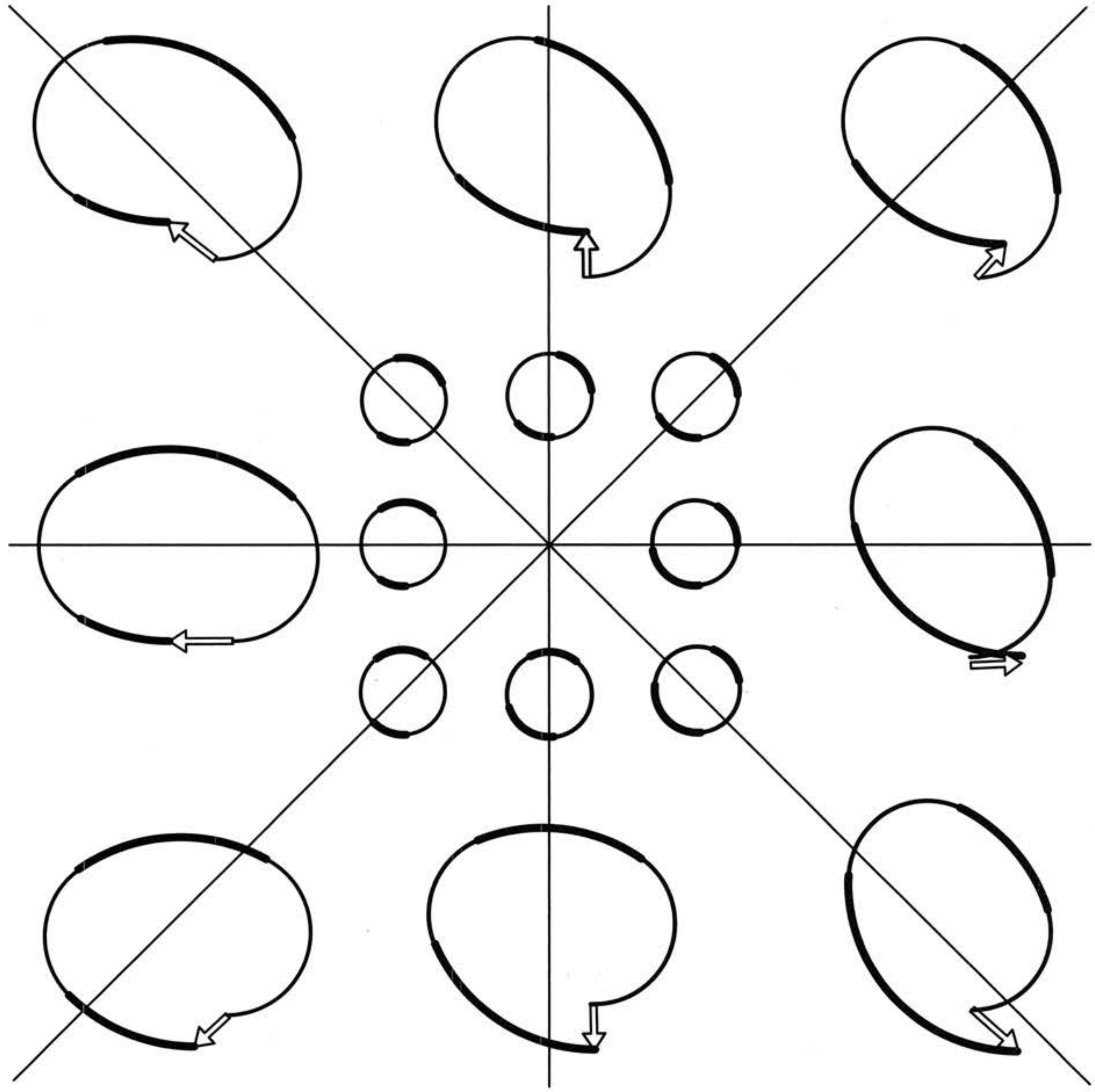


Figure 10: A curve tries unsuccessfully to close up.

How Do We Read This Picture?

The picture has eight portions, located at the eight points of the compass. Each contains a small circle that shows a curvature step function $\kappa_0 \circ h$, and a larger curve that realizes it, with common parameter the angle of inclination θ. This larger curve is built from four circular arcs, two cut from a circle of curvature a and two from a circle of curvature b. Heavier markings indicate the larger circle.

The curves fail to close up, and we show their error vectors. The figures are arranged so that the one in the east has an error vector pointing east, the one in the northeast has an error vector pointing northeast, and so on.

The eight diffeomorphisms h are samples from a loop of diffeomorphisms of the circle, and the corresponding error vectors $E(h)$ wind once around the origin. The loop is contractible in $\mathrm{Diff}(S^1)$ because each diffeomorphism leaves the bottom point of the circle fixed. The precise description of such a family of diffeomorphisms of the circle is given in Gluck (1971), but we think there is enough information in Figure 10 for the reader to work out the details. This picture can be seen in animated form at our website, `http://www.math.upenn.edu/~deturck/fourvertex`.

Since the loop of diffeomorphisms is contractible in $\mathrm{Diff}(S^1)$, it follows that for some other diffeomorphism h of the circle, the corresponding curve with curvature $\kappa_0 \circ h$ has error vector zero and therefore closes up. This is hardly news: if h is the identity, then the curve with curvature κ_0 closes up, as shown in Figure 11.

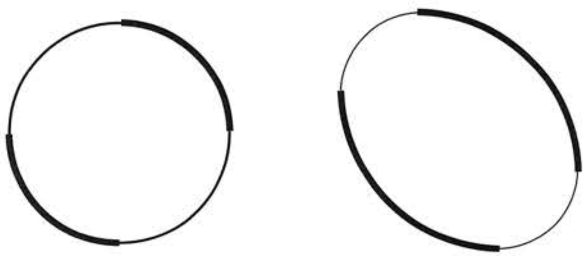


Figure 11: Preassign κ_0 ... and get this "bicircle".

But the point is that the above argument is robust and hence applies equally well to the curvature function $\kappa \circ h_1$ which is ϵ-close in measure to κ_0, since the corresponding curves are C^1-close. Hence there must also be a diffeomorphism h of the circle, so that the curve with curvature $\kappa \circ h_1 \circ h$ has error vector zero and therefore closes up to form a strictly convex simple closed curve. Reparametrizing this curve as discussed earlier shows that it realizes the preassigned curvature function κ, completing the proof of the converse to the Four Vertex Theorem for strictly positive curvature.

Why Does This Argument Sound Familiar?

Proving something that is obvious by using a robust argument reminds us of the proof that the polynomial $p_0(z) = a_n z^n$ has a zero by noting that it takes any circle in the complex plane to a curve that winds n times around the origin. After all, it is obvious that $p_0(z)$ has a zero at the origin.

But this argument is also robust and applies equally well to the polynomial

$$p(z) = a_n z^n + a_{n-1} z^{n-1} + \cdots + a_1 z + a_0,$$

when z moves around a suitably large circle, giving us the usual topological proof of the Fundamental Theorem of Algebra.

Where Does Our Winding Number Argument Come From?

Here is a higher-dimensional result proved in Gluck (1972) and surveyed in Gluck (1975).

Generalized Minkowski Theorem. *Let $K : S^n \to \mathbb{R}$, for $n \geq 2$, be a continuous, strictly positive function. Then there exists an embedding $\alpha : S^n \to \mathbb{R}^{n+1}$ onto a closed convex hypersurface whose Gaussian curvature at the point $\alpha(p)$ is $K(p)$ for all $p \in S^n$.*

The proof of this theorem is by a degree argument in the diffeomorphism group of the n-sphere S^n. The hypothesis that $n \geq 2$ is used to guarantee the existence of a diffeomorphism that arbitrarily permutes any finite number of points. This hypothesis fails for $n = 1$, but when we rewrite the argument in this case, we get the winding number proof of the converse to the Four Vertex Theorem for strictly positive curvature described above.

Building Curves From Arcs of Circles

Before we leave this section, we record the following observation of Dahlberg, and save it for later use.

Proposition 1. *A plane curve, built with four arcs cut in alternation from two different size circles, and assembled so that the tangent line turns continuously through an angle of 2π, will close up if and only if opposite arcs are equal in length.*

Evidence for this proposition is provided by the figure of a bicircle, and the large figure containing eight separate curves that fail to close up.

Proof. We parametrize such a curve by the angle of inclination of its tangent line, suppose that $0 < a < b$ are the curvatures of the two circles to be used, and record the curvature function $\kappa(\theta)$ in Figure 12.

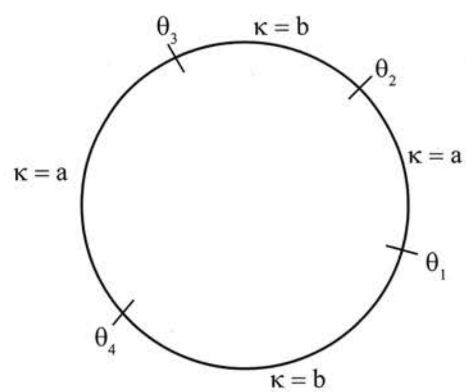


Figure 12: The curvature function $\kappa(\theta)$.

If $\alpha(\theta)$ is the resulting curve, then its error vector is given by

$$E = \alpha(2\pi) - \alpha(0) = \int_0^{2\pi} e^{i\theta}\, ds = \int_0^{2\pi} e^{i\theta} \frac{ds}{d\theta}\, d\theta = \int_0^{2\pi} \frac{e^{i\theta}}{\kappa(\theta)}\, d\theta.$$

We evaluate this explicitly as a sum of four integrals, and get

$$E = (1/ia - 1/ib)([\epsilon^{i\theta_2} - \epsilon^{i\theta_1}] + [\epsilon^{i\theta_4} - \epsilon^{i\theta_3}]).$$

We are left with the question of whether the two vectors shown in Figure 13 add up to zero. A glance at the figure makes the answer obvious and proves the proposition.

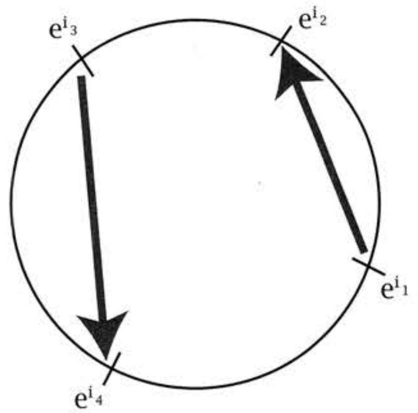


Figure 13: When do these two vectors add up to zero?

Dahlberg's Proof of the Full Converse to the Four Vertex Theorem

Dahlberg's Key Idea

When asked to draw a simple closed curve in the plane with strictly positive curvature, and another one with mixed positive and negative curvature, a typical response might be as shown in Figure 14.

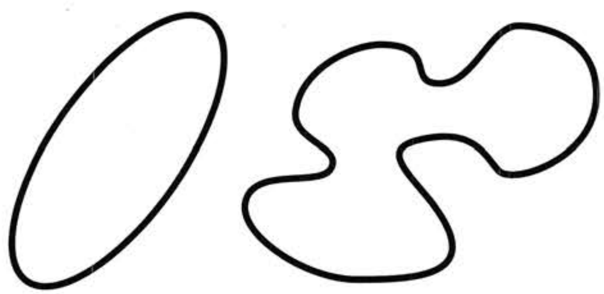


Figure 14: Typical Curves.

But for mixed positive and negative curvature, Dahlberg envisioned the curve shown in Figure 15.

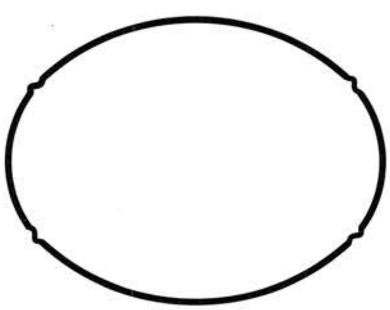


Figure 15: Dahlberg's Vision.

Its four major subarcs are almost circular. They are connected by four small wiggly arcs, each of which has an almost constant tangent direction, but largely varying curvature, including negative curvature. This curve "marginalizes" its negative curvature and emphasizes its positive curvature, and from a distance looks like a bicircle.

Dahlberg's Key Idea. *You can construct such a curve with any preassigned curvature that has at least two local maxima and two local minima. You can use the winding number argument to get it to close up smoothly, and you can also make it C^1-close to a fixed convex curve, which will imply that it is simple.*

Dahlberg's Proof Plan

The overall plan is to follow the winding number argument from the strictly positive curvature case, preserving the prominent role played by two-valued curvature step functions, but mindful of the need for the following changes.

(1) A smooth simple closed curve with strictly positive curvature has a distinguished parametrization by the angle of inclination of its tangent line. This does not work in general, so another parametrization scheme is needed.

(2) A smooth closed curve with strictly positive curvature whose tangent line turns through an angle of 2π is automatically simple. This is false without the curvature assumption, and part of Dahlberg's Key Idea is to force the curve to be C^1 close to a fixed convex curve in order to make it simple.

To accomplish this, he exhibits a 2-cell $\mathcal{D}$ in $\mathrm{Diff}(S^1)$, centered at the identity, and satisfying a certain transversality condition that guarantees that the winding number argument will work using arbitrarily small loops in $\mathcal{D}$ about its center.

Finding the Right Parametrization

Choose, as common domain for all our curves, the unit circle S^1 with arc length s as parameter. Since most of the curves will fail to close up, cut the circle open at the point $(1, 0)$ and think of the interval $[0, 2\pi]$ as the domain. All the curves will have length 2π, and at the end will be scaled up or down to modify their curvature.

We make sure the total curvature is always 2π as follows. Given a preassigned curvature function $\kappa : S^1 \to \mathbb{R}$ which is not identically zero, evaluate $\int_0^{2\pi} \kappa(s)\, ds$. If this is zero, precede κ by a preliminary diffeomorphism of S^1 so as to make the integral nonzero, but still call the composition κ. Then rescale this new κ by a constant c so that

$$\int_0^{2\pi} c\,\kappa(s)\, ds = 2\pi.$$

When we later modify this curvature function by another diffeomorphism $h : S^1 \to S^1$, we will rescale the new curvature function $\kappa \circ h$ by a constant c_h so that the total curvature is again 2π:

$$\int_0^{2\pi} c_h \, \kappa \circ h(s) \, ds = 2\pi.$$

We then build a curve $\alpha_h : [0, 2\pi] \to \mathbb{R}^2$, parametrized by arc length, that begins at the origin, $\alpha_h(0) = (0,0)$, starts off in the direction of the positive x-axis, $\alpha_h'(0) = (1,0)$, and whose curvature at the point $\alpha_h(s)$ is $c_h \, \kappa \circ h(s)$. The curve α_h is uniquely determined by these requirements.

The effect of these arrangements is that all our curves begin and end up pointing horizontally to the right. If any such curve closes up, it does so smoothly. Thus, just as in the positive curvature case, the emphasis is on getting the curve to close up.

At the end, using ideas expressed above, we will make sure the final curve is simple.

Configuration Space

Defining a configuration space of four ordered points on a circle will help us visualize what is to come and aid us in carrying out the transversality arguments mentioned in the proof plan.

As in the positive curvature case, we use the hypothesis that κ has at least two local maxima and two local minima to find positive numbers $0 < a < b$ so that κ takes the values a, b, a, b at four points in order around the circle. The only difference here is that we might first have to change the sign of κ to accomplish this.

Then we find a preliminary diffeomorphism h_1 of the circle so that the function $\kappa \circ h_1$ is ϵ-close in measure to the step function κ_0 with values a, b, a, b on the arcs $[0, \pi/2)$, $[\pi/2, \pi)$, $[\pi, 3\pi/2)$, $[3\pi/2, 2\pi)$.

As before, we focus on the step function κ_0 and its compositions $\kappa_0 \circ h$ as h ranges over $\mathrm{Diff}(S^1)$. These are all step functions with the values a, b, a, b on the four arcs determined by some four points p_1, p_2, p_3, p_4 in order on S^1. For each such step function, we follow Dahlberg's parametrization scheme from the previous section to construct a curve from circular arcs with curvatures proportional to a, b, a, b, scaled up or down to make the total curvature 2π. Let $E(p_1, p_2, p_3, p_4)$ denote the error vector for this curve.

To think visually about all this, let CS denote the configuration space of ordered 4-tuples (p_1, p_2, p_3, p_4) of distinct points on the unit circle S^1, arranged in counterclockwise order, as shown in Figure 16.

The configuration space CS is diffeomorphic to $S^1 \times \mathbb{R}^3$.

The error vector $E(p_1, p_2, p_3, p_4)$ defines an ***error map*** $E : CS \to \mathbb{R}^2$. The vanishing of the error vector is the signal that the curve closes up. We will call the set of such points the ***core*** of the configuration space CS, and denote it by CS_0.

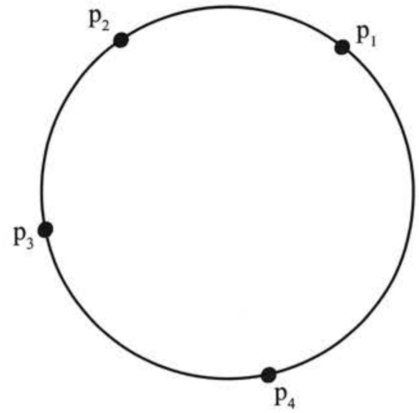


Figure 16: An element of the configuration space CS.

We noted in Proposition 1 that a curve built with four arcs cut in alternation from two different size circles will close up if and only if opposite arcs are equal in length.

Thus a point (p_1, p_2, p_3, p_4) of CS lies in the core if and only if p_1 and p_3 are antipodal, and also p_2 and p_4 are antipodal. A nice exercise for the reader is to check that this condition holds if and only if the equation $p_1 - p_2 + p_3 - p_4 = 0$ holds in the complex plane.

The core CS_0 is diffeomorphic to $S^1 \times \mathbb{R}^1$.

Reduced Configuration Space

To aid in visualization, and also to help with our proof of the required transversality results, we define the ***reduced configuration space*** $RCS \subset CS$ to be the subset where $p_1 = (1,0) = 1 + 0i = 1$. Then RCS is diffeomorphic to $\mathbb{R}^3$ and we use the group structure on S^1 to express the diffeomorphism $S^1 \times RCS \to CS$ by

$$(e^{i\theta}, (1, p, q, r)) \to (e^{i\theta}, e^{i\theta}p, e^{i\theta}q, e^{i\theta}r).$$

For the purpose of drawing pictures, we change coordinates by writing

$$p = e^{2\pi i x}, \quad q = e^{2\pi i y} \quad \text{and} \quad r = e^{2\pi i z}.$$

Then $RCS \cong \{(x, y, z) : 0 < x < y < z < 1\}$.

A point $(1, p, q, r)$ in RCS is in the core if and only if 1 and q are antipodal, and also p and r are antipodal. We let $RCS_0 = RCS \cap CS_0$ denote the core of the reduced configuration space.

In the x, y, z coordinates for RCS, the core RCS_0 is given by

$$0 < x < y = 1/2 < z = x + 1/2 < 1,$$

and appears as the open line segment connecting $(0, 1/2, 1/2)$ to $(1/2, 1/2, 1)$.

The reduced configuration space has an added advantage that derives from the fact that when we build curves in the plane by cutting the unit circle open at the point 1, this is already one of the four

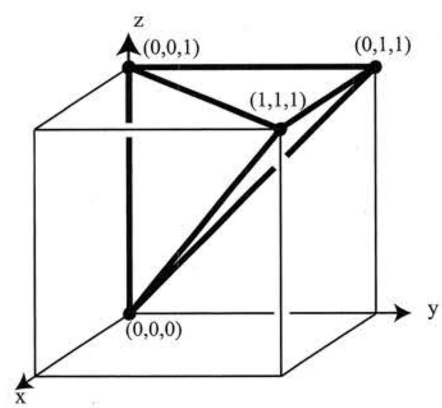


Figure 17: The reduced configuration space RCS appears as an open solid tetrahedron.

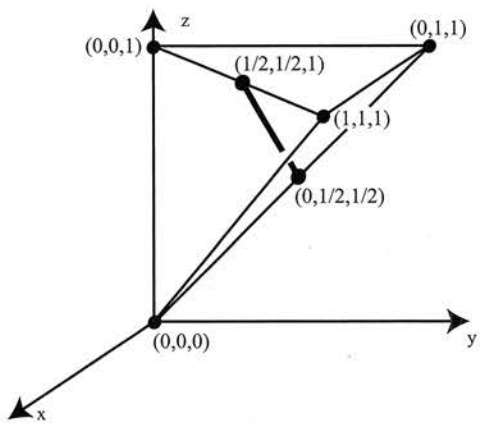


Figure 18: The core of the reduced configuration space.

division points for an element $(1, p, q, r)$ in RCS. This simplifies the construction of the curve, and the computation of its error vector $E(1, p, q, r)$, and we make use of this in the following section.

The Topology of the Error Map

The error map $E : CS \to \mathbb{R}^2$ takes the core CS_0 to the origin and the complement of the core to the complement of the origin.

Let λ be a loop in $CS - CS_0$ which is null-homologous in CS but links the core CS_0 once. For convenience, we go down one dimension and show this loop in $RCS - RCS_0$.

Any two such loops in $CS - CS_0$ are homotopic to one another, up to sign.

Proposition 2. *The image of the loop λ under the error map E has winding number ± 1 about the origin in $\mathbb{R}^2$.*

What this proposition says in effect is that plane curves, built with four arcs cut in alternation from two different size circles, are capable of exhibiting the winding number phenomenon that makes the proof of the converse to the Four Vertex Theorem actually work.

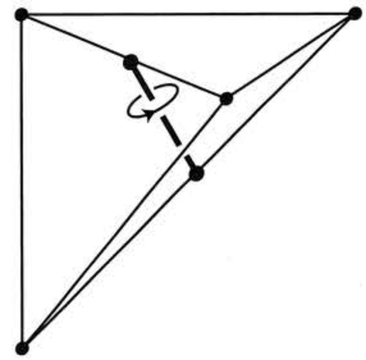


Figure 19: A loop in the reduced configuration space.

Proposition 2 is an immediate consequence of the transversality result below.

Proposition 3. *The differential of the error map $E : RCS \to \mathbb{R}^2$ is surjective at each point of the core.*

Proof. We are given distinct positive numbers $0 < a < b$ and a point $P = (1, p_2, p_3, p_4)$ in RCS. Let L_1, L_2, L_3, L_4 denote the lengths of the four arcs $1p_2, p_2p_3, p_3p_4, p_41$ on the unit circle. Scale a and b up or down to new values $a(P)$ and $b(P)$, preserving their ratio, to achieve total curvature 2π:

$$a(P)L_1 + b(P)L_2 + a(P)L_3 + b(P)L_4 = 2\pi.$$

Then construct a curve $\alpha : [0, 2\pi] \to \mathbb{R}^2$ according to Dahlberg's plan: begin at the origin and head in the direction of the positive x-axis along circles of curvatures $a(P), b(P), a(P), b(P)$ for lengths L_1, L_2, L_3, L_4. The error vector $E(P) = \alpha(2\pi) - \alpha(0)$ indicates the failure to close up.

Consider Figure 20, which shows the points $1, p_2$, p_3, p_4 on the unit circle parametrized by arc length s, and the corresponding division points $1, q_2, q_3, q_4$ on the unit circle parametrized by angle of inclination θ.

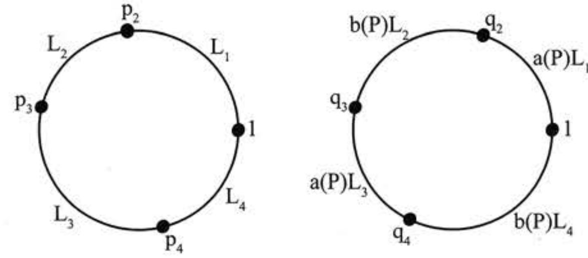


Figure 20: Arclength s, angle of inclination θ.

This momentary switch in loyalty from the arc length parameter s to the angle of inclination parameter θ will be rewarded by an explicit formula for the error map that makes the proof of the current proposition easy.

The map that takes

$$P = (1, p_2, p_3, p_4) \to Q = (1, q_2, q_3, q_4)$$

is a diffeomorphism from the s-parametrized version of RCS to a θ-parametrized version, taking the core $1-p_2+p_3-p_4 = 0$ to the core $1-q_2+q_3-q_4 = 0$.

This alternative version of RCS helps us to calculate the error map. First note that

$$E(P) = \int_0^{2\pi} e^{i\theta(s)}\, ds =$$
$$\int_0^{2\pi} e^{i\theta} \frac{ds}{d\theta}\, d\theta = \int_0^{2\pi} \frac{e^{i\theta}}{\kappa(\theta)}\, d\theta.$$

This can be computed explicitly as a sum of four integrals, and we get

$$E(P) = (1/ib(P) - 1/ia(P))(1 - q_2 + q_3 - q_4).$$

The differential of this map is particularly easy to compute along the core, since the vanishing of the expression $1 - q_2 + q_3 - q_4 = 0$ there frees us from the need to consider the rate of change of the factor $(1/ib(P) - 1/ia(P))$.

If we move q_2 counterclockwise at unit speed along the circle, we have $dq_2/dt = iq_2$, and hence

$$dE/dq_2 = (1/ib(P) - 1/ia(P))(-iq_2).$$

Likewise,

$$dE/dq_3 = (1/ib(P) - 1/ia(P))(iq_3).$$

These two rates of change are independent because q_2 and q_3 are always distinct, and along the core they cannot be antipodal. It follows that the differential of the error map is surjective at each point of the core of the θ-parametrized version of RCS. Since the map between the two versions of RCS is a diffeomorphism taking core to core, the same result holds for our original s-parametrized version of RCS, completing the proof of the proposition.

Dahlberg's Disk $\mathcal{D}$

Dahlberg's choice of 2-cell $\mathcal{D} \subset \mathrm{Diff}(S^1)$ consists of the ***special Möbius transformations***

$$g_\beta(z) = (z - \beta)/(1 - \bar{\beta} z),$$

where $|\beta| < 1$ and $\bar{\beta}$ is the complex conjugate of β.

These special Möbius transformations are all isometries of the Poincaré disk model of the hyperbolic plane. The transformation g_0 is the identity, and if $\beta \neq 0$, then g_β is a hyperbolic translation along the line through 0 and β that takes β to 0 and 0 to $-\beta$. The point $\beta/|\beta|$ and its antipode $-\beta/|\beta|$ on S^1 (the circle at infinity) are the only fixed points of g_β.

A unit complex number $e^{i\theta}$ acts by multiplication on the Poincaré disk model of the hyperbolic plane, and as such is a hyperbolic isometry that rotates the disk by angle θ about its center. These rotations interact with Dahlberg's transformations g_β by the intertwining formula

$$g_{e^{i\theta}\beta}(e^{i\theta} z) = e^{i\theta} g_\beta(z).$$

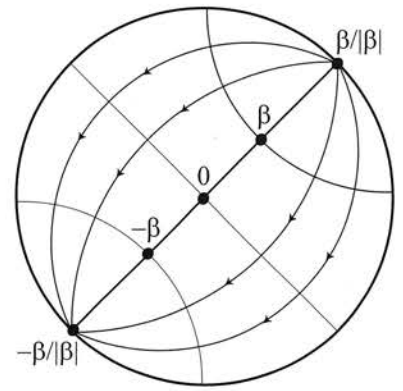


Figure 21: The action of g_β on the unit disk in the complex plane.

The Second Transversality Result

Let g_β be a point in Dahlberg's disk $\mathcal{D}$ and $P = (p_1, p_2, p_3, p_4)$ a point in the configuration space CS. We define

$$g_\beta(P) = (g_\beta(p_1), g_\beta(p_2), g_\beta(p_3), g_\beta(p_4)),$$

so that now $\mathcal{D}$ acts on CS.

Proposition 4. *The evaluation map $CS_0 \times \mathcal{D} \to CS$ defined by $(P, g_\beta) \to g_\beta(P)$ is a diffeomorphism.*

Proof. The evaluation map $CS_0 \times \mathcal{D} \to CS$ is smooth. To visualize it, start with a point $P = (p_1, p_2, p_3, p_4)$ in the core CS_0 and a transformation g_β in $\mathcal{D}$ which takes P to $Q = (q_1, q_2, q_3, q_4)$. In the Poincaré disk, the geodesic with ends at p_1 and p_3 is a straight line through the origin, and likewise for the geodesic with ends at p_2 and p_4. The isometry g_β takes them to geodesics with ends at q_1 and q_3, respectively q_2 and q_4, which appear to the Euclidean eye as circular arcs meeting the unit circle orthogonally and intersecting one another at the point $g_\beta(0) = -\beta$, as shown in Figure 22.

Vice versa, suppose we start with the point $Q = (q_1, q_2, q_3, q_4)$ in CS. Draw the hyperbolic lines, that is, circles orthogonal to the boundary of the disk, with ends at q_1 and q_3, likewise q_2 and q_4. The intersection point of these two circular arcs varies smoothly with the four end points.

Call this intersection point $-\beta$. The transformation $g_{-\beta}$ takes the point $-\beta$ to the origin, and hence takes the two hyperbolic lines through $-\beta$ to lines through the origin. It follows that $P = g_{-\beta}(Q)$ lies in the core CS_0 and that $g_\beta(P) = Q$. The association $Q \to (P, g_\beta)$ provides a smooth inverse to the evaluation map $CS_0 \times \mathcal{D} \to CS$, showing it to be a diffeomorphism.

Corollary 5. *For each fixed point P in the core CS_0, the evaluation map $g_\beta \to g_\beta(P)$ is a smooth embedding of Dahlberg's disk $\mathcal{D}$ into CS that meets the core transversally at the point P and nowhere else.*

This follows directly from Proposition 4.

The Image of Dahlberg's Disk in the Reduced Configuration Space

We seek a concrete picture of Dahlberg's disk $\mathcal{D}$ in action. Recall from the preceding section that for any point $P = (p_1, p_2, p_3, p_4)$ in CS, the correspondence

$$g_\beta \to (g_\beta(p_1), g_\beta(p_2), g_\beta(p_3), g_\beta(p_4))$$

maps $\mathcal{D}$ into CS. If we start with the point $P_0 = (1, i, -1, -i)$ and then follow the above map by the projection of CS to RCS, we get the correspondence

$$g_\beta \to (1, g_\beta(1)^{-1}g_\beta(i), g_\beta(1)^{-1}g_\beta(-1), \\ g_\beta(1)^{-1}g_\beta(-i)).$$

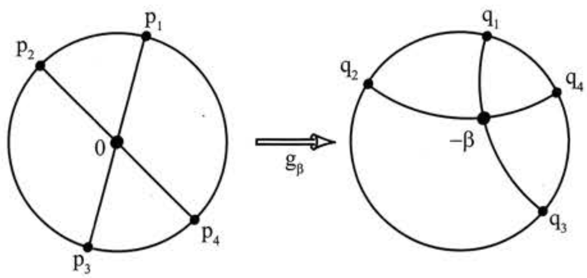


Figure 22: The transformation g_β.

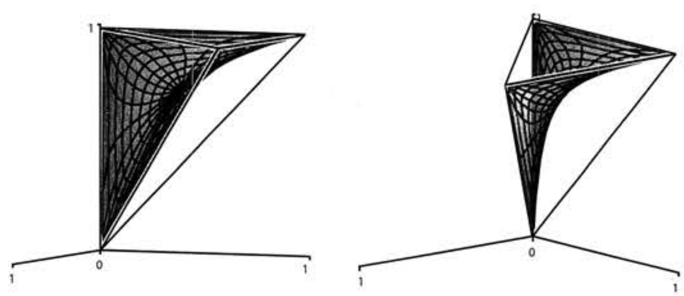


Figure 23: Two views of Dahlberg's disk $\mathcal{D}$ mapped into the tetrahedron.

If we convert to xyz-coordinates so that RCS is the open solid tetrahedron previously introduced, then the image of $\mathcal{D}$ is shown in Figure 23. In the picture on the left, the tetrahedron has its usual position; on the right, it is rotated so as to clearly display the negative curvature of the image disk.

These computer-drawn pictures of the image of $\mathcal{D}$ clearly show that its boundary lies along four of the six edges of the tetrahedron. This is a reflection of the fact that as β approaches the boundary of the unit disk, the special Möbius transformation g_β leaves the point $\beta/|\beta|$ on the boundary circle fixed, but moves all other points on the boundary circle towards the antipodal point $-\beta/|\beta|$, which is also fixed. Hence the four points 1, $g_\beta(1)^{-1}g_\beta(i)$, $g_\beta(1)^{-1}g_\beta(-1)$, $g_\beta(1)^{-1}g_\beta(-i)$ converge to at most two points. This "double degeneracy" corresponds to edges, rather than faces, of the tetrahedron.

Dahlberg's Proof

We are given a continuous curvature function $\kappa : S^1 \to \mathbb{R}$ that has at least two local maxima and two local minima and must find an embedding $\alpha : S^1 \to \mathbb{R}^2$ whose curvature at the point $\alpha(t)$ is $\kappa(t)$ for all $t \in S^1$.

Step 1. *We temporarily replace κ by a curvature step function κ_0, to which we apply the winding number argument.*

Changing the sign of κ if necessary, there are constants $0 < a < b$ so that κ takes the values a, b, a, b at four points in succession along S^1. Let κ_0 denote the curvature step function that takes these same values along the four quarter-circles with end points at $1, i, -1, -i$.

Given any $\epsilon > 0$, we can find a preliminary diffeomorphism h_1 of the circle so that the curvature function $\kappa \circ h_1$ is ϵ-close in measure to κ_0. We then rescale both κ_0 and $\kappa \circ h_1$ to have total curvature 2π. They will again be ϵ-close in measure, for some new small ϵ.

We apply the winding number argument to the curvature step function κ_0 as follows.

Consider the point $P_0 = (1, i, -1, -i)$ in the core CS_0 of the configuration space CS, and map Dahlberg's disk $\mathcal{D}$ into CS by sending $g_\beta \to g_\beta(P_0)$. By Corollary 5, this evaluation map is a smooth embedding of $\mathcal{D}$ into CS which meets the core CS_0 transversally at the point P_0 and nowhere else. By Proposition 2, each loop $|\beta| =$ constant in $\mathcal{D}$ is sent by the composition

$$\mathcal{D} \xrightarrow{\textit{evaluation map}} CS \xrightarrow{\textit{error map}} \mathbb{R}^2$$

into a loop in $\mathbb{R}^2 - \{\text{origin}\}$ with winding number ± 1 about the origin.

We translate this conclusion into more concrete terms as follows.

Let $c(\beta)\,\kappa_0 \circ g_\beta$ be the rescaling of the curvature step function $\kappa_0 \circ g_\beta$ that has total curvature 2π, and let $\alpha(\beta) : [0, 2\pi] \to \mathbb{R}^2$ be the corresponding arc-length parametrized curve with this curvature function. As β circles once around the origin, the corresponding loop of error vectors $E(\alpha(\beta))$ has winding number ± 1 about the origin.

Step 2. *We transfer this winding number argument to the curvature function κ.*

Let $c(h_1, \beta)\, \kappa \circ h_1 \circ g_\beta$ be the rescaling of the curvature function $\kappa \circ h_1 \circ g_\beta$ which has total curvature 2π, and let $\alpha(h_1, \beta) : [0, 2\pi] \to \mathbb{R}^2$ be the corresponding arc-length parametrized curve with this curvature function.

Fixing $|\beta|$, we can choose ϵ sufficiently small so that each curve $\alpha(h_1, \beta)$ is C^1-close to the curve $\alpha(\beta)$ constructed in Step 1. Then as β circles once around the origin, the corresponding loop of error vectors $E(\alpha(h_1, \beta))$ will also have winding number ± 1 about the origin. Note that we only need C^0-close for this step.

It follows that there is a diffeomorphism $g_{\beta'}$ with $|\beta'| \le |\beta|$ so that $E(\alpha(h_1, \beta')) = 0$, which tells us that the curve $\alpha(h_1, \beta')$ closes up smoothly. If $|\beta|$ and ϵ are sufficiently small, then the closed curve $\alpha(h_1, \beta')$ will be as C^1-close as we like to the fixed bicircle with curvature $c_0\, \kappa_0$, and will hence be simple.

The simple closed curve $\alpha(h_1, \beta')$ realizes the curvature function $c(h_1, \beta')\, \kappa \circ h_1 \circ g_{\beta'}$. Rescaling it realizes the curvature function $\kappa \circ h_1 \circ g_{\beta'}$, and then reparametrizing it realizes the curvature function κ.

This completes Dahlberg's proof of the Converse to the Four Vertex Theorem.

Extensions and Generalizations of the Four Vertex Theorem

During its almost hundred- year life span, the four vertex theorem has been extended and generalized in many different ways: we give the reader a glimpse of this here, mention some of the associated papers, and make a few suggestions for further reading.

More general surfaces. Hans Mohrmann (1917) stated that any simple closed curve on a closed convex surface has at least four vertices, meaning local maxima or minima of the geodesic curvature; the full proof was given by Barner and Flohr (1958). Jackson (1945) proved a four vertex theorem for simple closed curves that are null-homotopic on surfaces of constant curvature in Euclidean space. See also Thorbergsson (1976).

A new proof of the four vertex theorem for closed convex curves in the hyperbolic plane was given by David Singer (2001). He associated with such a curve γ a diffeomorphism f of the circle, proved that the vertices of γ correspond to the zeros of the Schwarzian derivative $S(f)$, and then applied a theorem of Ghys (1995), which says that $S(f)$ must vanish in at least four distinct points.

More than four vertices. Wilhelm Blaschke (1916) proved that a convex simple closed curve in the plane that crosses a circle $2n$ times has at least $2n$ vertices. S. B. Jackson (1944) generalized this to nonconvex curves; see also Haupt and Künneth (1967). Osserman focused on the circumscribed circle to get a $2n$-vertex theorem for simple closed curves, convex or not, and we summarized his (1985) exposition at the beginning of this paper.

Ulrich Pinkall conjectured that if a curve bounds an immersed surface of genus g in the plane, then it must have $4g + 2$ vertices. This was disproved by Cairns, Ozdemir, and Tjaden (1992), who constructed for any genus $g \ge 1$ a planar curve with only 6 vertices bounding an immersed surface of genus g. Later, Umehara (1994) showed that this result is optimal.

Nonsimple curves. Pinkall (1987) showed that if a closed curve bounds an immersed surface in the plane, then it must have at least four vertices. He also pointed out that there exist closed curves of any rotation index that have only two vertices. For a study of such curves, see Kobayashi and Umehara (1996).

The generalizations of Jackson and Pinkall may be combined to show that any closed curve that bounds an immersed disk on a complete orientable surface of constant curvature has at least four vertices. See Maeda (1998) and Costa and Firer (2000).

Space curves. In his (1912) paper, Adolf Kneser observed that stereographic projection maps the vertices of a plane curve to vertices (with respect to geodesic curvature) of its image on the sphere and used this to prove the four vertex theorem for all simple closed curves in the plane, not just the convex ones. Kneser's observation is a special case of the more general phenomenon that any conformal transformation of a surface preserves vertices of curves on it.

On a sphere, the points where the geodesic curvature vanishes are points of vanishing torsion. Thus Jackson's spherical four vertex theorem implies that every simple closed curve on the sphere has at least four points of vanishing torsion. Sedykh (1994) showed that this result holds more generally for all space curves that lie on the boundary of their convex hull, thus proving a conjecture of Scherk. The full generalization of this result, namely that every simple closed curve bounding a surface of positive curvature has at least four points where the torsion vanishes, is still unknown.

Many more results connected with the four vertex theorem can be found in the book by Ovsienko and Tabachnikov (2004) and in the two papers Umehara (1999) and Thorbergsson and Umehara (1999). Their bibliographies are excellent resources and will give the reader a sense of the breadth of research spawned by Mukhopadhyaya's original contribution.

History

Syamadas Mukhopadhyaya was born on June 22, 1866, at Haripal in the district of Hooghly. After graduating from Hooghly College, he took his M.A. degree from the Presidency College, Calcutta, and was later awarded the first Doctor of Philosophy in Mathematics from the Calcutta University, with a thesis titled, *Parametric Coefficients in the Differential Geometry of Curves in an N-space*, which earned for its author the Griffith Memorial Prize for 1910.

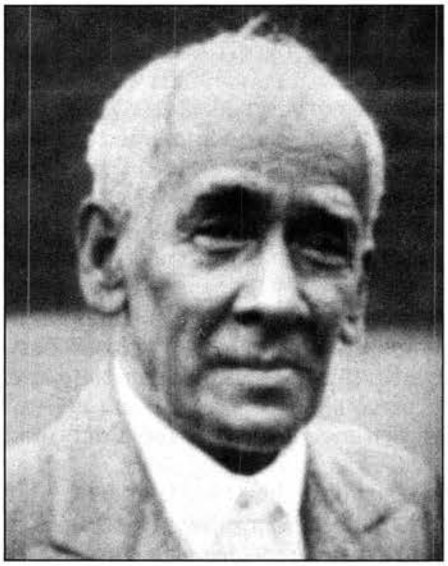


Figure 24: Syamadas Mukhopadhyaya (1866–1937).

Mukhopadhyaya began work as a professor in the Bangabasi College and some years later moved to the Bethune College, both in Calcutta. There he lectured not only on mathematics, but also on philosophy and English literature. He was later transferred to the Presidency College as professor of mathematics. When the Calcutta Mathematical Society was started in 1909, he was a founding member and in 1917 became vice president of the Society.

All of Mukhopadhyaya's mathematical works had a strong geometric flavor. He wrote many papers on the geometry of curves in the plane, and his proof of the Four Vertex Theorem in the case of strictly positive curvature came at the very beginning of his research career. His work on the geometry of curves in n-space, the early parts of which were submitted for his doctoral thesis, continued afterwards and was published in six parts in the *Bulletin of the Calcutta Mathematical Society* over a period of years.

After his retirement in 1932, Mukhopadhyaya went to Europe to study methods of education and on returning to India wrote a series of memoirs about this. He was elected President of the Calcutta Mathematical Society and served in this capacity until his death from heart failure on May 8, 1937.

> *His death has removed from the world of science a man of outstanding genius; but the intimate circle of his friends, admirers and pupils will remember him not only as an able Professor and a successful researcher with a deep insight into the fundamental principles of synthetic geometry but also as a sincere guide, philosopher, and friend, ever ready to help the poor in distress.*

Mukhopadhyaya's obituary appeared in the *Bulletin of the Calcutta Mathematical Society*, Vol. 29 (1937), pages 115–120. The comments above were taken from this obituary, and the final sentence was copied verbatim.

Adolf Kneser was born on March 19, 1862, in Grüssow, Germany. He received his Doctor of Philosophy from the University of Berlin in 1884, with a thesis *Irreduktibilität und Monodromiegruppe algebraischer Gleichungen*, written under the direction of Leopold Kronecker and Ernst Kummer and influenced by Karl Weierstrass. Kneser was appointed to the chair of mathematics in Dorpat and then later to the University of Breslau, where he spent the rest of his career.

Figure 25: Adolf Kneser (1862–1930).

After his initial interest in algebraic functions and equations, Kneser turned his attention to the geometry of space curves and in 1912 proved the Four Vertex Theorem in the general case of mixed positive and negative curvatures.

Adolf's son Hellmuth, born in 1898 while the family was still in Dorpat, followed in his father's mathematical footsteps and obtained his doctorate from Göttingen in 1921 under the direction of David Hilbert, with a thesis titled, *Untersuchungen zur*

Quantentheorie. The next year, in 1922, Hellmuth published a new proof of the Four Vertex Theorem. Hellmuth helped Wilhelm Süss to found the Mathematical Research Institute at Oberwolfach in 1944 and provided crucial support over the years to help maintain this world famous institution.

Hellmuth's son Martin continued in the family business, receiving his Ph.D. from the Humboldt University in Berlin in 1950 under the direction of Erhard Schmidt, with a thesis titled, *Über den Rand von Parallelkörpern*. He spent the early part of his mathematical career in Munich and then moved to Göttingen.

Adolf died on January 24, 1930, in Breslau, Germany (now Wroclaw, Poland). Hellmuth died on August 23, 1973, in Tübingen, Germany. Martin died on February 16, 2004.

The comments above were taken from the online mathematical biographies at the University of St. Andrews in Scotland, `http://www.history.mcs.st-and.ac.uk`.

Björn E. J. Dahlberg was born on November 3, 1949, in Sunne, Sweden. He received his Ph.D. in mathematics from Göteborg University in 1971 with a thesis, *Growth properties of subharmonic functions* and with Tord Ganelius as advisor. Dahlberg was 21 at the time, the youngest mathematics Ph.D. in Sweden.

Dahlberg's mathematical interests were shaped during his postdoctoral fellowship year at the Mittag-Leffler Institute in Stockholm, which Lennart Carleson had recently revitalized. Dahlberg was deeply influenced by Carleson and participated in the programs of harmonic analysis and quasiconformal mappings at the Institute, while learning about partial differential equations.

One issue of great importance to the mathematical community at that time was to extend known results in these areas to domains with complicated boundaries. In 1977 Dahlberg showed that, for bounded Lipschitz domains, surface measure on the boundary and harmonic measure are mutually absolutely continuous, which implies the solvability of the Dirichlet problem for the Laplacian on such domains.

For this work, Dahlberg was awarded the Salem Prize (Paris) in harmonic analysis in 1978 and the Edlund's prize from the Royal Academy of Science in Stockholm in 1979, and was invited to give a 45-minute address at the International Congress of Mathematicians in Warsaw, Poland, in 1982.

In 1980 Dahlberg was appointed to a full professorship at Uppsala University and three years later to a full professorship at Göteborg, which remained his home base for the rest of his life. He traveled a lot and held visiting faculty positions at the Universities of Minnesota, Michigan, and Texas, at Purdue University and Washington University in St. Louis, at the Université Paris-Sud, as well as at ETH (Zurich), Yale, Caltech, Chicago, and South Carolina.

While in Göteborg, Dahlberg started a project with Volvo on computer-aided geometric design of the surfaces of a car, leading to new theoretical results and a new design system. In his last years, Dahlberg worked on questions of discrete geometry connected to his work with Volvo and other companies, as well as to his older interest in non-smooth domains.

Figure 26: Björn E. J. Dahlberg (1949–1998).

Dahlberg died suddenly on January 30, 1998, from meningitis, an inflammation of the lining that protects the brain and spinal cord.

The comments above were taken mainly from a letter written by Vilhelm Adolfsson, one of Dahlberg's Ph.D. students who, along with Peter Kumlin, found Dahlberg's manuscript on the Converse to the Four Vertex Theorem after his death, edited it, and submitted it for publication. Ville went on to add some personal notes.

> *Björn was a very inspiring and charismatic person. Where other mathematicians tended to see difficulties, Björn saw possibilities: nothing was impossible! I remember leaving his office after discussing current problems, I always felt encouraged and full of enthusiasm. He often cheerfully exclaimed: The sky is the limit! One might then think that he was overly optimistic, but he was well aware of the difficulties and the uncertainties. One of his favorite sayings was "Hindsight is the only certain science."*

Acknowledgments

The entire mathematical community is indebted to Vilhelm Adolfsson and Peter Kumlin for rescuing Dahlberg's proof of the Full Converse to the Four Vertex Theorem, reading and editing it, and shepherding it through to publication. In addition, we are grateful to Ville for sending us a copy of the proof, to both Ville and Peter for telling us about Dahlberg's life and work, and to Ville for the detailed letter that supplied the information for the previous section.

We are enormously grateful to Benjamin Schak and Clayton Shonkwiler, two graduate students in mathematics at the University of Pennsylvania, for reading the entire manuscript and making many improvements, as well as for studying and explaining to us the proofs of Mukhopadhyaya and Kneser.

We are grateful to Mohammad Ghomi, Sergei Tabachnikov, and Masaaki Umehara for providing most of the information in the section about extensions and generalizations of the Four Vertex Theorem.

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Interview with Mikio Sato

Mikio Sato is a mathematician of great depth and originality. He was born in Japan in 1928 and received his Ph.D. from the University of Tokyo in 1963. He was a professor at Osaka University and the University of Tokyo before moving to the Research Institute for Mathematical Sciences (RIMS) at Kyoto University in 1970. He served as the director of RIMS from 1987 to 1991. He is now a professor emeritus at Kyoto University. Among Sato's many honors are the Asahi Prize of Science (1969), the Japan Academy Prize (1976), the Person of Cultural Merit Award of the Japanese Education Ministry (1984), the Fujiwara Prize (1987), the Schock Prize of the Royal Swedish Academy of Sciences (1997), and the Wolf Prize (2003).

This interview was conducted in August 1990 by the late Emmanuel Andronikof; a brief account of his life appears in the sidebar. Sato's contributions to mathematics are described in the article "Mikio Sato, a visionary of mathematics" by Pierre Schapira, in this issue of the *Notices.*

Andronikof prepared the interview transcript, which was edited by Andrea D'Agnolo of the Università degli Studi di Padova. Masaki Kashiwara of RIMS and Tetsuji Miwa of Kyoto University helped in various ways, including checking the interview text and assembling the list of papers by Sato. The *Notices* gratefully acknowledges all of these contributions.

—Allyn Jackson

Learning Mathematics in Post-War Japan

Andronikof: *What was it like, learning mathematics in post-war Japan?*

Sato: You know, there is a saying that goes like this: in happy times lives are all the same, but sorrows bring each individual a different story. In other words, I can tell of my hardships, but this will not answer your general question. Besides, I think the reader's interest should lie in the formation of the ideas of hyperfunctions, microlocal analysis, and so forth. It is true that in my young age I encountered some difficulties, but I don't think I should put emphasis on such personal matters.

Andronikof: *Still, I think we could start from a personal level. We could mix up journalism with mathematics, and go from one to the other. After all, you might not have become a—I would say, such a—mathematician without the experience of these hard times.*

Sato: Let me tell you this. In pre-war Japan, school was organized like the old German system. Elementary school ranged from the age of six to twelve, then followed middle school from twelve to seventeen, then three years of high school before entering university, where you graduated after three years. After the War, the system was changed to the American one: the five years of middle school were replaced by three years of junior high school and three years of high school. In order to become a graduate student, one then has to attend university for four years.

When I entered the middle school in Tokyo in 1941, I was already lagging behind: in Japan, the school year starts in early April, and I was born in late April 1928. The system was rigid, and thus I had to wait one year before getting in. Actually, it did not really matter, since I was not a quick boy. On the contrary, when I was a child, say, four like my son is now[1], I was called *bonchan,* which means a boy who is very slow in responding, very inadequate. I think I am very much the same now, ha! ha! Anyway, I turned thirteen right after entering middle school. In December of that year, Japan entered the war against the allied forces: U.S., UK, Holland, and China.

Andronikof: *Hectic times?*

Sato: Not so much in the beginning, as Japan was in a winning position. After Pearl Harbor, the British fleet was destroyed in the Far East, Singapore was occupied, and so on. Things looked favorable for Japan. But soon after, a year or so later, things started changing.

This was the beginning of my hard experiences. My regular courses in middle school lasted for only two years, and the rest of my school life was total chaos. The war in the Pacific ended on May 15, 1945. The first atomic bomb was dropped on August 6, 1945, after which the USSR declared war on Japan in order to secure the Kurilsk and Sachalin islands. At that time I was fifteen. Being a teenager, I had to work in factories. From 1943 to 1945, I had to carry coal. Very hard work... bad food... In late 1944, the systematic bombings of

[1] *That is, in August 1990.*

civilian targets by the U.S. started, after the fall of Micronesia, which then served as a base. In early 1945, Tokyo was a target. The first attack on Tokyo was on March 10, 1945, and some 80,000 were killed that night, but my family was spared. This was a short respite, since a month later there was a second attack and another broad area of Tokyo was burned down, including our house. I narrowly escaped the fire. We lost everything, but the family was safe. Due to the smoke, I partially lost my eyesight for a couple of weeks. Who cares about such details, anyway? Well, Japan had been rough on some people elsewhere, like the occupation army in China, and now it was hard for Japan. It was hard for many.

But I didn't intend to get into such detail... Isn't it tiresome?

Andronikof: *The tape recorder has no opinion, besides, I am personally interested.*

Sato: General Tōjō, Japan's military strong man, had taken power in Japan and conducted the whole war. He remained as prime minister at the time, and he, and the government, decided to move the schools to the countryside—they were practically closed, anyway. We could not find a place or job outside Tokyo. In a way, our family collapsed. We did not have any relatives in the countryside we could stay with, and we had no house. Pupils with family or friends in the countryside were supposed to go there, and those without such advantages had to join a party led by a schoolteacher. My father was a lawyer, but in 1941 or 1942 he fell ill and could not work as such anymore. Still, he thought that he could provide for his family. But then there was a sharp devaluation of the yen, by a factor of 100 (a yen was nearly the equivalent to a dollar before the war). Soon, the money my father had left from his work was down to practically nothing. We could not live on that anymore, and we nearly starved.

But let me talk about my formation. In elementary school we learned some arithmetic, coming from traditional Japanese mathematics. This is arithmetic for small boys. A typical example is the "counting of tortoises and cranes". Say there are several tortoises and several cranes. The total number is 7 and the total number of legs is 18. Then, how many tortoises are there? We had to manage to follow the reasoning without using equations.

I became very interested in mathematics at the age of twelve, I guess. This is when I moved from elementary school to middle school, and I had my first experience with algebra. We learned how to handle x's and y's, so things were solved very systematically. I was charmed by the simplicity of it. I was amazed by algebra, and in two years I made very quick progress and learned, for example, about complex numbers and their use in trigonometrical formulas, like the Euler formula. Of course, this was not taught at school. I remember saving my money systematically, by walking for hours instead of taking buses and streetcars to central Tokyo, and then spending hours in the bookstore to find the book that would give me the best value for my money. I remember an expository book by Fujimori on the theory of complex numbers where power series expansion and Taylor series were touched upon. The conformal transformation for the airplane wings was given as an example of the usefulness of complex numbers in the war industry... Some kind of propaganda book! Another book I read at that age was a book by Iwata on projective geometry: Desargues' theorem, Pascal's theorem, Brianchon's theorem dual to Pascal's...

My teacher of mathematics at that time was Mr. Ohashi, who is still alive. I actually met him again six years ago, after more than forty years. He contacted me after seeing my name in a newspaper or on television. I was lucky to have a good teacher. Of course I don't mean that he taught me such mathematical things during my first year. At that time I was rather timid, not talkative at all, and I did not try to consult him on my choice of books. But still, he was very encouraging: he always pushed me and taught me. That gave me the feeling that indulging in mathematics was not a game. This was very important, because on many occasions—at least in the Japanese educational system—pupils are supposed to follow the lead of the teacher and should not get off the track which he sets, whereas I was running completely off the track of the educational system. So I was just feeling it as a gift, so to speak, I was enjoying a kind of permitted pleasure.

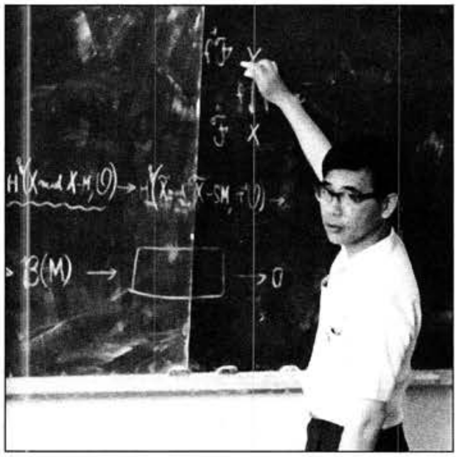
Andronikof: *Were the conditions such that you had plenty of time on your own?*

Sato: Well, in the daytime we were supposed to stay at school, whether we had any classes or not. Besides, the only mathematical library was in Tokyo, and not a big library. Unbelievable! It was the contrary of reality in Japan today.

Andronikof: *So, you have always been interested in mathematics.*

Sato: Since twelve years of age, yes, and also a little in physics. But you see, my interest in physics grew much later, around 1945, when I read a university textbook which I had the opportunity to borrow from some graduate student.

In a way, the first three years of middle school were very fruitful for me. Afterwards, I developed my way of mathematical thinking through reading books and making calculations, solving interesting problems and so on. But I did not receive any good education after that, ha! ha! I was lucky enough to have had a chance of awakening my ability in mathematics at an early age. For the rest, I was sort of a dull boy. In the Japanese school system there are such subjects as geography, where memorizing names and years and so on is important, and in this field my performance was extremely low. That gave me the feeling that studying at school was a kind of unpleasant job. Doing my own mathematics—that is, not school mathematics, but reading those books I mentioned—was like watching television would be for a present-day boy. See, I was probably indulging in such things to forget the unpleasant school courses. A way to escape the school system. During and after the war things became harder and harder and I went deeper and deeper into mathematics, so to speak, like another would dive into alcohol.


Sato at blackboard, around 1972.

After middle school—though we had not completed it...I was admitted to high school. At that time, high school was rather elitist, more like École Polytechnique or École Normale Supérieure in France. The high school that I entered was called the First High School, and was closely attached to Tōdai[2] (Imperial University at the time). Both were national, i.e., non-private. The First High School is considered to be the top of elite schools, and I was lucky enough to skip the entrance examinations, because of the war. Well, there was a kind of test, but just to check some ability in mathematics: if they had tested my knowledge, then I couldn't have entered. Today, there are entrance examinations at many universities, including Tokyo or Kyoto: a bad test... But this is not interesting.

After the war, chaos occurred again—or rather, persisted. As I said, because of the devaluation of the yen, my family was starving. My father was sick, and I had a younger sister (by nine years) and a younger brother (by five years). I had to support them, so, in 1948, after three years of the First High School, I immediately started to work as a full-time teacher at the *new* high school, just when the school system was changed and middle school was cut by half. Housing and food conditions were extremely bad at the time, as you can imagine: like in Eastern Europe or Southeast Asia now. I entered Tōdai in 1949, having failed to enter in 1948. I had very little time to get prepared, then.

These hard times as schoolteacher lasted ten years, from 1948 to 1958. In 1958 I published the theory of hyperfunctions, in order to get a job at the university. I was an old student at the time, but it was like today: finishing university is sort of automatic, provided you succeed in getting in, where the competition is very tough.

[2] *University of Tokyo.*

Andronikof: *I read in your CV that you got a BSc in physics after your BSc in mathematics at Tōdai.*

Sato: You see, in Japan teaching depends on each professor, and one of my professors was very strict. At the time I was to graduate, he called me up, and told me that my term paper was very good but I had not attended the mandatory exercise sessions—not even once. This was an obligation that I didn't know of. Remember, that's why I was called *bonchan* when I was a little boy, and I'm still very much that way now. So, he said: "I cannot give you the points, so you cannot graduate". Then, he remained silent and watched me for a good minute. He opened his mouth again and said: "Okay, I'll give you the lowest points, so you can just graduate. Your paper is the top one". But this barred me from getting a position at the university as an assistant, which is customary for top students. Being assistant in Japan is a tenured position. The second-best student may also get some special position, and hence is assured of some top financial support. Anyway, I lost that kind of chance then. Since at the time I had also become interested in theoretical physics, I just moved to physics for two years under the new, American-style university system. I was still teaching full time in high school, so in physics I ran into the same academic problems as in mathematics. After two years at the Tōdai Physics Department, I moved to the graduate school of another university, Tokyo School of Education, where Professor Tomonaga taught theoretical physics. I stayed there until 1958.

This was the end of my twenties. At the time I was undergoing some kind of crisis in physical strength. Since by then my younger brother and sister were able to support themselves, my duty to them was sort of accomplished. I was able to return to my own life, so to speak, and go back to mathematics.

The Birth of Hyperfunctions and Microfunctions

Andronikof: *So you decided to go back to mathematics, rather than physics?*

Sato: Yes, and it was a good decision since competition in physics seemed stiffer. See, after these tough years I was beginning to feel physically tired, and my youth was leaving me. Even if I wasn't a man of quick response, I nevertheless understood that I had to face real life, so to speak, and to try to show what I could do in mathematics.

Names Mentioned in the Interview

Below is a list of names of mathematicians mentioned during the interview.

Armand Borel
Élie Cartan
Etsurō Date
Pierre Deligne
Jean Ecalle
Leon Ehrenpreis
Daisuje Fujiwara
Roger Godement
Alexandre Grothendieck
Ryōgo Hirota
Sin Hitotumatu
Yasutaka Ihara
Kenkichi Iwasawa
Shōkichi Iyanaga
Michio Jimbo
Akira Kaneko
Masaki Kashiwara
Yukiyosi Kawada
Takahiro Kawai
Tatsuo Kimura
Hikosaburo Komatsu
Serge Lang
Jean Leray
André Martineau (1930–1972)
Yozō Matsushima
Barry M. McCoy
Tetsuji Miwa
Mitsuo Morimoto
Atsushi Nakayashiki
Yousuke Ohyama
Kiyoshi Oka
Frédéric Pham
Yasuko Sato
Pierre Schapira
Jean-Pierre Serre
Goro Shimura
Takuro Shintani (1943–1980)
Masuo Suzuki
Teiji Takagi
Kanehisa Takasaki
Shunichi Tanaka
Junichi Uchiyama
André Voros
Kōsaku Yosida
André Weil

My advisor at the mathematics department was Professor Iyanaga, and I wanted to show him what I was capable of. High school teachers had a forty-day vacation between the first and second semester. So, during the summer of 1957 I tried to prepare something that I could show him, and that was hyperfunctions. I worked out hyperfunction series and outlined the theory for several variables—though the complete theory was finished later, since it required a generalization of cohomology theory. In December of that year, I went to see Professor Iyanaga, after an interruption of some years, and told him about it. Professor Iyanaga showed interest in my work and persuaded Professor Kōsaku Yosida to offer me a position as an assistant.

Actually, it seems that Iyanaga was one of the professors who wanted me to get a position as an assistant already when I had graduated, but he was not a senior professor at the time, so his opinion did not prevail. I was glad that Professor Iyanaga showed interest in hyperfunction theory. I was lucky: if the professor had not been Iyanaga—if he were a specialist in analysis, for example—perhaps he would have told me: "You are doing nothing". Fortunately, Iyanaga was a generous and open-minded mathematician, open enough to appreciate what I was doing. He was a student of Professor Teiji Takagi, the founder of class field theory and number theory.

Of course, coming from ten years as a schoolteacher, this new position made me lose some financial advantages. But finally, after the hard times, I could have the pleasure of doing solely mathematics. What I wanted to do was to organize mathematics.

You see, being a high school teacher then was not like today. We had to work very hard. So, I couldn't do difficult things, but only general things like sheaf theory, category theory, and so on. I just tried to organize my own mathematics and studied a lot, always keeping my interest alive. During that period, I had the opportunity to see many papers published in *Sūgaku*[3]. In particular, my construction of relative cohomology was inspired by a report on complex variables by Hitotumatu, which contained a short account on sheaf theory and cohomology of sheaves, perhaps in three pages. *Sūgaku* was a very useful journal, which has been central to me: a compact publication covering every branch of mathematics. There were many journals that I could not get, so *Sūgaku* was essentially the only publication I was reading. And this, usually, when I was commuting on crowded public transportation, during rush hour. Well, some people read newspapers, anyway.

I believe that after ten years I had quite good ideas about theoretical physics and diverse branches of mathematics. Like a spider, I went on spinning my web for ten years, extending it by attaching it to different places. Some things get stuck in it, some go through. You go to some

[3]*A journal published in Japanese by the Mathematical Society of Japan. Recent volumes are translated into English and published by the AMS under the title* Sugaku Expositions.

things, keeping some others for later. But you don't let go.

Anyway, I was assistant to Professor Yosida in Tōdai for two years, and in 1960 I moved to Tokyo University of Education as a lecturer—a higher position than assistant. Professor Iyanaga sent a copy of my work to André Weil who showed some interest, and suggested that I come to the Institute for Advanced Study (IAS). I visited the IAS from the fall of 1960 to 1962. But before leaving for Princeton, in June 1960, I gave a talk at the Extended Colloquium of Tōdai. This was a periodic meeting, organized by the Tōdai Mathematics Department twice a year. There, I had the opportunity to present my program in analysis. I explained how a manifold is the geometric counterpart of a commutative ring, and vector bundles are the counterpart of modules over that ring, and if you go to the non-commutative case you can treat linear and nonlinear differential equations. From this point of view, linear equations are defined to be $\mathcal{D}$-modules, and if you write $\mathcal{D}$ in a more general form, you can consider nonlinear systems.

At that time, that method was only built to establish the algebraic theory of Picard-Vessiot. This has not much contact with pure analysis, like the study of hyperbolic equations. In that field, the more geometrical methods of Élie Cartan, based on the theory of differential systems, were considered more effective. Nonetheless, as I have told several people, like Masaki Kashiwara or Pierre Schapira, I already had the feeling that Cartan's methods were not the right ones to build a general nonlinear theory. But it was only after 1970 that I—how should I say—I became determined to throw away exterior differential methods and stick to this new point of view.

Anyway, in my 1960 talk I clearly stated the setting of $\mathcal{D}$-module theory in the linear case, the notion of maximally overdetermined systems (a name that we later changed to *holonomic systems*), and the important role that holonomic systems play even in the study of overdetermined systems, through elementary solutions. For example, the Riemann function of a hyperbolic equation usually satisfies a holonomic system. I also explained my program using homological methods: $\mathcal{H}om$ describing the homogeneous solutions to the system, $\mathcal{E}xt^1$ the obstruction to solvability, and things like that.

Andronikof: *Did that talk contain maximally overdetermined systems? That is, did you have an idea of the involutivity theorem[4]?*

Sato: Mmm... Not exactly. It was only ten years later, after the establishment of microlocal analysis, that everything was clarified. Actually, I already had some vague ideas before 1960, but then I had only spent two years on these problems. I then moved to Princeton, and there I had to change my subject. I'll tell you about that later.

The first half of my talk at the colloquium in June 1960 was recorded in the notes by Hikosaburo Komatsu.

Andronikof: *What happened to the second half?*

Sato: Well, I kept going on and went into the nonlinear systems, and so on and so on... and he just couldn't keep up, ha! ha! You don't have to tell him this. Anyway, I am certainly indebted to Komatsu because this is a very rare case of a record of my talks. He was introduced to me in 1958 by Professor Yosida, of whom he was the best student. Komatsu was the first man who really understood hyperfunction theory, and he was just a graduate student!

At that time I gave a lot of talks at different occasions: for example, I gave a talk about derived categories. I needed that kind of theory because the notion of spectral sequence by Jean Leray was inconvenient in my theory. So I wanted to improve it and produced derived categories between 1958 and 1960.

Andronikof: *Were derived categories included in your 1960 colloquium talk?*

Sato: No, not at the colloquium talk. Professor Kawada, a number theorist at Tōdai, was very kind to me and organized some sort of seminar in 1959—small periodic meetings—to offer me the chance to expose my theory in a systematic way. There were a few lectures in his office, for a limited audience. But I found that no one understood me. So after a few times, I don't remember the exact number, this collapsed. Actually, Professor Kawada himself wondered daily how long it would last, ha! ha! He couldn't get the participants to understand.

This was before the summer vacation of 1959/1960. During the vacation, I had to attend some English training, before moving to Princeton, to be able to get a Fulbright grant. This is the kind of competition I'm not too good at... Then, I remember crossing the ocean on a 10,000-ton ship and crossing the USA by train: a very interesting trip. The first one for me.

Andronikof: *So you left behind some people pondering over your theories?*

Sato: Mmm... Well, I do a poor expository job in general. Most of the audience gets lost on the way.

Andronikof: *That might be due to the contents, which are always new.*

Sato: You see, it seems I cannot adapt to the audience. I just expose my ideas according to my way of thinking and pay little attention to how the audience receives them.

[4]*This theorem is a kind of analogue in the theory of differential equations to the uncertainty principle in quantum mechanics. It asserts that characteristic (co)directions constitute a variety of low codimension in the phase space.*

Let me tell you one more thing that happened before leaving for Princeton. It concerns the birth of microfunctions. On one occasion, a summer school I think, Professor Hitotumatu—who was just four years my senior—talked about the edge-of-the-wedge theorem in the theory of several complex variables. Of course, this was not done in the framework of hyperfunctions. So, I just mentioned that that concept could be better handled in the hyperfunction category: I had the cotangent nature of boundary values in mind.

Andronikof: *You knew at once that it should be the cotangent bundle[5] and not the tangent bundle?*

Sato: Yes, because of Cousin-like theorems: a holomorphic function can be decomposed into greater domains. At that time, I clearly felt the existence of some kind of microlocal structure underlying hyperfunctions, but I didn't consider it seriously. Anyway, that impression didn't leave me for a long time. It stayed with me.

For nine years, after my active period of 1958-1960, there was a long intermission for hyperfunctions. From 1960 to 1969 I didn't work in that field at all. Then, in April 1969, Professor Yosida held an international symposium on functional analysis at RIMS[6], and I was asked to give a talk. I think I was told this in December 1968. So I tried to organize those ideas I had ten years before and started to compute the theory. I found that my thought was correct. This time I wanted to show that the decomposition of hyperfunctions into cotangent components is actually important in analysis. I wanted to show that it would be useful in order to establish some results in mathematical physics. I wrote this down in less than a month, and this was the start of microfunction theory.

Andronikof: *The interruption in hyperfunction theory was due to your stay in Princeton?*

Sato: Yes. It seemed to me that even André Weil did not like my way of putting things in terms of cohomology very much. In fact, I learned that he was very much against cohomology. I got the idea that hyperfunctions were not taken very seriously, and since I was sort of a little boy (though I was 32!) I just wanted to show the usefulness of my ideas. My general program, which I had expanded at the colloquium talk of 1960, was just a very formal kind of general nonsense. I then wanted to give some concrete example of it in the analysis of differential equations. But my knowledge of that field was very poor. I'm not a reader of big books and specialized papers. I live for practical examples and, just as now, I was very slow in developing my deeper thoughts.

But let me go back to the talk I had occasion to give in 1969. I found that microlocal analysis could explain several interactions with classical analysis. This time I wanted to show that my theory was not just nonsense, but could be applied to explicit problems. I was confident that microlocal analysis, once organized, could persuade people of the usefulness of hyperfunction theory.

Andronikof: *Microfunctions were devised to help hyperfunction theory—so to speak!*

Sato: Yes, so that hyperfunction theory could at least be perceived as a method in analysis. $\mathcal{D}$-modules and things like that were not accepted at the time. The only one who really appreciated $\mathcal{D}$-modules was Masaki Kashiwara, who became interested in developing a survey of the theory. It was in 1969 or in 1970 that he did it, to get his master's degree. In Japan, this degree is considered of primary importance in order to obtain a position. So he published a very nice paper on $\mathcal{D}$-modules.

Andronikof: *You mean Kashiwara's master's thesis, handwritten in pencil, that can be found in Tōdai library[7].*

Sato: Yes, precisely. That was completely his own work. He had a very good background in general nonsense. In the lectures before the colloquium, I already developed as much general nonsense as I thought was needed for hyperfunction and $\mathcal{D}$-module theory. But it was rather informal, because I didn't do it in a systematic way, whereas Kashiwara started his mathematical career in a clear way from the very beginning. To perceive some of the difficulties of his task, recall that it was a kind of hunting age for such general nonsense. He learned Bourbaki, Grothendieck, and these things when he was eighteen or nineteen years old. He studied it by himself, with no teacher, when he was only—what do you call it?—a senior mathematics student. Yes, he is very ingenious. The best young boy I ever met.

Andronikof: *But who put him onto these subjects?*

Sato: After the first two years at Tōdai, he moved to Hongo campus. There, he first learned of hyperfunction theory in 1968, at a lecture by Komatsu. I think this lecture is fundamental in the history of algebraic analysis. It was published in the Seminar Notes of the University of Tokyo after notes taken by student participants like Kawai, Uchiyama, ...

Andronikof: *How did $\mathcal{D}$-modules come to Kashiwara?*

Sato: In 1968 Komatsu and I organized a weekly seminar on algebraic analysis at the Tōdai Mathematics Department, where I gave several talks—very disorganized, as my talks always are. It wasn't

[5] *The phase space of classical mechanics.*

[6] *Research Institute for the Mathematical Sciences, which is part of Kyoto University.*

[7] *Kashiwara's thesis has been translated into English by Andrea D'Agnolo and Jean-Pierre Schneiders: Masaki Kashiwara,* Algebraic study of systems of partial differential equations, *Mém. Soc. Math. France (N.S.) (1995), no. 63, xiv+72.*

an official seminar in Tōdai, but rather a kind of "Jacobin Club". Among the participants, there were many very eager young students, including Kawai and Kashiwara. I met them there for the first time, and the group of Kawai, Kashiwara, and myself was formed that year.

In spring 1969 some old friends of mine in Komaba, which is part of the Faculty of General Education of the University of Tokyo, arranged to have me go there as a professor. I stayed in Komaba for two years.

Andronikof: *And when did you come to RIMS?*

Sato and Emmanuel Andronikof, 1990.

Sato: It was in June 1970. Actually, in Tokyo I had a great understanding with Komatsu and other seniors, as well as with many young mathematicians who gathered at our seminar. Among the participants, besides Kashiwara and Kawai who were extremely active, there were Morimoto, Kaneko, Fujiwara, Shintani, Uchiyama, and some others. So, I could supervise a lot of people who were very eager to study mathematics with me, and I thought I should better stay at Tōdai than come to RIMS. Anyway, Professor Kôsaku Yosida, who was director of the Institute from 1969 to 1972, and of whom I was once an assistant, put great pressure on me to come to RIMS. He had already asked on the occasion of the seminar he had organized in 1969. But since I had a position at Komaba, that was delayed until 1970. I was unhappy when I had to move to Kyoto because it meant I would be separated from this group: I could bring Kawai and Kashiwara to Kyoto, but I had to leave others behind.

The Katata Conference and S-K-K

Andronikof: *As for the "milestones" in the birth of hyperfunction and microfunction theory, can you comment on the famous Katata conference in fall 1971?*

Sato: Actually, what I said at that conference was sort of completed quite early, just after 1969. I have already told you how microfunctions originated in preparing the talk I gave at the international symposium at RIMS in April 1969. I had planned to present some of the things I had in mind, like the cotangential decomposition of hyperfunctions, so I had to check whether my ideas were working or not. I started to check this in the three-hour *shinkansen*[8] trip, commuting from Tokyo to Kyoto (or vice versa, I don't remember) to attend a pre-symposium meeting at RIMS. You could say that the basic part of the theory was conceived during these three hours. But later I checked it in detail, and it was completed at the international symposium. The final touch was a proof of microlocal regularity for elliptic systems[9]. At the time, I employed Fritz John's method of plane wave decomposition. Of course, the idea went back to 1960, when I attended Professor Hitotumatu's talk on the edge-of-the-wedge theorem.

Andronikof: *When were the famous S-K-K*[10] *proceedings written?*

Sato: The basic structure of the paper hinges on my talk at the Katata conference, but the manuscript was completely prepared by Kawai and Kashiwara. Let us say I presented the whole story, but did not prove every detail. For example, concerning the notion of microdifferential operators, I worked out some cohomological constructions, but then Kawai and Kashiwara gave a better, more direct presentation, by which the proof of the invertibility for microelliptic operators, instead of using Fritz John's plane wave method, reduced to a kind of abstract nonsense. Kawai and Kashiwara must have taken a lot of effort to complete every detail.

The work was done between 1969 and 1971: surely the golden age of microfunctions. At the time, the three of us were working together, in the same places. In 1969 we were in Tokyo, then we moved to RIMS in 1970. Kawai came here as an assistant, while Kashiwara had only a kind of grant since he was very young at the time. He became assistant in 1971. I think the main part of the job was finished prior to the Katata conference, and was already presented in my talk at the Nice Congress [International Congress of Mathematicians] in 1970. To be precise, in the Nice talk the structure theorem for microdifferential systems was not yet finished. It was presented at the summer school on partial differential equations at Berkeley in 1971. I also prepared a kind of preprint, which did not appear in the proceedings of the Berkeley summer school, though it was distributed. There, I stated the structure theorem, asserting that all microdifferential systems are—at least generically—classified into three categories, the most important being what we called Lewy-Mizohata type system. The proof of this reduced to some simple nonlinear equations

[8] *A high-speed Japanese train.*

[9] *Now known as Sato's theorem.*

[10] *M. Sato, T. Kawai, and M. Kashiwara,* Microfunctions and pseudo-differential equations, *In Komatsu (ed.),* Hyperfunctions and pseudo-differential equations, *Proceedings Katata 1971, Lecture Notes in Mathematics, no. 287, Springer, 1973, pp. 265–529.*

describing some geometrical transformations[11]. I clearly remember discussing it with Kawai and Kashiwara. Actually, at Berkeley this was stated only for the simply characteristic case. The multiple characteristic case was done the following month, and all this was finished for the Katata conference. I must also say that at Katata I was given plenty of time, while at Berkeley my work was not taken into great consideration. I was sort of neglected there.

Andronikof: *So, when was the S-K-K manuscript ready?*

Sato: It was ready in 1971, but then Komatsu asked me to write a preface. I kept putting it off, so it was my fault that the publication was delayed by more than a year. I always behave in that silly way.

Andronikof: *Concerning another important result in S-K-K, could you comment on what is now called the* Fourier-Sato transformation? *When was it cooked up?*

Sato: As I told you, during my years as a schoolteacher I began to develop my own ideas in mathematics. Since the beginning, I had chosen the subject of generalized functions: both as one of the building blocks of my mathematical world and as a way to present some of my mathematical results, in order to get a job. It seemed to me that this subject could be quite easily appreciated. I estimated that the classical functional analytic approach, considering dual spaces to Banach spaces or to locally convex spaces, was not satisfactory at all. I was determined to throw away all these things, and to construct a theory which completely relied upon algebraic methods, like cohomology. What I wanted was to build something in the spirit of Cartan-Serre's presentation of Oka's theory of complex variables, or of Godement's work on sheaf theory. That was the idea of algebraic analysis, around 1960. You see, in this context the Fourier transform was not such a drastic idea to me, but rather a natural consequence of my kind of thinking. Of course, the actual theory of the Fourier transform was made later, in the course of systematizing microfunction theory, after 1969. At first, I constructed it using a quite straightforward method, considering the edge-of-the-wedge and the microlocal decomposition. But then I tried to describe it in a more algebraic way. That is when I arrived at the formulation of the Fourier transform as it appears in the S-K-K proceedings, with the three exact sequences: one on the base space, and two in the tangent and cotangent bundles.

[11] *What they called* quantized contact transformations.

The Theory of Prehomogeneous Vector Spaces

Andronikof: *Between 1960 and 1967, what happened to the broad program in mathematics that you devised? You said that you had stopped working in microfunction theory.*

Sato: Things are not so linear, of course. Let us say that I was working on microfunction theory in the background, while considering several other problems in parallel. In my twenties, my thoughts were scattered. While trying to organize analysis on an algebraic basis, I was also very much interested in subjects such as special functions via concrete examples, class field theory, automorphic forms, and of course quantum field theory. As I told you, after mathematics I had switched to the physics department for six years, from 1952 to 1958. Since I had to work as a high school teacher, I couldn't participate in research activities at the university, but nevertheless physics was one of my major subjects of interest.

Anyway, when I moved to Princeton in 1960, I wasn't acquainted with the mathematical society. I always pursued mathematics my own way, which was not the academic one. I was a kind of amateur in mathematics, certainly not a professional. As a consequence, whenever I tried to explain my ideas, I did not know which parts were well known or which were new. Most of the time people did not understand me. In Princeton there were a number of eminent and active mathematicians, but to them I just seemed a strange man with some very strange ideas. So I decided that in order to connect with some audience, I should devise some applications of my theory to differential equations. Of course, I then thought of developing the theory of differential equations from scratch. In my talk in Tokyo in 1960, I had already pointed out how holonomic systems are a powerful tool in understanding other differential equations, and how they give an algebraic way of defining special functions. But gradually, I understood that fundamental solutions may not satisfy holonomic systems in the usual sense: to understand the situation better you have to go to some wider class of equations: nonlinear, of infinite degree, or with an infinite number of independent variables.

To develop the theory of differential equations from the beginning, I thought I had to get acquainted with differential equations through concrete examples. As you know, the differential equations one usually encounters are mainly of second order, like the Laplace equation, the wave equation, the heat equation, or some modifications of these where the coefficients are variable. So, I tried to get a good example that was beyond the second order but that was still manageable through a special function. That is how, in spring

1961 I think, I devised the theory of prehomogeneous vector spaces (PHVS). Though the name is not a good one, I wanted it to mean a vector space that is not exactly homogeneous, but homogeneous except for a rather inessential subspace. PHVS gave a good generalization of the Laplacian, whose principal part is a quadratic form. A quadratic form is connected with orthogonal transformations, and PHVS generalizes this to the case of arbitrary groups. In this framework, instead of a quadratic form we can consider other interesting polynomials, associated to differential equations of higher order, whose principal part is very symmetrical, like a determinant or a discriminant. Moreover, I immediately realized that PHVS could also be useful in the theory of the Fourier transform, or to get generalized ζ-functions, and so on. Throughout this month of 1961, I was engaged in this theory, and in connection with this concept I introduced the notion of the a-function and b-function. The most important is the b-function[12], since it makes it possible to define a generalization of hypergeometric functions, and the a-function is nothing but the principal symbol of the b-function. The reason for "a" and "b" is that a is easier but b can also be developed from this concept. In late 1961, I explained these things at a seminar at Princeton conducted by Armand Borel. I gave two talks there, but again I think the subject was not fashionable at the time. It was something people were quite unfamiliar with, out of the focus of contemporary mathematicians, and so they just ignored or forgot it.

Because of this situation, the following year I tried to do something fashionable. So, I took up something else which I had in mind, about number theory. I was quite well acquainted with algebraic number theory and especially class-field theory and ζ-functions or automorphic forms. You know, Japan had a strong tradition in algebraic number theory, since Takagi and its school: Iwasawa, Shimura... It was one of my favorite subjects, and I started investigating it more seriously. I was interested in the Ramanujan conjecture, and I began working on it during the summer of 1962. Actually, Shimura was also working very actively in that field at that time. My term in Princeton expired that summer, and just before my departure I succeeded in establishing the relation between Ramanujan-type functions and the Dirichlet series. I won't go into detail about this, since I think we should stay within microlocal analysis. We cannot focus on too many subjects at a time.

In August 1962 I returned to Japan. At that time, mathematics departments were very small. Including all universities like Tokyo, Osaka, and Kyoto, there were only five positions for professors. A professor of analysis from Osaka University was retiring, and Matsushima invited me very strongly to go there. So I moved to Osaka University in spring 1963. There, I had a couple of good young students working with me. Once again, what I then did remained unpublished, with the possible exception of a talk that I gave at Tōdai, and of which Ihara wrote a report: some record of it exists in the form of handwritten notes in Japanese, in a journal for young mathematicians. Later, Ihara wrote a paper about this work of mine, but the story is rather complicated since there is a relation with later work by Deligne, and if I present it briefly I risk being imprecise. So just forget about it.

The following year, in 1964, I went to Columbia University, where I stayed as a visiting professor for two years. Serge Lang invited me there. You see, he came to Japan and was impressed by my work: that is, my work in number theory! Ha!, ha!

Andronikof: *Let me return to PHVS. You said the theory came about through your interest in high order PDEs.*

Sato: Yes, but at the same time it has a relation with algebra, geometry, number theory, θ-functions, generalized ζ-functions, and so on. It is a very interesting subject, related to later developments of microlocal calculus. But again, this is another subject, and so I won't go into detail. Let me just mention that a very good mathematician, Takuro Shintani, who unfortunately died some years ago, wrote a paper which is the basis for the theory of PHVS applied to ζ-functions. After a seminar he gave in Tokyo, a number of mathematicians from Japan, the USA, and Europe began to work on that subject. So, although I am not active in that field at the moment, the theory of PHVS is far from being buried, and instead is a rapidly developing subject.

This is more or less how my time was spent from 1960 to 1967. In 1967 I really started considering PDEs through algebraic analysis, i.e., in the category of hyperfunctions and microfunctions.

Andronikof: *What happened just after 1966, when you came back from Columbia?*

Sato: I resigned from Osaka in fall 1966 and was out of the university for a year and a half, when I became professor at Komaba. In fact, I had been living in Tokyo since early 1967. There, I met Komatsu, and we started the Tokyo seminar on algebraic analysis I told you about. It lasted until Kawai, Kashiwara, and I left for Kyoto in 1970.

Toward Mathematical Physics

Andronikof: *And after the congress in Nice, you went to France.*

Sato: Yes, Kawai, Kashiwara, and I stayed in Nice from September 1972 until the next aca-

[12]*Now called* Bernstein-Sato polynomial.

Emmanuel Andronikof

Pierre Schapira

Emmanuel Andronikof passed away on September 15, 1995, from a brain tumor discovered two years earlier, just after he had been named professor at the University of Nantes. He faced his illness with exceptional courage, never complaining about his misfortune or about the unfairness of this world. Perhaps his character was a product of his strict orthodox and aristocratic Georgian education. An excellent sportsman, especially in boxing and swimming, he had a unique vision of life and was able to spend long days in a forest with nothing but a book of Russian poetry. Needless to say, he was not interested in the games of power, not even in his own career. While he was devoted to science, he looked at the scientific world as a theater with very few actors and many jokers, considering himself to be an extra.

Nevertheless, his contribution to mathematics is highly significant. In his thesis, he succeeded in making a synthesis of the microlocalization functor of M. Sato and the temperate cohomology of M. Kashiwara, defining the functor of temperate microlocalization. This opened the way to the linear analysts to study microlocally (i.e., in the cotangent bundle) distributions, or more generally temperate cohomology classes, with the tools of homological algebra, sheaf theory, and $\mathcal{D}$-module theory. In other words, this was the first step towards a "temperate microlocal algebraic analysis", and Emmanuel Andronikof began to apply his functor to handle various problems. He provided an illuminating proof of the Nilsson theorem on the integrals of holomorphic functions of "Nilsson class", he proved that the C^∞-wave front set of a distribution solution of a regular holonomic system coincides with its analytic wave front set, and he was the first to give a microlocal version of the Riemann-Hilbert correspondence, this last work being at the origin of further important developments (see [7] and [6]). He also had many projects that he was unfortunately unable to carry out to completion.

The departing of Emmanuel Andronikof leaves us with the memory of an excellent man, both rigorous and open, tough and gentle.

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demic year. There, I became acquainted with a number of mathematical physicists who Frédéric Pham had invited from different parts of Europe. Moreover, Pham stimulated my interest in studying a program in mathematical physics. He introduced me to the momentum space structure of an S-matrix and Green functions in quantum field theory. This was the first time I became interested in applying microlocal analysis to such subjects. Later, Pham worked in that field for quite a long time.

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Then I returned to Japan in the spring of 1973. In April of that year, Tetsuji Miwa came to Kyoto and obtained a position as an assistant at RIMS. He was a very good student of Komatsu at Tōdai and had studied hyperbolic equations with him. The following year, in 1974, Michio Jimbo had just finished his undergraduate courses and was preparing to enter the graduate school of Kyoto. He spent two years there and then got a position as an assistant at RIMS in 1976.

Miwa, Jimbo, and I worked on the subject in mathematical physics in which I'd become interested through Pham and his friends. We began studying the momentum space structure. In order to have a clearer idea than from the general quantum field theory, I intended to use some very concrete examples. Working in that direction, I just took up the Ising model. In fact, when I was a student in physics I was very much interested in quantum field theory, of course, but also in statistical physics and statistical mechanics. At that time, Dr. K. Ito, a theoretical physicist who was then a graduate student, mentioned a paper by a young Russian mathematician on correlation functions in the Ising model that we found very interesting. Later, Professor Masuo Suzuki from Tōdai mentioned the work of Wu-McCoy-Tracy-Barouch ([1]) on the two-point function of the Ising model. It was probably published in 1976, but I learned later from Barry McCoy that their work had been conceived much earlier, around 1973. The remarkable point is that their work contained a correct expression by means of Painlevé transcendents. It was a pleasant surprise to me that such special functions actually appeared in concrete problems of theoretical physics, especially in one of my favorite subjects, the Ising model. So, we developed this much further with Miwa and Jimbo. We started doing this around 1976, having spent the previous three years doing much more elementary things, in order to get acquainted with the subject. Everything worked very effectively, and very quickly, in 1977, we finished working in that direction. 1976–1978 was a very fruitful time. Since then, Jimbo and Miwa have done quite a lot of things.

Andronikof: *What about the KP hierarchy?*

Sato: We became acquainted with many people in soliton physics. Date was a student of Professor Tanaka, who was in Osaka at that period and then moved to Kyushu University. Tanaka and Date were pioneer mathematicians, who introduced soliton theory in Japan, including Krichever's work, Jacobian variety, θ-function, KdV, and KP equations. We learned about these things through them during that period. Of course, there were many people in physics departments or engineering departments who were interested in soliton theory, but in the world of pure mathematics in Japan, it was Tanaka who introduced such modern developments in connection with soliton theory. I also learned a lot from Hirota. He is a very important name in soliton theory, although he is not a mathematician in the strict sense. He is very unique, in that he has his own system of mathematics, so to speak, and has devised quite a unique method of analysis of soliton theory. And this inspired me. You see, most of the time, when I meet some new subject in mathematics, I don't find it very strange. I'm thinking about the traditional systems of mathematics, like those of Newton, Leibniz, or even Descartes, Gauss, Riemann, and so on. But Hirota's mathematics seemed to me quite strange, so I just wanted to understand it in the language of modern mathematics. In this way I finally arrived at the concept of infinite-dimensional Grassmannian manifold around Christmas 1980, in collaboration with my wife. We performed lots of computations, using BASIC programs. Looking at them day after day, I finally realized that in the background of the whole story stood a Grassmannian manifold of infinite dimension. Again, once I arrived at this concept of Grassmannian manifold and Plücker coordinates, things developed quite quickly, and in a very short period—less than a month—everything was almost finished.

Andronikof: *Who works on KP nowadays here?*

Sato: I don't think that anyone is working seriously on it now. But at the time Miwa and Jimbo and others developed the theory in connection with Kac-Moody algebras. I worked to generalize this to higher dimensions. You see, KP is a kind of one-dimensional theory, using microdifferential operators in one variable, so we tried to generalize it to higher dimensions and did it in part with my graduate students Ohyama and Nakayashiki. But I am not yet satisfied with this. I gave some talks on this subject at the AMS summer institute organized by Ehrenpreis in 1988. They have been written down by Takasaki([4]).

Andronikof: *It seems that many subjects have been lying dormant inside like still waters, like a volcano waiting to erupt. Where did you turn your attention to after KP theory?*

Sato: Life is not limited to mathematics, and one is forced to engage in other things. So, unwillingly of course, at some times I was prevented from focusing in mathematics. Starting from about 1980, I was not able to concentrate on mathematics for several years, and I was rather unhappy. As I told you, mathematics give me relief from everyday life, so to speak. Anyway, it has only been in the last two or three years that I have been able to work again. I'm now trying to reorganize my own mathematics these days.

Sato's School

Andronikof: *Which mathematicians played a role as supporters of your ideas, as propagators of the theory?*

Sato: At the early stage the most important names were Iyanaga, Komatsu, Martineau and, in a sense, André Weil. After 1970 I became acquainted with a lot of French people, like Schapira, who is a student of Martineau, or Pham, as I told you, and Jean Leray.

Andronikof: *Did you create a school?*

Sato: This may be partly true, but in fact many of the active people were students of Komatsu at Tōdai. Kawai graduated with him in 1968 and came to RIMS in 1970 as an assistant. In 1968 I also met Kashiwara, who was only a junior student at Tōdai. Since I was at Komaba at the time, he formally registered with Kodaira, but in practice he was with me. Miwa was also a student of Komatsu and came to RIMS in 1973 as an assistant. Jimbo was my only graduate student among these people. As concerns PHVS, Shintani was the most important person. He was not a permanent member of the Tokyo seminar, because Komatsu was not interested in PHVS. He was a very talented mathematician, and if he were alive he would now be a major figure in the world of mathematics, like Kashiwara. Kimura was in the same generation as Miwa. Though not in a formal sense, he was also my student and often came to Kyoto to study PHVS—in which he is an important figure.

Andronikof: *For nonlinear equations you had Takasaki, Ohyama, Nakayashiki?*

Sato: Yes. Actually, Takasaki was a student of Komatsu, and he joined me rather late. After finishing his course at Tōdai, he formally stayed in Tokyo for three more years, but actually came to Kyoto. Ohyama and Nakayashiki are from Kyoto University and came as graduate students to RIMS, so they are really my students.

Andronikof: *Do you have any students working on your ideas on number theory?*

Sato: Mmmhh... Not many.

Andronikof: *Tōdai has been a good source of students for you.*

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Sato: True. Remember that when I came here twenty years ago I didn't want to leave Tokyo because I didn't want to sever ties with the young mathematicians who were eager to work with me, and it was with some regret that I came to Kyoto. In spring 1992 I'll be retiring from the University of Kyoto, and I will have no other choice but to work here, ha! ha!

Andronikof: *Is there such a thing as retirement in mathematics?*

Sato: Well, I'm not retiring from mathematics at all, but I have less time to work now. I am not young anymore, and my brain is not as fast...

Research Now and Future[13]

Andronikof: *What is left of your colonies of ideas? What has not been exploited yet of the program you exposed at the colloquium in 1960?*

Sato: In that sense: nonlinear equations. I have been keeping it in mind since that time, and it's still not worked out very well. I now want to include singular perturbation in my framework, but all this is not enough.

Andronikof: *So you are not yet satisfied with the form you gave to nonlinear equations?*

Sato: It is just a starting point, as you see... In 1960 I proposed the $\mathcal{D}$-module concept as the most natural way to deal with linear equations, so everything can be worked out by means of homological algebra, and I also introduced what are now called holonomic systems. But in the case of nonlinear equations, the only application of differential algebra was to a kind of Galois theory for equations of the Picard-Vessiot type. It is a rather minor branch in analysis, the major stream in analysis being, say, Hadamard's theory of hyperbolic equations.

At the time, the major battlefield in nonlinear PDEs was mathematical physics, as described for example in Courant-Hilbert's famous book, and differential geometry, with the Monge-Ampère, Hamilton-Jacobi, and Einstein equations, and contact transformation theories. These concepts naturally fitted in Élie Cartan's scheme, and I was not sure that my approach by means of the nonlinear filtered differential algebra $\mathcal{D}$ could work as effectively... But later I became more and more confident that this algebraic method was the only natural way to develop a general theory, because it represents the structure of differential equations without depending on how you write down the equations. Anyway, in my 1960 talk I just touched upon two main methods to develop the general theory of nonlinear equations, without sorting out either of them.

Andronikof: *In the one-dimensional case what do you think of Jean Ecalle's approach?*

[13] *That is, in August 1990.*

Sato: My way of understanding it is that this kind of problem is close to what Pham noticed at a meeting in Greece three years ago and is related to my oldest problem in connection with PDEs. In my talk of 1960 I explained that linear nonholonomic systems can be related to holonomic ones by considering elementary solutions: what Riemann called singular functions. Suppose you have a PDE on a manifold X. Then its fundamental solution can be expected to satisfy some holonomic system, not on X but on $X \times X$. In that way, one could hope to control the whole theory of PDEs through holonomic systems.

However, it soon appeared that this program could not be carried out, because in certain cases the fundamental solution may not be holonomic in a strict sense. For example, some particular fundamental solutions may contain a factor of the form x^y, with both x and y being variables (of course, x^α, α constant, is a solution to a holonomic system). This happens quite often, and this means that you have to further extend the concept of holonomic system by considering equations of infinite order, or by involving an infinite number of independent variables. This is now a quite natural thing in modern mathematical physics. The work of Pham, Ecalle, André Voros, as well as some earlier works by mathematical physicists, seem to have close connections with such difficulties. This is also related to singular perturbation theory. There, an equation involves a parameter and at some value—which could be a coupling constant, or Planck's constant—the system becomes singular, so convergence is lost, although it is summable by some kind of Borel resummation. This kind of resummation is not unique—contrary to the convergent case—but depends on the chosen direction. If you move the direction it may suddenly change, yielding a kind of Stokes phenomenon. And this again is related to concepts like instantons or tunneling, which are also quite common in mathematical physics and are related to monodromy groups and so on. It is clear that such quite general concepts should be handled systematically in analysis.

In my talk at Okayama[14], I explained that singular perturbation can be dealt with by considering solutions of nonlinear equations which are neither holomorphic nor hyperfunctions but rather a kind of modified microfunctions, living in a filtered formal function space. For example, microfunctions supported at the origin are generated by the Dirac δ function together with its derivatives. If you apply microdifferential operators of order zero you get something like a Heaviside function times analytic functions, and this is the kind of special microfunction whose

[14] *On the occasion of ICM-90 Satellite Conference on Special Functions.*

support is the origin. In several variables solutions have to be holomorphic in some variables but in the remaining ones it can be like a δ function or Heaviside function. Such mixed solutions can give a singular perturbation situation. This is what I tried to explain in Okayama—though I did not develop my talk in a very organized way. Anyway, this is how I see the work of Ecalle, Voros, or others. I think these things are very important and very natural in many problems of mathematical physics.

Andronikof: *Like shock waves?*

Sato: Yes, shock waves or diffraction, which are described by subdominant terms. The magnitude of the backward wave is exponentially small, so that the C^∞-theory cannot take it into account. But the analytic theory can single it out. This subdominant effect is related to Ecalle's notion of resurgency. In quantum physics, tunneling is also related to subdominant or Stokes phenomena. This aspect of analysis should be exploited to reach a consistent understanding, a correct general theory of such phenomena. I think this should be done in coming years.

During the congress [15] it should have clearly appeared that mathematical physics is very important, not only in applied, but also pure mathematics, including analysis, geometry, algebraic geometry, and number theory. But there are actually deeper connections with mathematical physics. This is not fully exploited yet. Ecalle's, Voros's, or earlier works, like Balian-Bloch ([2]) and Bender-Wu ([3]), are instances of applications of analysis to mathematical physics. But, in my opinion, this is still very primitive. There is work for the next decade in order to settle things so that analysis can really be applied to mathematical physics. While methods of mathematical physics in quantum field theory have profited various branches of mathematics (topology, braid theory, number theory, geometry), the converse is not necessarily true. Today, mathematical physicists mostly use number theory or algebraic geometry. Mathematical physics is receptive only to higher developed areas of mathematics, some of which are exploited in superstring theory, though not to its full extent. Mathematics has not succeeded in providing a more effective way of computation than perturbation expansions. Of course, there are some primitive methods of computation, like the Monte-Carlo method. All these are kind of brute force computations, not refined mathematics, surely not refined enough for the problems physics is now confronted with, like determining the mass of particles or quarks. All these things are discussed on a very abstract level, not on a quantitative level. So I think that mathematical analysis should be developed much further to match the reality of physics.

Andronikof: *What could remain of these problems in the twenty-first century?*

Sato: I cannot say: a good mathematician can appear in each branch. If one of these branches attracts a good young mathematician, this branch might develop quite rapidly. Look for instance at the past: if there were no Grothendieck or Deligne, things in algebraic geometry would have developed in a different way. But you can imagine how it is going to evolve in the next few years, because a number of very active mathematicians at this congress gave a number of very interesting talks and would give you an idea of what mathematicians in the 1990s will look like.

Andronikof: *My last question is about Japanese mathematics—the fact that in modern mathematics Japan has risen from nowhere to its current outstanding place.*

Sato: I'm not a specialist in Japanese mathematical history, but as I have explained it, Japan has a good background for modern mathematics. About two or three hundred years ago, at the time of Leibniz and Newton, we had Seki, one of the founders of Japanese mathematics. He and some of his great followers developed a kind of algebra. Some elementary mathematics, related to counting, was introduced from China. But Seki developed a major system of algebra and even infinitesimal calculus. He developed a theory for algebraic equations, with Chinese characters instead of x and y. He dealt with linear equations in several variables, with higher-order algebraic equations, though he did nothing like Galois theory or Cardano formulas for cubic equations: instead he developed approximate solutions akin to Newton-Horner methods. Also, he knew how to solve linear equations using the Cramer method, since he had the notion of determinant, earlier than in Europe. He used derivatives to determine maxima and minima of a polynomial in several variables. But the biggest defect of his system was that they did not see at the time that integration is the converse of differentiation. So they computed integrals the way Archimedes did, obtaining volumes and areas using a kind of slicing procedure. One of the typical integrals appearing in connection with computing area or volume for which they had such a formula, is $\int_0^1 (\sqrt{1-x^2})^n dx$, for n odd. This is just one type of accomplishment of Japanese mathematics in the seventeenth and eighteenth century.

Andronikof: *Did it go on?*

Sato: Although we had this tradition, mathematics declined to a kind of hobby. The government in the Meiji era decided to adopt Western mathematics, because Japanese mathematics is just a kind of empirical thing. They did not pay

[15] *Kyoto, ICM 1990.*

much attention to logic. So even in geometry, they did not develop a demonstration. Just a discussion is given, but not a completely logical inference.

Andronikof: *What about RIMS[16]?*

Sato: When the Russians sent the Sputnik into orbit in 1957, it was a big shock in the USA. This certainly motivated them to develop their science. At that time, the number of professors in scientific branches, including mathematics, simply doubled. The same thing took place in Japan, a little later. Scientists had a good excuse to get more money. A number of institutes of technology and physics, but also of pure sciences, were built at that time. Many senior mathematicians, like Yosida and Iyanaga, persuaded our government to found a new institute for mathematics. The Institute was created in 1959, when I had just started my career.

Tōdai had already too many research institutes independent of the departments and was reluctant to have a new one. So it was finally decided that the new mathematical institute should be opened within Kyoto University, which supported the idea.

Andronikof: *And from the start it was devoted to pure mathematics?*

Sato: It was devoted to mathematical sciences. The fact is that its emphasis is on pure mathematics, but it also includes a few mathematical physicists and a few computer scientists. We are even trying to put emphasis on applied mathematics. This balance has now changed. We have to recover this. The importance of computer science in mathematics is recognized, as we can see by the Nevanlinna Prize, dedicated to that discipline.

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Interview with Abel Prize Recipient Lennart Carleson

Martin Raussen and Christian Skau

Lennart Carleson is the recipient of the 2006 Abel Prize of the Norwegian Acdemy of Science and Letters. On May 22, 2006, prior to the Abel Prize celebration in Oslo, Carleson was interviewed by Martin Raussen of Aalborg University and Christian Skau of the Norwegian University of Science and Technology. The interview was later shown on Norwegian television. The first two questions in the interview, and their answers, were originally phrased in three Scandinavian languages: Norwegian, Danish, and Swedish. They are here translated into English. This interview originally appeared in the September 2006 issue of the *European Mathematical Society Newsletter*.

R & S: *On behalf of the Norwegian and Danish mathematical societies, we want to congratulate you on winning the Abel Prize for 2006.*

This year we commemorate the 100th centenary of the death of the Norwegian dramatist and poet Henrik Ibsen. He passed away on the 23rd of May just a stone's throw away from this place. The longest poem he ever wrote is called "Balloon letter to a Swedish lady" and it contains a verse which reads as follows:

"—aldri svulmer der en løftning
av et regnestykkes drøftning
—ti mot skjønnhet hungrer tiden—"

Translated into English this becomes:
"—never arises elation
from the analysis of an equation
—for our age craves beauty—"

Without drawing too far-reaching conclusions, Ibsen seems to express a feeling shared by many people, i.e., that mathematics and beauty or art are opposed to each other, that they belong to different spheres. What are your comments to this view?

Carleson: I do not think that Ibsen was very well-oriented about beauty in mathematics, which you certainly can find and enjoy. And I would even maintain that the beauty of many mathematical arguments can be easier to comprehend than many modern paintings. But a lot of mathematics is devoid of beauty. Maybe particularly in modern mathematics, where problem areas have often gotten extremely complex and complicated, with the result that the solution can only be formulated on several hundreds of pages. And that can scarcely be called beautiful. But in classical mathematics you find many striking theorems and arguments that hit you as something really original. It is reasonable to use the term beauty for those.

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Photo: Terje Bendiksby/Scanpix.

From left to right: Lennart Carleson, Martin Raussen, and Christian Skau.

R & S: *Mathematicians all over Scandinavia are proud of counting one of their own among the very first recipients of the Abel Prize. How would you characterize and evaluate Scandinavian, and particularly Swedish, mathematics in an international perspective?*

Carleson: I think that Scandinavia does quite well in this respect. In Sweden, we have a fine new generation of young mathematicians. And I think it looks very much alike in the other Scandinavian

Lennart Carleson receives the Abel Prize for 2006 from Queen Sonja.

countries. It is difficult to perceive a new Abel on the horizon, but that is probably too much to hope for.

R & S: *Could you please characterize the unique contribution that the Finnish/Swedish school of Lindelöf, M. Riesz, Carleman, R. Nevanlinna, Phragmen, Beurling, and Ahlfors brought to analysis in the first half of the 20th century, which was formative and decisive for your own contribution to hard analysis?*

Carleson: In your list, you miss another Scandinavian mathematician: J. L. Jensen. The importance of "Jensen's inequality" can hardly be exaggerated. He and Lindelöf started the Scandinavian school, building of course on Riemann's approach to complex analysis rather than that of Cauchy-Weierstrass; Nevanlinna and Carleman continued, followed by Ahlfors and Beurling, a remarkable concentration of talent in Scandinavia. My lecture tomorrow will give more details.

Mathematical Achievements in Context

R & S: *Abel first thought that he had solved the general quintic by radicals. Then he found a mistake and subsequently he proved that it was impossible to solve the quintic algebraically. The famous and notoriously difficult problem about the pointwise convergence almost everywhere of L^2-functions, which Lusin formulated in 1913 and actually goes back to Fourier in 1807, was solved by you in the mid-1960s. We understand that the prehistory of that result was converse to that of Abel's, in the sense that you first tried to disprove it. Could you comment on that story?*

Carleson: Yes, of course. I met the problem already as a student when I bought Zygmund's book on trigonometric series. Then I had the opportunity to meet Zygmund. He was at Harvard in 1950 or 1951. I was at that time working on Blaschke products, and I said maybe one could use those to produce a counterexample. Zygmund was very positive and said "of course, you should do that." I tried for some years and then I forgot about it before it again came back to me. Then, in the beginning of the 1960s, I suddenly realized that I knew exactly why there had to be a counterexample and how one should construct one. Somehow, the trigonometric system is the type of system where it is easiest to provide counterexamples. Then I could prove that my approach was impossible. I found out that this idea would never work; I mean that it couldn't work. If there were a counterexample for the trigonometric system, it would be an exception to the rule.

Then I decided that maybe no one had really tried to prove the converse. From then on it only took two years or so. But it is an interesting example of "to prove something hard, it is extremely important to be convinced of what is right and what is wrong". You could never do it by alternating between the one and the other because the conviction somehow has to be there.

R & S: *Could we move to another problem, the so-called Corona problem that you solved in 1962? In this connection, you introduced the so-called Carleson measure, which was used extensively by other mathematicians afterwards. Could you try to explain why the notion of the Carleson measure is such a fruitful and useful notion?*

Carleson: Well, I guess because it occurs in problems related to the general theory of BMO and H^1-spaces. I wish this class of measures had been given a more neutral name. In my original proof of the Corona problem, the measures were arc lengths on the special curves needed there. Beurling suggested that I should formulate the inequality for general measures. The proof was the same and quite awkward. Stein soon gave a natural and simple proof and only then the class deserved a special name.

R & S: *I'll move to another one of your achievements. Hardy once said that mathematics is a young man's game. But you seem to be a counterexample; after you passed sixty years of age, you and Michael Benedicks managed to prove that the so-called Hénon map has strange attractors exhibiting chaotic behaviour. The proof is extremely complicated. It's a tour de force that took many years to do. With this as a background, what is your comment on mathematical creativity and age?*

Carleson: I guess and hope that you don't get more stupid when you get older. But I think your stamina is less, your perseverance weakens (keeping lots of facts in your mind at the same time).

Probably this has to do with the circulation of the blood or something like that. So I find it now much harder to concentrate for a long period. And if you really want to solve complicated problems, you have to keep many facts available at the same time.

Mathematical Problems

R & S: *You seem to have focused exclusively on the most difficult and profound problems of mathematical analysis. As soon as you have solved any one of these, you leave the further exploration and elaboration to others, while you move on to other difficult and seemingly intractable problems. Is this a fair assessment of your mathematical career and of your mathematical driving urge?*

Carleson: Yes, I think so. Problem solving is my game, rather than to develop theories. Certainly the development of mathematical theories and systems is very important but it is of a very different character. I enjoy starting on something new, where the background is not so complicated. If you take the Hénon case, any schoolboy can understand the problem. The tools also are not really sophisticated in any way; we do not use a lot of theory.

The Fourier series problem of course used more machinery that you had to know. But that was somehow my background. In the circles of dynamical systems people, I always consider myself an amateur. I am not educated as an expert on dynamical systems.

R & S: *Have there been mathematical problems in analysis that you have worked on seriously, but at which you have not been able to succeed? Or are there any particular problems in analysis that you especially would have liked to solve?*

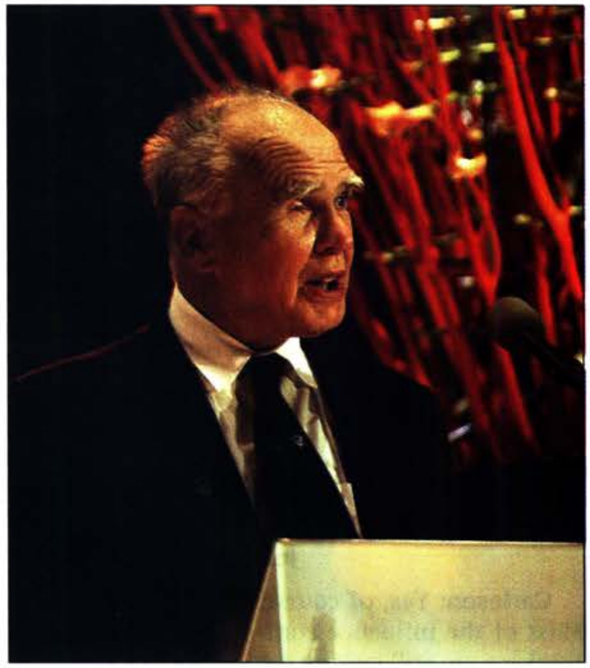
Carleson: Yes, definitely. There is one in dynamical systems, which is called the standard map. This is like the Hénon map but in the area-preserving case. I spent several years working on it, collaborating with Spencer for example, but we never got anywhere.

If you want to survive as a mathematician, you have to know when to give up also. And I am sure that there have been many other cases also. But I haven't spent any time on the Riemann hypothesis... and it wouldn't have worked either.

Characterization of Great Mathematicians

R & S: *What are the most important features, besides having a good intellectual capacity of course, that characterize a great mathematician?*

Carleson: I don't think they are the same for everybody. They are not well defined really. If you want to solve problems, as in my case, the most important property is to be very, very stubborn. And also to select problems which are within reach. That needs some kind of intuition, I believe, which is a little closer to what we talked about initially, about beauty. You must somehow have a feeling for mathematics: What is right, what is wrong, and what is feasible. But, of course, there are many other mathematicians who create theories and they combine results into new buildings and keep other people working. It is a different kind of a mathematician. I don't think you should try to find a simple formula for people.



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Lennart Carleson

R & S: *For several decades, you have worked hard on problems that were known to be exceptionally difficult. What drove you and what kept you going for years, with no success guaranteed? What drives a person to devote so much energy to an arcane subject that may only be appreciated by a handful of other mathematicians?*

Carleson: Yes, that's a big issue. Stubbornness is important; you don't want to give up. But as I said before, you have to know when to give up also. If you want to succeed you have to be very persistent. And I think it's a drive not to be beaten by stupid problems.

R & S: *Your main research contribution has been within mathematical analysis. What about your interest in algebra and topology/geometry?*

Carleson: Geometry is of course very much part of the analysis. But I have no feeling for algebra or topology, I would say. I have never tried to... I should have learned more!

Mathematics of the Future

R & S: *What do you consider to be the most challenging and exciting area of mathematics that will be explored in the twenty-first century? Do you have any thoughts on the future development of mathematics?*


Photo: Scanpix.

Abel laureates Peter Lax (2005), Lennart Carleson (2006), and Jean-Pierre Serre (2003).

Carleson: Yes, of course I have had thoughts. Most of the influence comes from the outside. I think we are still lacking a good understanding of which kind of methods we should use in relation to computers and computer science. And also in relation to problems depending on a medium-sized number of variables. We have the machinery for a small number of variables, and we have probability for a large number of variables. But we don't even know which questions to ask, much less which methods to use, when we have ten variables or twenty variables.

R & S: *This leads to the next question. What is the significance of computers in mathematics? Is it mainly checking experimentally certain conjectures? Or is it completing proofs by checking an enormous amount of special cases? What are your thoughts on computers in mathematics?*

Carleson: There are a few instances that I have been involved with. I had a student, Warwick Tucker, who proved that the Lorenz attractor exists. The proof was based on explicit computations of orbits. And in that case you could get away with a finite number of orbits. This is very different from the Hénon map, where you could never succeed in that way. You could never decide whether a parameter was good or bad. But for the Lorenz attractor he actually proved it for the specific values that Lorenz had prescribed. Because it is uniformly expanding, there is room for small changes in the parameter. So this is an example of an actual proof by computer.

Of course then you could insist on interval arithmetics. That's the fine part of the game so to say, in order to make it rigorous for the people who have very formal requirements.

R & S: *But what about computers used, for instance, for the four-color problem, checking all these cases?*

Carleson: Probably unavoidable, but that's okay. I wouldn't like to do it myself. But it's the same with group structures, the classification of simple groups, I guess. We have to accept that.

R & S: *The solution of the 350-year-old Fermat conjecture, by Andrew Wiles in 1994, uses deep results from algebraic number theory. Do you think that this will be a trend in the future, that proofs of results which are simple to state will require a strong dose of theory and machinery?*

Carleson: I don't know.

The striking part in the proof of the Fermat theorem is the connection between the number theory problem and the modular functions. And once you have been able to prove that, you have moved the problem away from what looked like an impossible question about integers, into an area where there exists machinery.

Career. Teachers.

R & S: *Your CV shows that you started your university education already at the age of seventeen and that you took your Ph.D. at Uppsala University when you were twenty-two years old. Were you sort of a wunderkind?*

Carleson: No, I didn't feel like a wunderkind.

R & S: *Can you elaborate about what aroused your mathematical interests? And when did you become aware that you had an exceptional mathematical talent?*

Carleson: During high school I inherited some books on calculus from my sister. I read those but otherwise I didn't really study mathematics in any systematic way. When I went to university it was natural for me to start with mathematics. Then it just kept going somehow. But I was not born a mathematician.

R & S: *You already told us about your Ph.D. advisor, Arne Beurling, an exceptional Swedish mathematician, who is probably not as well known as he deserves. Could you characterize him as a person and as a researcher in a few sentences? Did he have a lasting influence on your own work?*

Carleson: Yes, definitely. He was the one who set me on track. We worked on the same type of problems but we had a different attitude towards mathematics. He was one of the few people about whom I would use the word genius. Mathematics was part of his personality somehow. He looked at mathematics as a piece of art. Ibsen would have profited from meeting him. He also considered his papers as pieces of art. They were not used for education and they were not used to guide future researches. But they were used as you would use a painting. He liked to hide how he found his ideas. If you would ask him how he found his result, he would say a wizard doesn't explain his tricks.

So that was a rather unusual education. But of course I learned a lot from him. As you said, he has never been really recognized in a way which he deserves.

R & S: *Apart from Arne Beurling, which other mathematicians have played an important part in your development as a mathematician?*

Carleson: I have learnt from many others, in particular from the people I collaborated with and in particular from Peter Jones. I feel a special debt to Michel Herman. His thesis, where he proved the global Arnold conjecture on diffeomorphisms of the circle, gave me a new aspect on analysis and was my introduction to dynamical systems.

R & S: *You have concentrated your research efforts mainly on topics in hard analysis, with some spices from geometry and combinatorics. Is there a specific background for this choice of area?*

Carleson: I don't think so. There is a combinatorial part in all of the three problems we have discussed here. And all of them are based on stopping time arguments. You make some construction and then you stop the construction, and you start all over again.

R & S: *This is what is called renormalization?*

Carleson: Yes, renormalization. That was something I didn't learn. Probability was not a part of the Uppsala school. And similarly for coverings, which is also part of the combinatorics.

R & S: *Which mathematical area and what kind of mathematical problems are you currently the most interested in?*

Carleson: Well, I like to think about complexity. I would like to prove that it's harder to multiply than to add.

R & S: *That seems to be notoriously difficult, I understand.*

Carleson: Well, I am not so sure. It's too hard for me so far.

R & S: *You have a reputation as a particularly skillful advisor and mentor for young mathematicians; twenty-six mathematicians were granted a Ph.D. under your supervision. Do you have particular secrets on how to encourage, to advise, and to educate young promising mathematicians?*

Carleson: The crucial point, I think, is to suggest an interesting topic for the thesis. This is quite hard since you have to be reasonably sure that the topic fits the student and that it leads to results. And you should do this without actually solving the problem! A good strategy is to have several layers of the problem. But then many students have their own ideas. I remember one student who wanted to work on orthogonal polynomials. I suggested that he could start by reading Szegö's book. "Oh, no!" he said, "I don't want to have any preconceived ideas."

Publishing Mathematics

R & S: *I would like to move to the organization of research. Let's start with the journal* Acta Mathematica. *It is a world famous journal founded by Gösta Mittag-Leffler back in 1882 in Stockholm as a one-man enterprise at that time. It rose very quickly to be one of the most important mathematical journals. You were its editor in chief for a long period of time. Is there a particular recipe for maintaining* Acta *as a top mathematical journal? Is very arduous refereeing most important?*

Carleson: It is the initial period that is crucial, when you build up a reputation so that people find it attractive to have a paper published there. Then you have to be very serious in your refereeing and in your decisions. You have to reject a lot of papers. You have to accept being unpopular.

R & S: *Scientific publication at large is about to undergo big changes. The number of scientific journals is exploding and many papers and research results are sometimes available on the Internet many years before they are published in print. How will the organization of scientific publication develop in the future? Will printed journals survive? Will peer review survive as today for the next decades?*

Carleson: I've been predicting the death of the system of mathematical journals within ten years for at least 25 years. And it dies slowly, but it will only die in the form we know it today. If I can have a wish for the future, I would wish that we had, say, 100 journals or so in mathematics, which would be very selective in what they publish and which wouldn't accept anything that isn't really finalized, somehow. In the current situation, people tend to publish half-baked results in order to get better promotions or to get a raise in their salary.

The printing press was invented by Gutenberg 500 years ago in order to let information spread from one person to many others. But we have completely different systems today which are much more efficient than going through the printing process, and we haven't really used that enough.

I think that refereeing is exaggerated. Let people publish wrong results, and let other people criticize. As long as it's available on the 'net it won't be any great problem. Moreover, referees aren't very reliable; it doesn't really work anyway. I am predicting a great change, but it's extremely slow in coming. And in the meantime the printers make lots of money.

Research Institutions

R & S: *I've just returned from a nice stay at the Institute Mittag-Leffler, which is situated in Djursholm, north of Stockholm; one of the leading research institutes of our times. This institute was, when you stepped in as its director in 1968, something that I would characterize as a sleeping beauty. But you turned it into something very much different, very active within a few years. By now around thirty mathematicians work together there at any given time but there is almost no permanent staff. What was the inspiration for the concept of the Institute Mittag-Leffler as it looks today? And how was it* *possible to get the necessary funds for this institute? Finally, how would you judge the present activities of the institute?*

Carleson: To answer the last question first, I have to be satisfied with the way it worked out and the way it continues also. I just hope that it can stay on the same course.

In the 1960s, there was a period when the Swedish government (and maybe also other governments) was willing to invest in science. There was a discussion about people moving to the United States. Hörmander had already moved and the question was whether I was going to move as well. In this situation, you could make a bargain with them. So we got some money, which was of course the important part. But there was a rather amusing connection with the *Acta*, which is not so well known. From Mittag-Leffler's days, there was almost no money in the funds of the academy for the Mittag-Leffler Institute. But we were able to accumulate rather large sums of money by selling old volumes of the *Acta*. Mittag-Leffler had printed large stocks of the old *Acta* journals which he never sold at the time. They were stored in the basement of the institute. During the 1950s and early 1960s one could sell the complete set of volumes. I don't remember what a set could be sold for, maybe US$1,000 dollars or so. He had printed several hundred extra copies, and there were several hundred new universities. If you multiply these figures together you get a large amount of money. And that is still the foundation of the economy of the institute.

R & S: *A bit later, you became the president of the International Mathematical Union, an organization that promotes international cooperation within mathematics. This happened during the cold war and I know that you were specifically concerned with integrating Chinese mathematics at the time. Could you share some of your memories from your presidency?*

Carleson: Well, I considered my main concern to be the relation to the Soviet Union. The Chinese question had only started. I went to China and talked to people in Taiwan, and to people in mainland China. But it didn't work out until the next presidential period, and it simply ripened. The main issue was always whether there was to be a comma in a certain place, or not, in the statutes.

It was somehow much more serious with the Russians. You know, they threatened to withdraw from international cooperation altogether. The IMU committee and I considered that the relation between the West and the East was the most important issue of the International Mathematical Union. So that was exciting. Negotiations with Pontryagin and Vinogradov were kind of special.

R & S: *Did these two express some anti-semitic views also?*

Wreath ceremony at the Abel monument in Oslo.

Carleson: No, not officially. Well they did, of course, in private conversation. I remember Vinogradov being very upset about a certain Fields Medal being given to somebody, probably Jewish, and he didn't like that. He said this is going to ruin the Fields Medal forever. Then I asked him if he knew who received the first Nobel Prize in literature. Do you? It was a French poet called Sully Prudhomme; and that was during a period when Tolstoy, Ibsen, and Strindberg were available to get the prize. Well, the Nobel Prize survived.

Mathematics for Our Times

R & S: *You wrote a book,* Matematik för vår tid *or* Mathematics for Our Times, *which was published in Sweden in 1968. In that book, you took part in the debate on so-called New Mathematics, but you also described concrete mathematical problems and their solutions. Among other things you talked about the separation between pure and applied mathematics. You described it as being harmful for mathematics and harmful for contact with other scientists. How do you see recent developments in this direction? What are the chances of cross-fertilization between mathematics on the one side and, say, physics, biology, or computer science on the other side? Isn't computer science somehow presently drifting away from mathematics?*

Carleson: Yes, but I think we should blame ourselves; mathematics hasn't really produced what we should, i.e., enough new tools. I think this is, as we talked about before, really one of the challenges. We still have lots of input from physics, statistical physics, string theory, and I don't know what. I stand by my statement from the 1960s.

But that book was written mostly as a way to encourage the teachers to stay with established values. That was during the Bourbaki and New Math period, and mathematics was really going to pieces, I think. The teachers were very worried, and they had very little backing. And that was somehow the main reason for the book.

R & S: *If you compare the 1960s with today, mathematics at a relatively elevated level is taught to many more people and other parts of the subject are emphasized. For example the use of computers is now at a much higher state than at that time, where it almost didn't exist. What are your main points of view concerning the curriculum of mathematics at, say, high school level and the early years of university? Are we at the right terms? Are we teaching in the right way?*

Carleson: No, I don't think so. Again, something predictable happens very slowly. How do you incorporate the fact that you can do many computations with these hand-computers into mathematics teaching?

But in the meantime, one has also expelled many things from the classroom which are related to the very basis of mathematics, for example proofs and definitions and logical thinking in general. I think it is dangerous to throw out all computational aspects; one needs to be able to do calculations in order to have any feeling for mathematics.

You have to find a new balance somehow. I don't think anybody has seriously gotten there. They talk a lot about didactics, but I've never understood that there is any progress here.

There is a very strong feeling in school, certainly, that mathematics is a God-given subject. That it is once and for all fixed. And of course that gets boring.

Public Awareness

R & S: *Let us move to public awareness of mathematics: It seems very hard to explain your own mathematics to the man on the street; we experience that right now. In general pure mathematicians have a hard time when they try to justify their business. Today there is an emphasis on immediate relevance, and it's quite hard to explain what mathematicians do to the public, to people in politics, and even to our colleagues from other sciences. Do you have any particular hints on how mathematicians should convey what they are doing in a better way?*

Carleson: Well, we should at least work on it; it's important. But it is also very difficult. A comment which may sound kind of stupid is that physicists have been able to sell their terms much more effectively. I mean, who knows what an electron is? And who knows what a quark is? But they have been able to sell these words. The first thing we should try to do is to sell the words so that people get used to the idea of a derivative, or an integral, or whatever.

R & S: *As something mysterious and interesting, right?*

Carleson: Yes, it should be something mysterious and interesting. And that could be one step in that direction, because once you start to talk about something you have a feeling about what it is. But we haven't been able to really sell these terms. Which I think is too bad.

R & S: *Thank you very much for this interview on behalf of the Norwegian, the Danish, and the European Mathematical Societies!*

Book Review

From Zero to Infinity (50th Anniversary Edition)

Reviewed by Bruce Reznick

From Zero to Infinity (50th Anniversary Edition)
Constance Reid
A K Peters, Ltd., 2006, 5th Edition
208 pages, US$19.95
ISBN 1568812736

In the interest of full disclosure, readers should know that this was the reviewer's favorite childhood book. As an adult, he had the uncommonly satisfying experience of serving on the MAA Publications Committee when the book was brought back into print in its fourth edition in 1991 after Constance Reid recovered the copyright from its original publisher. The reviewer has had the pleasure of several conversations with the author and was solicited to write a blurb for this edition in advance of its publication. He is not unbiased.

The story of how *From Zero to Infinity* came to be written is close to legendary and serves as the "Author's Note" for the present edition. Here is an excerpt:

> It begins with a phone call from my sister, Julia Robinson, on the morning of January 31, 1952. ... Julia tells me that a program by her husband, Raphael Robinson, had turned up the first new "perfect numbers" in seventy-five years—not one but two of them. ... Julia explains the problem simply: *perfect numbers*—the name itself is intriguing—are numbers like 6 that are the sum of all the divisors except themselves: $6 = 1 + 2 + 3$. Then she tells me there is a particular form of prime necessary for the formation of such numbers, the amount of calculation involved in determining their primality, the enormousness of such primes. For me the whole thing is fascinating. I decide to write an article on the discovery of new perfect numbers. ... It is Emma [Lehmer] who suggests that I send my article to *Scientific American*. ... After reading my article, [publisher Robert L.] Crowell immediately wrote to ask if I would be interested in writing a book on numbers that he could pair with a book on the letters of the alphabet. Even I found the combination a bit incongruous, but it gave me an idea. The title of Mr. Crowell's book, already in print, was *Twenty-six Letters.* I would write a book about the ten digits; and because I had found what Julia had told me to be so interesting, I would call it *What Makes Numbers Interesting.* [pp. xiii–xiv][1]

The article on perfect numbers became the chapter on "6" in the original, 1955 edition. The

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[1] *All pagination refers to the 2005 edition under review.*

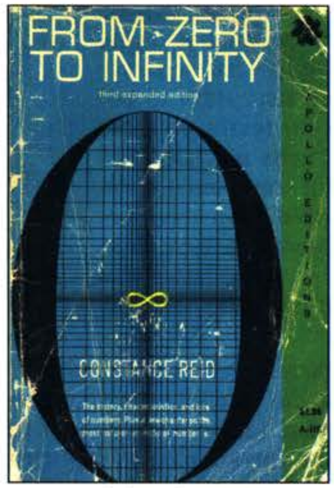
chapter on "0" mainly discussed positional notation, "1" covered factorization and primes, "2" was binary arithmetic, "3" more on primes and prime testing, "4" talked about squares and the Pythagorean theorem, "5" was on pentagonal numbers and Euler's generating function for the partition function, "7" discussed constructible polygons and Fermat numbers, "8" touched on Waring's Problem, and "9" introduced congruences and quadratic reciprocity. There is a short paragraph on "..." giving the well-known proof by contradiction that there are no uninteresting numbers. Each chapter concludes with a short set of questions, and this was the part of the book that influenced me most.

> The book was finished in a little over a year, then came a problem. The sales department flatly vetoed my proposed title—*What Makes Numbers Interesting.* The word *interesting* bothered them. Nobody would buy a book about things that were described as "interesting".... The sales department simply loved the one that I disliked the most—*From Zero to Infinity.* My reasons for disliking it were the following. First, in ascending order of importance, it was similar to the title of a then very popular novel, *From Here to Eternity.* ... Second, it was too similar to George Gamow's *One, Two, Three... Infinity* (although Gamow had begun with the number 1 while I had begun with the number 0). My real objection to the proposed title, however, was that I had not written anything in my book about the theory of the infinite. [p. xv]

As a possible compromise, the publisher's invoice on the reviewer's copy referred to *From Hero to Infinity.* A comparison of this edition to the original shows that there are now an "Author's Note" and two additional chapters added back in the 1960s: one on "Euler's constant" (oddly, not placed between "2" and "3") and one on "Aleph-Zero".

The email message from the *Notices* asking me to review this book noted that the book is already well known among mathematicians, so rather than giving a detailed description of the book, the review should serve as a "jumping-off point" for an essay about the book's contents. "Such an essay might comment on how the book influenced you personally..." the email said.

Before I leap into a reverie of possibly unreliable childhood memories, I want to say that, upon reading this edition anew, I was struck by its superb mathematical taste. The author knows what is important, what to talk about, and what to omit.



Cover of the third edition. Image by Tori Corkery.

I was the sort of child who always carried a book wherever he went. In fifth and sixth grades, that book was most frequently *From Zero to Infinity.* Like many readers of this journal, I have always been fascinated by numbers. Some time before my fifth birthday, my parents remember hearing me announce that it was "July 48". No, they corrected me, it's "August 17". "But they're the same thing," I am alleged to have replied. My father was writing at the time for the Robert Q. Lewis comedy variety show on radio, and he would bring home the unused tickets so I could play with the numbers printed on them. I had favorites (suspiciously, in retrospect): those ending in "1","4","5","6" and "9". Of these, "4" was the very best, but only if it was written as an isoceles right triangle with extended legs. The open version of the numeral with parallel vertical lines was somehow frightening to me then.

The wind was at my back as a budding mathematician: my parents were supportive of any interest that my brother or I might have and could afford to buy me the books I wanted, and my school, Hunter College Elementary School in New York City, was a laboratory for teaching techniques. A kind and gifted high school teacher, Dr. Harry D. Ruderman, visited HCES regularly and met with me periodically to explain the wonders of mathematics, many of which I understood. My parents would go to used magazine stores on Second Avenue and bring back copies of *Scientific American,* at first because they'd have those attached "reader response" cards listing numbers from 1 to 600, but later because of Martin Gardner's column. A birthday treat was to be let loose in a book store with a fixed budget. I'm sure that is where I first saw *From Zero to Infinity.*

I was entranced, even though some of the material was too advanced for me, such as Euler's infinite product. The story of how the new perfect numbers were discovered was as exciting as any childhood adventure story:

> The program had to be written entirely in machine language. One hundred and eighty-four separate commands were necessary to tell the SWAC how to test a possible prime by the Lucas method. The same program of commands, however, could be used for testing any number of the Mersenne type from $2^3 - 1$ to $2^{2297} - 1$. The latter was the largest that could be handled. [p. 93]

I had no idea what "machine language" could be, but I was hooked. This was much better than the *Justice League of America*. I knew I was meant to spend my life loving numbers and working with them; *From Zero to Infinity* crucially told me that there was a large community of People of Number I could hope to join when I grew up. (And it was particularly exciting decades later to hear John Selfridge, who searched for Mersenne primes in the 1960s, describe the process. You punched the cards, loaded them into the machine, and started it up. You could tell by the *sound* of the computer's actions when you found a new one!)

To be sure, I had other interests, but they were inextricably wound up with mathematics. I wondered how "6" could be a perfect number if it was on the back of Clete Boyer's Yankees uniform while Mickey Mantle wore a "7".

Nothing in *From Zero to Infinity* grabbed my attention as much as the challenge presented in the appendix to Chapter "4":

> There is nothing to keep a person occupied like trying to represent all numbers by four 4's. All four 4's must be used for every number, but various mathematical notations may also be used, as in the four examples below.
>
> $$1 = \frac{44}{44}, \quad 2 = \frac{4 \times 4}{4+4}, \quad 3 = 4 - \left(\frac{4}{4}\right)^4,$$
> $$4 = 4 + 4 - \sqrt{4} - \sqrt{4}.$$
>
> Try now to find similar representations for 5 through 12 in terms of four 4s. [p. 71]

Printed upside down on the same page was one such list of representations, and then the most consequential sentence:

> There is no need to stop with 12, for it is possible, if we do not limit ourselves as to notations, to represent *all* numbers by four 4's. [p. 71]

For this ten-year-old, here is what *From Zero to Infinity* really meant. The game was afoot!

Around the same time, the problem of the four 4's arose as a topic in Martin Gardner's "Mathematical Games" column of January 1964 (quoted here from its reprint in *The Magic Numbers of Dr. Matrix*)[2], and the formulation here allowed more flexibility in the use of notations.

> One seeks to form as many whole numbers as possible, starting with 1, by using only the digit 4 four times—no more, no less—together with simple mathematical symbols. Naturally one must establish which is meant by a "simple" symbol. This traditionally includes the arithmetical signs..., together with the square-root sign (repeated as many finite times as desired), parentheses, decimal points and the factorial sign. ... A decimal point may also be placed above .4, in which case it indicates the repeating decimal .4444... or $\frac{4}{9}$. [p. 49]

In the article, Dr. Matrix traces the history back to 1881, adding

> ...there have been scores of subsequent articles, including tables that go above 2000. Even now the mania will suddenly seize the employees of an office or laboratory, sometimes causing a work stoppage that lasts for days. [p. 50]

The mania lasted for weeks for me, and my work product is preserved on a tightly wound scroll of adding machine tape still buried in a box somewhere in my study. I had to adjudicate my own rules, so that $.\dot{4}$ was okay, but $.\dot{\sqrt{4}}$ wasn't, on the grounds that once you take $\sqrt{4}$, it ceases to be a numeral and becomes an integer. (I didn't think 4!4! should be 2424 either.) I'd earlier scoured the HCES library for math books and was fascinated by the older algebra texts, the sort which computed $\cos(18^o)$ and gave the explicit solutions to the cubic and quartic equations. I'd discovered the somewhat obscure notation $!n$ or *subfactorial*, which counts the number of derangements of $\{1, \dots, n\}$. If factorial was allowed, then surely subfactorial should be too. (In writing this review, I looked up the 1911 edition of W. W. Rouse Ball's *Mathematical Recreations and Essays* and saw that Rouse Ball takes credit for allowing both factorials

[2] *Prometheus Books, Buffalo, NY, 1985.*

in the problems (Errata and Addenda, p. 1).) Conveniently enough, $!4 = 9$, so $\sqrt{!4} = 3$ and $(\sqrt{!4})! = 6$ can be constructed with only one 4.

Every Friday afternoon in school, we were given a large sheet of newsprint paper to draw free-style and express our creativity. Every Friday afternoon, my sheet of newsprint was filled with numbers, as I tuned out the rest of the world and concentrated my attention on the arithmetic at hand. This feeling of oneness with the subject has, fortunately, not left me as I've grown older.

There has been considerable literature on this topic in the subsequent forty years, easily accessible via your favorite search engine. In an explicit response to one of Dr. Matrix's challenges, a newly-minted mathematics Ph.D. named Donald Knuth wrote an article[3] showing how to write 64 using one 4 and lots and lots of square roots, factorials, and greatest integer (not yet floor) functions. He reported that every integer $n < 208$ had such an expression, the limitations being round-off error. Tragically, this paper does not appear in *Mathematical Reviews*, and I do not know the current status of the problem. More recently, a computer scientist named David A. Wheeler, in a webpage[4] called "The definitive four fours answer key", links a 368-page PDF file giving expressions of integers up to 40,000. He presents an elaborate metric for evaluating such expressions. Somewhat strangely, Wheeler allows Γ (which seems to me to be a letter, not punctuation or symbolism) and eschews both kinds of factorial. He also allows "%" to indicate division by 100. (Like most mathematicians, I've never really liked "%" and try not to use it.) For example, the following is taken from p. 29 of his file:

$$2006 = \frac{4+4}{.4\%} + \Gamma(4).$$

I have gone on at such length about this problem because "The Four 4's" is simple to state and impossible to master, and deciding the nature of an acceptable solution is part of the problem. In this way, it was a far more useful introduction to mathematical research than most classroom presentations.

As I got older, I continued to read *From Zero to Infinity* and the other influential math books I knew, among them: Constance Reid's *Introduction to Higher Mathematics* (which was less numerical and which I didn't understand as well), George Gamow's *One, Two, Three... Infinity*, E. T. Bell's *Men of Mathematics*, and all of Martin Gardner's collections. As I moved into high school, I devoured *Recreations in the Theory of Numbers* by A. H. Beiler. Fortunately for today's Young Person of Number, these books are all still in print. The real transition came when my parents asked me what I wanted for my sixteenth birthday. We were living in Los Angeles by then, and I'm sure I was the only kid at Uni High who got L. E. Dickson's three-volume *History of the Theory of Numbers*, which Martin Gardner had cited so often. My classmates' birthday cars are rusted, but the three volumes of Dickson continue to inspire my work.

Accompanying this review is a picture showing the well-worn cover of my oldest copy of *From Zero to Infinity*. Careful readers will note that this is the third edition from 1966. What happened is that my first copy (of the second edition) disintegrated from use; this is the replacement.

I was truly fortunate to have run across *From Zero to Infinity* when I did, and I can only wish Constance Reid and her audience another

$$44 + \frac{4!}{4} = \frac{4! - \sqrt{\sqrt{4^4}}}{.4} =$$
$$4! + (\sqrt{4 \cdot 4})! + \sqrt{4} = \left\lceil \frac{44}{.4 \cdot \sqrt{4}} \right\rceil$$

years of great reading.

[3]*Representing numbers using only one 4,* Mathematics Magazine, *37 (1964), pp. 308–310.*

[4]`http://www.dwheeler.com/fourfours/`.

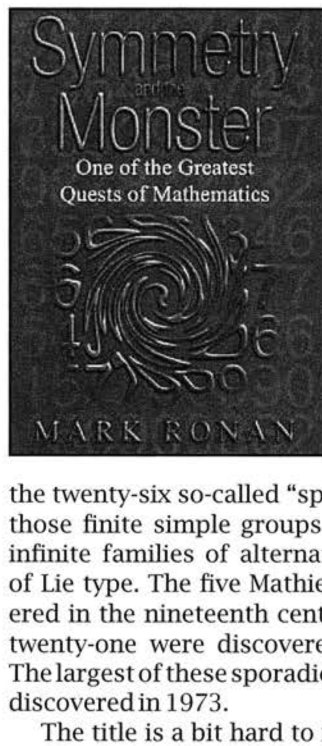
Symmetry and the Monster, One of the Greatest Quests of Mathematics

Reviewed by Robert L. Griess Jr.

Symmetry and the Monster, One of the Greatest Quests of Mathematics
Mark Ronan
Oxford University Press, 2006
272 pages, US$27.00
ISBN 0192807226

A new book about simple groups has appeared, this one for general audiences. The title refers to the wide role of groups as symmetries in mathematics and science, as well as to the "monster", a particular large finite simple group that has gotten much attention during the last three decades. The author, Mark Ronan, does research in groups and geometries.

This book tells a history of simple groups, mainly continuous groups (Lie groups) and finite simple groups, in a nontechnical way. (Many kinds of groups, simple and otherwise, constructed in combinatorial group theory, arithmetic, topology, etc., are not considered.) Historical figures in the story are described (Niels Abel, Évariste Galois, Wilhelm Killing, Felix Klein, Friedrich Engel, William Burnside, . . .). There are lengthy accounts of their personal and professional dramas. The effects of the world wars and major societal changes on mathematics are discussed. Group theorists from recent decades, many of whom are still active, are quoted. The author gives an account of connections between continuous and finite simple groups and other areas of mathematics and theoretical physics, notably the significant role of group theory in physics and the moonshine phenomena.



The "monster" of the title plays an unusually interesting role in the big story. The text contains descriptions of many of the twenty-six so-called "sporadic simple groups", those finite simple groups that do not lie in the infinite families of alternating groups or groups of Lie type. The five Mathieu groups were discovered in the nineteenth century, and the following twenty-one were discovered around 1965–1975. The largest of these sporadic groups is the monster, discovered in 1973.

The title is a bit hard to interpret. The monster is treated as the conclusion of a long journey. In a really unique way, the monster embodies important and mysterious connections between areas of mathematics and physics, and much more of this could be discovered in the future. A more cautious view is that the monster is one actor among many (obviously, an important one) in the ongoing story of groups in mathematics and science. I did not find the "quest" defined. I suppose it is a quest for the simple groups themselves and for fuller understanding of groups in the scientific universe.

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The book is pitched towards the scientifically aware general audience and is appropriate for young people. It gives a satisfying account of how the story of Lie groups and finite simple groups evolved, both as a human struggle to understand the universe and as an introduction to the theories. The reader gets a taste of technicalities. One sees both the common example of a dihedral group of order 8 (p. 48) as well as the exotic-looking special calculation (p. 176)

$$1+3{,}968{,}055+23{,}113{,}728+2{,}370{,}830{,}336+$$

$$11{,}174{,}042{,}880=13{,}571{,}955{,}000$$

of the number of $2A$-involutions in the "baby monster", a simple group discovered by Bernd Fischer in 1973.

The visuals are thoughtfully done (e.g., rigid symmetries of Platonic solids in Chapter 1 and automorphisms of graphs and geometries in Chapter 9). There are helpful tables, such as the "periodic table" of Lie groups (p. 66) and all sporadic groups (called "The 26 Exceptions") in Appendix 4, p. 244.

Stories of mathematicians through the early twentieth century are adapted from other authors. This author adds new material from published quotations and his own interviews with mathematicians. This single book covers two hundred years of group theory, essentially the entire relevant historical interval. The narrative moves briskly. I found myself eager to turn the pages and move on to the next chapter. The author is articulate and chooses well.

The general reader will likely appreciate the book's many side remarks on such topics as the Nobel and Abel Prizes, the Fields Medals, and the Oberwolfach Forschungsinstitut. The book also relates anecdotes about mathematicians the author knew personally.

The classifications of Lie groups and of finite simple groups are treated, but rather lightly. These two classifications have very different natures.

The Contents

A Quick Tour

The author treats many topics. We shall devote more space to the recent ones, since they have generally received less attention.

The text begins with Theaetetus and the story of the Platonic solids. The dramatic story of the young and brilliant Évariste Galois is discussed in detail, and there is a generous exposition on solving low-degree polynomial equations. From degree 5 and up, one is unable to solve polynomials with formulas involving only radicals and rational operations. Finite simple groups are lurking!

The story of Sophus Lie is colorful, and his interactions with Felix Klein, Wilhelm Killing, and Élie Cartan are quite significant and fascinating. Lie algebras and Lie groups have deeply affected mathematics for over a century and will continue to do so for a long time.

The chapter on Lie groups and physics gives a brief account of relativity, special relativity, and subatomic particles. It notes that electrons are limited to lie in discrete states and that these correspond to properties of the Lie groups.

The contributions of Leonard Eugene Dickson to finite simple groups are enormous and not widely appreciated. He created finite field analogues of the exceptional Lie groups of types G_2, F_4, and E_6. He was a fantastically productive worker in algebra and number theory. Dickson's early book [4] contains a wealth of information about many finite groups.

In the 1950s Claude Chevalley gave a uniform procedure for defining analogues of Lie groups over any field, a beautiful and very important broadening of Lie theory [3]. These "Chevalley groups" included the families of groups created by Dickson and placed them in a context.

The book offers an account of the Bourbaki group and how the world wars affected mathematics and the immigration of mathematicians to North America, especially European Jews.

The chapter title "The Man from Uccle" is both a reference to Jacques Tits's hometown Uccle, Belgium, and a pun on a popular 1960s television show. The author gives Tits special status as a great architect of geometric theories (covering Lie groups, arithmetic groups, finite groups, and other algebraic systems) and as an insightful group theorist. Tits's theory of buildings includes his important characterization of groups of Lie type by geometries.

The next chapter, "The Big Theorem", is about the Odd Order Theorem of Walter Feit and John Thompson (that all finite groups of odd order are solvable) and its context, the early thinking about the classification of finite simple groups. Thompson is considered the great pathbreaker in modern finite group theory, starting with his graduate work in the late 1950s and continuing for years of profoundly influential results. In 1970 Thompson was awarded a Fields Medal for work on N-groups (finite groups in which local subgroups are solvable). Richard Brauer's significant role and life are sketched. Michio Suzuki's contributions are mentioned in a few places in the book. I feel that Suzuki's early work in the classification could have been emphasized more in this chapter (his later works on simple groups are adequately reported). Finally, one reads about the surprise of Zvonimir Janko's finite simple group of order 176,560, the first sporadic group discovered in about a century [13].

"Pandora's Box" gives an introduction to groups and finite geometries, Mathieu groups, and the ideas in the mid-1960s that led to discoveries of many other sporadic groups.

Algebraist Reinhold Baer had a broad view of mathematics and was quite supportive of young talent. He had particular influence on the young Bernd Fischer, who pursued rather personal interests about algebraic systems (great success followed years later). The influence of Reinhold Baer on finite groups seems not to be widely known. Dieter Held, Zvonimir Janko, John Thompson, Jacques Tits, and others attended his seminars. Another account of Baer's career is [7].

Zvonimir Janko, like Fischer, had very strong personal ideas about where to look for new simple groups, and he worked them quite hard. Janko's most successful theme was the so-called "O_2 extraspecial" hypothesis for centralizers of involutions. The flavor of Janko's program was more "internal group theory" rather than "external geometry". Fischer and Janko each found several new sporadic groups but by mining rather different parts of the group theory terrain.

The chapter on the Leech lattice explains the concepts of sphere packing, lattices, and the exceptional 24-dimensional packing discovered by John Leech. It reports the amazing half-day in the life of John Conway when he understood the Leech lattice and its isometry group and saw how to explain their remarkable treasures. (In Appendix 3, p. 242, the author lists all minimal vectors of the Leech lattice, a pretty counting exercise.)

The chapter "Fischer's Monsters" starts with the basic theory of dihedral groups, which are finite groups generated by pairs of distinct involutions, and how they arise as linear transformations on high-dimensional vector spaces. Bernd Fischer explored a very natural class of groups generated by involutions and found new sporadic groups. The central hypothesis is simply stated: a conjugacy class of involutions is given and any pair of involutions from that class either commutes or generates a dihedral group of order 6. This property is held by the transpositions in symmetric groups and by particular conjugacy classes in classical matrix groups in characteristics 2 and 3. It is still so amazing to me that this simple and geometrically natural property leads through familiar examples to three new sporadic groups, Fi_{22}, Fi_{23}, and Fi_{24} (the first two are simple and the third has a simple commutator subgroup Fi_{24}' of index 2). Michael Aschbacher, Franz Timmesfeld, and Bernd Fischer relaxed these conditions to analyze wider classes of groups. Developing this theme further, Fischer found the evidence for the "baby monster" and (a bit later) the "monster".

The chapter on the Atlas is about the collaborative effort to compile, check, and refine data on simple groups such as their character tables, maximal subgroups, and presentations. It is interwoven with a brief account of the program to classify finite simple groups, emphasizing the 1970s decade. This reviewer feels that the relationship between these programs may not be clear in the text. The effort to classify finite simple groups is far more vast than the program to compile the Atlas and indeed enabled that program.

The team classification effort was led by the energetic and visionary Daniel Gorenstein. This book's account of Gorenstein's amazing life force is truthful. I am happy that his fantastic dedication and organizational skills are reported here in some detail; they were significant to the classification team effort and to the Rutgers University mathematics department. Michael Aschbacher was the younger leader of this team, due to his aggressive new techniques and sustained rapid output. A feeling developed only in the late 1970s that a classification might finally become reality. It would depend on solving a few specific problems, and this was indeed clarified by a theorem of Gorenstein and Richard Lyons. In the early 1980s (possibly at the AMS meeting, January 1981), Gorenstein announced that the classification was done. At first, that declaration was generally supported by the classification theorists. However, it became increasingly difficult to defend as the decade of the 1980s went by.

The completeness claim created a serious dilemma for me personally. On one hand, I had great respect for the top finite group theorists and the impressive classification machinery. However, such a huge claim seemed rushed to me. If the classification were indeed complete, it would be not only the longest proof in history but also an *induction* proof. The expected list of finite simple groups does not yet correspond exactly to anything else in mathematics, and we were aware that past technical mistakes had incorrectly ruled out groups later found to exist. Not all relevant manuscripts had been turned in at that time, and there were many separate efforts in progress.

Since the declaration, gaps were found and treated, and improvements were achieved. Especially noteworthy is the recent [1] (two volumes!), in which Michael Aschbacher and Stephen Smith finally settle the "quasithin" problem. A solution was claimed in the mid-1980s by another mathematician who ultimately did not publish his long manuscript. Another example is the 1989 article [10], which finally proved a necessary classification result. The person who originally claimed this result in the early 1980s never published a proof.

Revision continues, led principally by Richard Lyons and Ronald Solomon. The wait for resolution is justified, given the extreme length and difficulty of the material (thousands of journal pages) and the importance of knowing the finite simple groups. No new finite simple group has been found since 1975.

The chapter "A Monstrous Mystery" shows how surprising connections ("moonshine") were discovered between the monster and a set of genus 0 function fields which correspond to the group of 2- by-2 integral matrices of determinant 1 and some closely related matrix groups. The latter topic has been well studied since the nineteenth century. These connections, discovered by John McKay and John Thompson (late 1970s) and enriched by John Conway and Simon Norton, were truly a surprise and to this day remain a challenge to explain. Thompson conjectured the existence of a graded representation of the monster whose graded traces give the Hauptmoduln, certain normalized generating series for the genus 0 function fields mentioned above.

The chapter "Construction" is about the work of Robert Griess (this reviewer). In 1973 Fischer and Griess independently produced group theoretic evidence that there could be a sporadic simple group with the order $2^{46}3^{20}5^{9}7^{6}11^{2}13^{3}17\cdot 19\cdot 23\cdot 29\cdot 31\cdot 41\cdot 47\cdot 59\cdot 71 \sim 8.08\times 10^{53}$ and additional specific properties. Their evidence was the passage of many local tests by the hypotheses, but there was at that time no existence proof. Furthermore, because such a putative group would be so large and lack any small dimensional representation, the possibility of construction seemed doubtful, even with computers. In late 1979 Griess returned to thoughts of a possible existence proof. He constructed such a group as matrices in dimension 196883 over the rational numbers and announced the results by mail on January 14, 1980. It was quite important that this group leave invariant an algebra structure (a product) on the 196883-dimensional vector space, because such a requirement gave useful constraints for making definitions (earlier work of Norton indicated that if an irreducible 196883-dimensional representation exists, then there should exist some invariant algebra structure). Finally, Griess defined a particular product on the space and constructed enough symmetries of it to generate a large finite simple group. This was done with abstract group theory, "by hand" as it were, by labeling the 196883-space with data from the famous Leech lattice and its ambient 24-dimensional vector space. Corollaries of the construction included new and easy existence proofs of many previously known sporadic groups. Twenty of the sporadic groups were unified, in a sense.

The final chapter introduces some ideas from physics and sketches their connections to simple group theory. Richard Borcherds made two important contributions here. First, he showed the relevance of vertex algebras and how to work with them. The hyperbolic geometry that is important in working with space and time is useful for explaining lattices, vertex algebras, and sporadic groups. Borcherds furthermore verified the basic conjecture of Thompson, that the moonshine vertex operator algebra of Igor Frenkel, James Lepowsky, and Arne Meurman does afford graded traces, which are the relevant Hauptmoduln. In 1998 Richard Borcherds won a Fields Medal for his work on moonshine.

What the Book Gives Us

Ronan's real achievements in this popular science book are (1) gathering testimony about modern work on finite simple groups and providing expositions of the new ideas that arose, (2) integrating the older and newer parts of the group theory history in a single narrative, (3) revealing the human sides to the story and how they mesh with the scientific.

The mathematics community is generally aware of certain highlights of modern finite group theory such as Brauer's proposals (mid-1950s) to start the classification program, the breakthroughs of John Thompson, the Feit-Thompson Odd Order Theorem, discoveries of sporadic groups, and the announcement by Gorenstein that finite simple groups were classified. Many human aspects of the story are not widely known.

The material from recent times is especially welcome. This history could be lost within decades.

Notations and Terminology

The author never seems to give the definition of a group, as one would see in a text or college course. Certain standard mathematical concepts are given new names. The author insists on the term "atoms" rather than simple groups. He uses the term "cross section" for centralizer of involutions (a footnote offered a definition, but I was disappointed). There is also an avoidance of subscripts. The text uses $A2, D5, \ldots$ for the Lie groups of respective type $A_2, D_5, \ldots$ and $M22$ for the Mathieu group M_{22}. Could this be to make things easier for the reader? On the other hand, one finds superscripts (M^{22}, etc.; p. 178).

I find these "simplifications" not only unnecessary but probably counterproductive. As a youngster, I enjoyed reading popularizations of science and mathematics (George Gamow's *One, Two, Three... Infinity* is a delightful example). Such friendly guidance gave access to the proper names of the scientific objects and concepts. To me it meant being treated as an adult and valued as a potential scientist, even though I felt overwhelmed by the great ideas.

Comments and Corrections

Marshall Hall independently discovered, constructed, and proved uniqueness of the simple group of order 604,800 [12] around the same time as Janko made his discovery [14]; each refers to the work of the other. Joint credit is appropriate. Most of the time I use the notation HJ instead of J_2; both notations are used by the group theory community.

"John McLaughlin" should be Jack McLaughlin.

I disagree with parts of the author's account about the character table of the monster (it appears in [2]), whose determination presented unusual difficulties. This character table was calculated in the late-1970s [15], *based on the reasonable hypothesis* that there was an irreducible character of degree 196883 (a conjecture of mine [8]). Existence of such a character followed from the later works [9, 10]. As far as I know, there is no other existence proof of such a character, and there is no character table determination that avoids starting with an irreducible of degree 196883.

The "Notes" section was enjoyable. The author used a lot of recent scholarship.

After the four appendices comes the glossary. Some of its "definitions" seem vague (e.g., j-function, Lie group), and there are terms (cross section, deconstruction, periodic table) that are not generally used the way the author does. The item on "group" is disappointing (there is no reference to the associative law). The meaning suggested by the definition of "periodic table" is misleading, because the families of finite simple groups of Lie type in positive characteristic are not in one-to-one correspondence with the families of Lie groups (see [2, 11, 5, 6]; there are nearly twenty families, not seven as the author says). A complete list would take two pages.

The book makes brief mention of group character theory in connection with Burnside from a century ago, but there is no discussion of its important role in the classification of finite simple groups, especially around the 1950s and 1960s (for example, early centralizer of involution problems and characterizations by Sylow 2-subgroups).

Summary

The book is quite accessible, artfully written, and rich in specifics, and it stresses the human side of the drama. Though I have been a long-time participant in the story, I found myself learning much in every chapter and not wanting to put the book down.

Ronan's book is not the unique way to tell the story. It reflects his tastes (e.g., emphasis on buildings). My own version would tell more about methods that led to new sporadic simple groups (meaning methods not directly inspired by Lie theory, such as centralizer of involution studies and explorations of rank 3 graphs). Many ideas which drove finite simple group theory are best understood as part of the evolution of *general finite group theory*. Also, I would describe the group theory community around Chicago and Champaign-Urbana in the late 1960s: Jon Alperin, Helmut Bender, Norman Blackburn, Everett Dade, Len Evens, Paul Fong, George Glauberman, David Goldschmidt, Christof Hering, Morton Harris, Marty Isaacs, Noboru Ito, Bill Kantor, Richard Lyons, Len Scott, Gary Seitz, Michio Suzuki, John Thompson, John Walter, Warren Wong.... The heavy schedule of seminars, the many visitors, and the intellectual ferment were great catalysts to the development of general finite group theory. This includes representation theory, group cohomology, local group theory, geometry, and permutation groups, not just simple groups, the main topic of this book. I was fortunate to have been there and learned so much. It was a great time.

The author gives a nuanced account of the research process, describing both the scientific content and the psychological aspects. He describes learning from the masters, the loneliness of doing groundbreaking research, collaborations both harmonious and strained, and the sometimes difficult path to ultimate recognition. The many examples in the book should be informative, especially for young readers. They can help develop survival skills and attitudes for success. The world of mathematicians is competitive.

Symmetry and the Monster, One of the Greatest Quests of Mathematics is rewarding and recommended for established scientists and young people.

Acknowledgment

I thank Jon Alperin and Len Scott for reading an early draft of this review, and I acknowledge research support from grants NSF (DMS-0600854) and NSA (NSA-H98230-05-1-0024).

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About the Cover

The zero of Gwalior

The cover displays a photograph of what may be the oldest extant decimal '0' in India, where decimal place notation was invented. It was suggested by the opening chapter of Constance Reid's well known book *From zero to infinity*, which is reviewed in this issue on the occasion of a new printing. The number '270' visible in the photograph is found on a tablet on the wall of a small temple on the eastern approach to the medieval fortress of Gwalior, a city in the north of the state of Madhya Pradesh. The temple itself was erected in 876 A. D., and inside it is a tablet commemorating the donation of land, of dimension 270 *hastas* by 187 *hastas* and other gifts to another local temple, as well as a daily gift of 50 garlands of flowers to the two temples. All these numbers appear in decimal place notation, in more or less recognizable form.

There are plausible arguments that full decimal place notation for integers was invented in India some time in the 6th century. It seems at least clear from this tablet that it had come into common usage by the mid 9th century. The Babylonians, followed by the the Alexandrian Greeks, had used a symbol for zero in astronomical calculations with sexagesimal notation, and it seems almost certain that this usage was imported into India sometime in the years 200–400 A. D. To what extent this influenced the invention of decimal place notation is not clear.

Another candidate for the oldest extant zero is the Bakhshali Manuscript, now in the Bodleian Library of Oxford University, but it has not been dated, except on uncertain if reasonable paleographical grounds. In this manuscript can be found the manipulation of rational numbers with a facility equal to our own and an enthusiasm that exceeds the average of modern times—at one point in the course of a calculation involving the square root of a non-square integer can be found the rational number

$$\frac{507533837627467432719 36}{72504833946750000000}!$$

(The calculation yielding this has been reconstructed by Takao Hayaishi in his treatment of folio 46 *recto* in his impressively thorough edition of the MS.)

I wish to thank Renu Jain of the mathematics department of Gwalior University, as well as A. K. Singh of the archaeology department, for acting as guides in Gwalior.

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

WHAT IS...
a Young Tableau?

Alexander Yong

Young tableaux are ubiquitous combinatorial objects making important and inspiring appearances in representation theory, geometry, and algebra. They naturally arise in the study of symmetric functions, representation theory of the symmetric and complex general linear groups, and Schubert calculus of Grassmannians. Discovering and interpreting enumerative formulas for Young tableaux (and their generalizations) is a core theme of *algebraic combinatorics*.

Let $\lambda = (\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_k \geq 0)$ be a **partition** of size $|\lambda| = \lambda_1 + \ldots + \lambda_k$, identified with its **Young diagram**: a left-justified shape of k rows of boxes of length $\lambda_1, \ldots, \lambda_k$. For example, $\lambda = (4,2,1)$ is drawn $\begin{array}{|c|c|c|c|}\hline & & & \\ \hline & \\ \cline{1-2} \\ \cline{1-1}\end{array}$. A **(Young) filling** of λ assigns a positive integer to each box of λ, e.g., $\begin{array}{|c|c|c|c|}\hline 2 & 1 & 1 & 4 \\ \hline 6 & 2 \\ \cline{1-2} 4 \\ \cline{1-1}\end{array}$. A filling is **semistandard** if the entries weakly increase along rows and strictly increase along columns. A semistandard filling is **standard** if it is a bijective assignment of $\{1, 2 \ldots, |\lambda|\}$. So $\begin{array}{|c|c|c|c|}\hline 1 & 2 & 2 & 4 \\ \hline 2 & 3 \\ \cline{1-2} 4 \\ \cline{1-1}\end{array}$ is a **semistandard Young tableau** while $\begin{array}{|c|c|c|c|}\hline 1 & 3 & 4 & 6 \\ \hline 2 & 7 \\ \cline{1-2} 5 \\ \cline{1-1}\end{array}$ is a **standard Young tableau**, both of **shape** λ.

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We focus on the enumeration and generating series of Young tableaux. Frame-Robinson-Thrall's elegant (and nontrivial) **hook-length formula** states that the number of standard Young tableaux of shape λ is $f^{\lambda} := \frac{|\lambda|!}{\prod_b h_b}$, where the product in the denominator is over all boxes b of λ and h_b is the **hook-length** of b, i.e., the number of boxes directly to the right or below b (including b itself). Thus, $f^{(4,2,1)} = \frac{7!}{6 \cdot 4 \cdot 2 \cdot 1 \cdot 3 \cdot 1 \cdot 1} = 35$.

A similar *hook-content formula* counts the number of semistandard Young tableaux, but we now consider instead their generating series: fix λ and a bound N on the size of the entries in each semistandard tableau T. Let $\mathbf{x}^T = \prod_{i=1}^{N} x_i^{\#i\text{'s in } T}$. The **Schur polynomial** is the generating series $s_\lambda(x_1, \ldots, x_N) := \sum_{\text{semistandard } T} \mathbf{x}^T$. For example, when $N = 3$ and $\lambda = (2,1)$ there are eight semistandard Young tableaux:

$$\begin{array}{|c|c|}\hline 1 & 1 \\ \hline 2 \\ \cline{1-1}\end{array},\ \begin{array}{|c|c|}\hline 1 & 2 \\ \hline 2 \\ \cline{1-1}\end{array},\ \begin{array}{|c|c|}\hline 1 & 3 \\ \hline 2 \\ \cline{1-1}\end{array},\ \begin{array}{|c|c|}\hline 1 & 2 \\ \hline 3 \\ \cline{1-1}\end{array},\ \begin{array}{|c|c|}\hline 1 & 1 \\ \hline 3 \\ \cline{1-1}\end{array},\ \begin{array}{|c|c|}\hline 1 & 3 \\ \hline 3 \\ \cline{1-1}\end{array},\ \begin{array}{|c|c|}\hline 2 & 2 \\ \hline 3 \\ \cline{1-1}\end{array},\ \begin{array}{|c|c|}\hline 2 & 3 \\ \hline 3 \\ \cline{1-1}\end{array}.$$

The corresponding Schur polynomial, with terms in the same order, is $s_{(2,1)}(x_1, x_2, x_3) = x_1^2 x_2 + x_1 x_2^2 + x_1 x_2 x_3 + x_1 x_2 x_3 + x_1^2 x_3 + x_1 x_3^2 + x_2^2 x_3 + x_2 x_3^2$. In general, these are **symmetric polynomials**, i.e., $s_\lambda(x_1, \ldots, x_N) = s_\lambda(x_{\sigma(N)}, \ldots, x_{\sigma(N)})$ for all σ in the symmetric group $\mathfrak{S}_N$ (the proof is a "clever trick" known as the *Bender-Knuth involution*).

Both the irreducible complex representations of $\mathfrak{S}_n$ and the irreducible degree n polynomial representations of the general linear group $GL_N(\mathbb{C})$ are indexed by partitions λ with $|\lambda| = n$. The associated irreducible $\mathfrak{S}_n$-representation has dimension equal to f^λ, while the irreducible $GL_N(\mathbb{C})$ representation has character $s_\lambda(x_1, \ldots, x_N)$. These facts can be proved with an explicit construction of the respective representations having a basis indexed by the appropriate tableaux.

In algebraic geometry, the Schubert varieties, in the complex Grassmannian manifold $Gr(k,\mathbb{C}^n)$ of k-planes in $\mathbb{C}^n$, are indexed by partitions λ contained inside a $k\times(n-k)$ rectangle. Here, the Schur polynomial $s_\lambda(x_1,\dots,x_k)$ represents the class of the Schubert variety under a natural presentation of the cohomology ring $H^\star(Gr(k,\mathbb{C}^n))$.

Schur polynomials form a vector space basis (say, over $\mathbb{Q}$) of the ring of symmetric polynomials in the variables $x_1,\dots,x_N$. Since a product of symmetric polynomials is symmetric, we can expand the result in terms of Schur polynomials. In particular, define the **Littlewood-Richardson coefficients** $C^\nu_{\lambda,\mu}$ by

$$
\begin{aligned}
&s_\lambda(x_1,\dots,x_N)\cdot s_\mu(x_1,\dots,x_N)=\\
&\qquad\sum_\nu C^\nu_{\lambda,\mu}\,s_\nu(x_1,\dots,x_N).
\end{aligned}
\tag{1}
$$

In fact, $C^\nu_{\lambda,\mu}\in\mathbb{Z}_{\geq 0}$! These numbers count tensor product multiplicities of irreducible representations of $GL_N(\mathbb{C})$. Alternatively, they count *Schubert calculus* intersection numbers for a triple of Schubert varieties in a Grassmannian. However, neither of these descriptions of $C^\nu_{\lambda,\mu}$ is really a means to calculate the number.

The **Littlewood-Richardson rule** combinatorially manifests the positivity of the $C^\nu_{\lambda,\mu}$. Numerous versions of this rule exist, exhibiting different features of the numbers. Here is a standard version: take the Young diagram of ν and remove the Young diagram of λ, where the latter is top left justified in the former (if λ is not contained inside ν, then declare $C^\nu_{\lambda,\mu}=0$); this **skew-shape** is denoted ν/λ. Then $C^\nu_{\lambda,\mu}$ counts the number of semistandard fillings T of shape ν/λ such that (a) as the entries are read along rows from right to left, and from top to bottom, at every point, the number of i's appearing always is weakly less than the number of $i-1$'s, for $i\geq 2$; and (b) the total number of $i's$ appearing is μ_i. Thus $C^{(3,2,1)}_{(2,1),(2,1)}=2$ is witnessed by

$$
\begin{array}{|c|c|c|}\hline & & 1\\ \hline & 1 \\ \cline{1-2} 2 \\ \cline{1-1}\end{array}
\text{ and }
\begin{array}{|c|c|c|}\hline & & 1\\ \hline & 2 \\ \cline{1-2} 1 \\ \cline{1-1}\end{array}.
$$

Extending the $GL_N(\mathbb{C})$ story, a generalized Littlewood-Richardson rule exists for all complex semisimple Lie groups, where *Littelmann paths* generalize Young tableaux. In contrast, the situation is much less satisfactory in the Schubert calculus context, although in recent work with Hugh Thomas, we made progress for the *(co)minuscule* generalization of Grassmannians.

No discussion of Young tableaux is complete without the **Schensted correspondence**. This associates each $\sigma\in\mathfrak{S}_n$ bijectively with pairs of standard Young tableaux (T,U) of the same shape λ, where $|\lambda|=n$. This can be used to prove the Littlewood-Richardson rule but is noteworthy in its own right in geometry and representation theory.

Given a permutation (in one-line notation), e.g., $\sigma=21453\in S_5$, at each step i we add a box into some row of the current **insertion tableau** $\widetilde{T}$: initially insert $\sigma(i)$ into the first row of $\widetilde{T}$. If no entries y of that row are larger than $\sigma(i)$, place $\sigma(i)$ in a new box at the end of the row and place a new box containing i at the same place in the current **recording tableau** $\widetilde{U}$. Otherwise, let $\sigma(i)$ replace the leftmost $y>\sigma(i)$ and insert y into the second row, and so on. This eventually results in two tableaux of the same shape; Schensted outputs (T,U) after n steps. In our example, the steps are

$$
(\emptyset,\emptyset),\ (\boxed{2},\boxed{1}),\ \left(\begin{array}{|c|}\hline 1\\ \hline 2\\ \hline\end{array},\begin{array}{|c|}\hline 1\\ \hline 2\\ \hline\end{array}\right),\ \left(\begin{array}{|c|c|}\hline 1&4\\ \hline 2\\ \cline{1-1}\end{array},\begin{array}{|c|c|}\hline 1&3\\ \hline 2\\ \cline{1-1}\end{array}\right),
$$

$$
\left(\begin{array}{|c|c|c|}\hline 1&4&5\\ \hline 2\\ \cline{1-1}\end{array},\begin{array}{|c|c|c|}\hline 1&3&4\\ \hline 2\\ \cline{1-1}\end{array}\right),\ \left(\begin{array}{|c|c|c|}\hline 1&3&5\\ \hline 2&4\\ \cline{1-2}\end{array},\begin{array}{|c|c|c|}\hline 1&3&4\\ \hline 2&5\\ \cline{1-2}\end{array}\right)=(T,U).
$$

It is straightforward to prove well-definedness and bijectivity of this procedure. Also, T and U encode interesting information about σ. For example, it is easy to show that λ_1 equals the length of the longest increasing subsequence in σ (see e.g. work of Baik-Deift-Johansson for connections to random matrix theory). A sample harder fact is that if σ corresponds to (T,U) then σ^{-1} corresponds to (U,T).

An excellent source for more on the combinatorics of Young tableaux is [Sta99], whereas applications to geometry and representation theory are developed in [Ful97]. For a survey containing examples of Young tableaux for other Lie groups, see [Sag90]. Active research on the topic of Young tableaux continues. For example, recently in collaboration with Allen Knutson and Ezra Miller, we found a simplicial ball of semistandard tableaux, together with applications to Hilbert series formulae of determinantal ideals.

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Mikio Sato, a Visionary of Mathematics

Pierre Schapira

Like singularities in mathematics and physics, ideas propagate, and the speed of propagation depends highly on the energy put into promoting them. Mikio Sato did not spend a great deal of time or energy popularizing his ideas. We can hope that his receipt of the 2002/2003 Wolf Prize[1] will help make better known his deep work, which is perhaps too original to be immediately accepted. Sato does not write a lot, does not communicate easily, and attends very few meetings. But he invented a new way of doing analysis, "Algebraic Analysis", and created a school, "the Kyoto school".

Born in 1928[2], Sato became known in mathematics only in 1959–1960 with his theory of hyperfunctions. Indeed, his studies had been seriously disrupted by the war, particularly by the bombing of Tokyo. After his family home burned down, he had to work as a coal delivery man and later as a school teacher. At age 29 he became an assistant professor at Tokyo University. He studied mathematics and physics, on his own.

To understand the originality of Sato's theory of hyperfunctions, one has to place it in the mathematical landscape of the time. Mathematical analysis from the 1950s to the 1970s was under the domination of functional analysis, marked by the success of the theory of distributions. People were essentially looking for existence theorems for linear partial differential equations (PDE), and most of the proofs were reduced to finding "the right functional space", to prove some *a priori* estimate and apply the Hahn-Banach theorem.

It was in this environment that Mikio Sato defined hyperfunctions in 1959–1960 as boundary values of holomorphic functions, a discovery that allowed him to obtain a position at Tokyo University thanks to the clever patronage of Shokichi Iyanaga, an exceptionally open-minded person and a great friend of French culture. Next, Sato spent two years in the USA, in Princeton, where he unsuccessfully tried to convince André Weil of the relevance of his cohomological approach to analysis.

Sato's method was radically new, in no way using the notion of limit. His hyperfunctions are not limits of functions in any sense of the word, and the space of hyperfunctions has no natural topology other than the trivial one. For his construction, Sato invented local cohomology in parallel with Grothendieck. This was truly a revolutionary vision of analysis.

But besides its evident originality, Sato's approach had deep implications since it naturally led to microlocal analysis, as I will try to explain.

The theory of linear PDE with variable coefficients was in its early beginnings in the years 1965–1970 and under the shock of Hans Lewy's example showing that the first order linear equation $(-\sqrt{-1}\partial_1 + \partial_2 - 2(x_1 + \sqrt{-1}x_2)\partial_3)u = v$ had no solution, even a local solution, in the space of distributions[3]. The fact that an equation had no

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[1] *Translation of a paper appearing in* La Gazette des Mathématiciens ***97*** *(2003) on the occasion of Sato's receiving the 2002/2003 Wolf Prize.*

[2] *In 1990, Sato gave an interview to Emmanuel Andronikof who unfortunately passed away in 1994. I have made use of his notes, which were edited by A. D'Agnolo. I also have benefited from the scientific comments of J-B. Bost and A. Chambert-Loir, whom I warmly thank.*

[3] *The slightly simpler equation* $(\partial_1 + \sqrt{-1}x_1\partial_2)u = v$ *does not have any solution in the space of germs at the origin of distributions in* $\mathbb{R}^2$ *either, nor even in the space of germs of hyperfunctions.*

Mikio Sato (left) with Pierre Schapira, around 1972.

solution was quite disturbing at that time. People thought that it was a defect of the theory, that the spaces one had considered were too small to admit the solutions. Of course, often just the opposite is true and one finds that the occurrence of a cohomological obstruction heralds interesting phenomena: the lack of a solution is the demonstration of some deep and hidden geometrical phenomena. In the case of the Hans Lewy equation, the hidden geometry is "microlocal", and this equation is microlocally equivalent to an induced Cauchy-Riemann equation on a real hypersurface of the complex space.

In mathematics, as in physics, in order to treat phenomena in a given (affine) space, one is naturally led to compute in the dual space. One way, the most commonly used in analysis, is via the Fourier transform. This transform, far from being of a local nature, is not easily adapted to calculus on manifolds. By contrast, Sato's method is perfectly suited for this case: you can complexify a real analytic manifold and, instead of looking at the behavior at infinity of the Fourier transform, you look "where the boundary values come from". In technical terms, one regards the cotangent bundle (more precisely, $\sqrt{-1}$-times the cotangent bundle) as the conormal bundle to the real space in the complex space. This is how Sato defines the analytic wave front set of hyperfunctions (in particular, of distributions), a closed conic subset of the cotangent bundle, and he shows that if a hyperfunction u is a solution of the equation $Pu = 0$, then its wave front set is contained in the real part of the characteristic variety of the operator P. This is the starting point of microlocal analysis, invented by Sato, a kind of revolution in analysis.

Of course, at this time other mathematicians (especially L. Hörmander) and physicists (e.g., D. Iagolnitzer) had the intuition that the cotangent space was the natural space for analysis, and in fact this intuition arose much earlier (in the work of J. Hadamard, F. John, and J. Leray, in particular). Indeed, pseudo-differential operators did exist before the wave front set. But Sato was the first to make the objects of analysis, such as distributions, live in the cotangent space, and for that purpose he constructed a key tool of sheaf theory, the microlocalization functor, that is, the "Fourier-Sato" transform of the specialization functor. This is also the origin of the microlocal theory of sheaves of [3]. In 1973 Sato and his two students, M. Kashiwara and T. Kawai, published a treatise on the microlocal analysis of PDE [8]. Certainly this work had a considerable impact, although most analysts did not understand a single word. Hörmander and his school then adapted the classical Fourier transform to these new ideas, leading to the now popular theory of Fourier-integral operators.

Already in the 1960s, Sato had the intuition of $\mathcal{D}$-module theory, of holonomic systems, and of the b-function (the so-called Bernstein-Sato b-function). He gave a series of talks on these topics at Tokyo University but had to stop for lack of combatants. His ideas were reconsidered and systematically developed by Masaki Kashiwara in his 1969 thesis ([1], [2]). As its name indicates, a $\mathcal{D}$-module is a module over the (sheaf of) ring(s) $\mathcal{D}$ of differential operators, and a module over a ring essentially means "a system of linear equations" with coefficients in this ring. The task is now to treat (general) systems of linear PDE. This theory, which also simultaneously appeared in Moscow in a more algebraic framework developed by Gelfand's student J. Bernstein, quickly had considerable success in several branches of mathematics. In 1970–1980, Kashiwara obtained almost all the fundamental results of the theory, in particular those concerned with holonomic modules, such as his constructibility theorem, his index theorem for holomorphic solutions of holonomic modules, the proof of the rationality of the zeroes of the b-function, and his theory of regular holonomic modules.

The mathematical landscape of 1970–1980 had thus considerably changed. Not only did one treat equations with variable coefficients, but one treated systems of such equations and moreover one worked microlocally, that is, in the cotangent bundle, the phase space of the physicists. But there were two schools in the world: the C^∞ school issuing from classical analysis and headed by Hörmander, who developed the calculus of Fourier integral operators[4], and the analytic school that Sato established, which was almost nonexistent outside Japan and France.

France was a strategic place to receive Sato's ideas since they are based on those of both Jean Leray and Alexandre Grothendieck. Like Leray, Sato

[4] *Many names should be quoted at this point, in particular those of V. Maslov and Yu. Egorov.*

understood that singularities have to be sought in the complex domain, even for the understanding of real phenomena. Sato's algebraic analysis is based on sheaf theory, a theory invented by Leray in 1944 when he was a prisoner of war, clarified by Cartan, and made extraordinarily efficient by Grothendieck and his formalism of derived categories and the *six opérations*.

Sato, motivated by physics as usual, then tackled the analysis of the S-matrix in light of microlocal analysis. With his two new students, M. Jimbo and T. Miwa, he explicitly constructed the solution of the n-points function of the Ising model in dimension 2 using Schlesinger's classical theory of isomonodromic deformations of ordinary differential equations. This naturally led him to the study of KdV-type nonlinear equations. In 1981, with his wife Yasuko Sato, he interpreted the solutions of the KP-hierarchies as points of an infinite Grasmannian manifold and introduced his famous τ-function. These results would be applied to other classes of equations and would have a great impact in mathematical physics in the study of integrable systems and field theory in dimension 2.

In parallel with his work in analysis and in mathematical physics, Sato obtained remarkable results in group theory and in number theory.

He introduced the theory of "prehomogeneous vector spaces", that is, of linear representations of complex reductive groups with a dense orbit. The important case where the complement of this orbit is a hypersurface gives good examples of b-functions.

In 1962 Sato also discovered how to deduce the Ramanujan conjecture on the coefficients of the modular form Δ from Weil's conjectures concerning the number of solutions of polynomial equations on finite fields. His ideas allowed M. Kuga and G. Shimura to treat the case of compact quotients of the Poincaré half-space, and it would be necessary to wait another ten years for P. Deligne to definitely prove that Weil's conjectures imply the Ramanujan-Petersson conjecture.

While M. Sato and J. Tate shared the 2002/2003 Wolf Prize, they also share a famous conjecture[5] in number theory concerning the repartition of Frobenius angles. Let P be a degree 3 polynomial with integer coefficients and simple roots. Hasse showed that for any prime p that does not divide the discriminant of P, the number of solutions of the congruence $y^2 = P(x) \pmod p$ is like $p - a_p$, with $|a_p| \le 2\sqrt{p}$. When writing $a_p = 2\sqrt{p}\cos\theta_p$ with $0 \le \theta_p \le \pi$, the Sato-Tate conjecture predicts that the repartition of the angles θ_p follows the probability law with density $(2/\pi)\sin^2\theta d\theta$. Note that Tate was led to this conjecture by studying algebraic cycles and Sato by computing numerical data.

[5] *For recent developments on this conjecture, see [4].*

Sato's most recent works are essentially unpublished and have been presented in seminars attended only by a small group of people. They treat an algebraic approach to nonlinear systems of PDE, in particular holonomic systems, of which theta functions are examples of solutions!

Looking back, forty years later, we realize that Sato's approach to mathematics is not so different from that of Grothendieck, that Sato did have the incredible temerity to treat analysis as algebraic geometry, and that he was also able to build the algebraic and geometric tools adapted to his problems.

His influence on mathematics is, and will remain, considerable.

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Presidential Views: Interview with James Arthur

Every other year, when a new AMS president takes office, the *Notices* publishes interviews with the outgoing and incoming presidents. What follows is an edited version of an interview with James G. Arthur, whose two-year term as president ends on January 31, 2007. The interview was conducted in fall 2006 by *Notices* senior writer and deputy editor Allyn Jackson. Arthur is a University Professor of Mathematics at the University of Toronto.

An interview with president-elect James G. Glimm is scheduled to appear in the March 2007 issue of the *Notices*.

Notices: *What were your main activities as president?*

Arthur: One was the Einstein Lecture Series, which we started in 2005. That year was the 100th anniversary of Einstein's so-called *annus mirabilis*, in which he published three fundamental papers that changed the course of twentieth century physics. The idea is to present some aspects of mathematics in the broadest possible sense to a large public audience who might not realize how encompassing mathematics is. We have been very lucky to have people who have made it a great success so far. Michael Atiyah gave the first Einstein Lecture in October 2005 at the University of Nebraska, a brilliant talk on relations of mathematics with fundamental physics. It was a huge success, with eight hundred people in the audience. Much of this we owe to the people at the University of Nebraska. John Meakin was chair, and he and others there did a wonderful job. Benoît Mandelbrot spoke at San Francisco State University in May 2006. That was in a smaller room, with a capacity of four hundred, but it was filled. He gave a remarkable lecture. I was not familiar with his work, so it was really a revelation for me to see the following that he has. After the lecture thirty or forty people crowded around the podium and wouldn't let him leave for half an hour. They treated him a bit like a mathematical rock star. The next Einstein Lecture will be at Rutgers University in the fall of 2007, and we are very pleased to have Roger Penrose give that one. The fourth one will take place in the fall of 2008 in Vancouver.

Notices: *So you were thinking a lot about the Einstein Lectures. What else did you work on?*

Arthur: Among the things that have taken time have been activities related to the policy committees. The president serves on all five policy committees. For the Science Policy Committee, this has been a pretty interesting time in Washington. Sam Rankin runs the Washington office. After some years of doing this, he has a very good understanding of how Washington works and how best to make the case for mathematics. There has been a turnover at NSF [National Science Foundation]: Peter March is now director of the DMS [Division of Mathematical Sciences], and Tony Chan now heads MPS [Directorate of Mathematical and Physical Sciences]. These are two prominent mathematicians whom we feel fortunate to have serving in these positions of leadership. We are looking forward to seeing what directions they take over the next few years. NSF is critical for many, though not all, of our members. It is the agency that puts the most funding into the mathematics that our members do. However, I think that it also has larger symbolic importance.

The Bush administration came to a conclusion earlier in the year that the teaching of mathematics was of great strategic importance and created a panel to examine it. There have been various meetings about this. We have tried to use it to make mathematics a part of the broader discussion in Washington.

Notices: *Were you or the AMS Committee on Education involved in the appointment of the panel?*

Arthur: I was not, and I don't believe the Committee on Education was. The COE has been involved in other related things, for example, in the work of a committee chaired by Richard Schaar. This committee attempted to reach an agreement among research mathematicians and mathematical educators about what would be an appropriate curriculum for kindergarten through eighth grade. They produced what seemed to many to be a very sensible list of recommendations. This is now getting wider discussion, and I would expect it is part of the deliberations of the national panel for mathematics education.

The COE has in recent years been concerned about K-through-12 education, although traditionally the focus was more on undergraduate and graduate education in mathematics. Many of our members are worried that the level of preparation of the students they see is not what it used to be. But I think the long-term focus of the COE really ought to be undergraduate and graduate teaching.

Notices: *Can you tell me about your work on the Council and the Board of Trustees?*

Arthur: It has been generally a great pleasure. I chair the Council and the Executive Committee, and I also serve on the Board of Trustees. The Board is involved in any matter that is financial, whereas the Council deals with all other matters before the AMS. People don't realize that the AMS has a budget of something like US$23 million. In principle, how that money is spent is at the discretion of the Council and Board of Trustees, which are elected by the 30,000 members. So the work of the Council and the Board is very important.

One example of something that occupied a great deal of time was the question of whether there should be a fellows program in the AMS. Many other professional societies have such a program, whereby members who have achieved great distinction are designated as fellows of the society. For good reasons, mathematicians feel very strongly about this, in both directions. An AMS committee, chaired by Susan Friedlander, made an explicit proposal for an AMS fellows program. The proposal was discussed at the Council meeting in San Antonio [in January 2006], and it was really quite impressive how thoughtful people were. Whatever their views—and they were strong on both sides—people had a very good idea of and respect for the views from the opposite side. In the end the Council decided to put the matter up for a vote, with the pretty tough requirement that the proposal would go forward only with a two-thirds majority of the voting membership. This will have been resolved by the time this interview appears in the *Notices*, but as we speak today, the polls are still open. There are no exit polls, so we don't have any idea how it's going! But indications are that there is an extremely heavy vote, perhaps much greater than in any other election. Whichever way it goes, I hope we will be the stronger for it. I think discussion of matters like this is very healthy for the AMS, and I trust that members will respect whatever decision is eventually voted on.*

Notices: *You see many aspects of the culture of mathematicians come out in the debate over the fellows program.*

Arthur: Yes, you do. On the one hand, mathematics is somewhat hierarchical, more so than in other subject areas, perhaps because it's easier to assess how important mathematical discoveries are, and so there is perhaps less dispute about them. On the other hand, mathematicians have a strong egalitarian streak. Both are influencing the discussion. The discussion of the fellows program has perhaps symbolized these sometimes contradictory feelings. ***Notices:*** *What challenges do you see for the AMS?*

Arthur: One challenge is attracting younger members, who are not joining the AMS in the numbers that they used to. The AMS has to persuade them somehow that it is important to their concerns and that as mathematicians they are better off being members of the AMS. There are many concrete ways the AMS serves mathematicians. What people think of less is that the AMS is also a network of moral support for mathematicians. It is a way of banding together to make the case for mathematics to others, but it also serves to amplify our own very personal feelings for the subject. We see other mathematicians at meetings, read their papers in journals, and even just know that there are many who share the same values we do and who are part of the same enterprise. Knowing that there are others in the society you belong to who love mathematics and who are working on many of the same concerns that you have can be potentially a very powerful force of encouragement for individual mathematicians.

We also have a problem of membership among the most senior and distinguished mathematicians, who do not always remain members. Perhaps this has always been the case. I worry that some people may not see the AMS as being relevant to their mathematical interests, a view that I think is not at all correct. We need to persuade senior distinguished mathematicians to join so that at the very least they set an example for young mathematicians.

Notices: *You have been concerned about public awareness in mathematics. What do you see as the AMS's role here?*

Arthur: The AMS has a Public Awareness Office, and there are just two people in it. They do a very good job, but the size of the operation precludes very many major projects. They create wonderful Web resources on the AMS site: Mathematical Moments, Mathematics in the Media, and several others as well. Many people don't know about these things. It would be useful to try to figure out some way to make them more visible, both to our members and to nonmathematicians.

There is some interest now on the part of the Clay Mathematics Institute and other institutions of working with the AMS on the public awareness of mathematics. One idea is to figure out a more systematic way, perhaps a training session, for mathematicians to learn how to talk effectively about mathematics to the media. When we mathematicians talk about mathematics to a broader audience, in particular to the media, we see our colleagues peering over our shoulders, and we think anything we say is going to be criticized for inaccuracy or grandstanding, and probably both!

But I think this is changing. Mathematicians are now coming to the view that any publicity within reason for mathematics is good. Our greatest enemy in the past has simply been the total ignorance of how important mathematics is. For example, the coverage of the recent proof of the Poincaré conjecture tended to focus on the controversy and also on the idiosyncrasies of the individuals involved. We shudder a bit at that, perhaps feeling that it is not doing the subject any good. I think that this perception is incorrect. It may be that the human side of the subject is needed as a hook to get the public interested.

Notices: *Often it is difficult for mathematicians to communicate the beauty and mystery of their subject.*

Arthur: Those are the things that appeal to mathematicians, but they also potentially are of great appeal to the public. I think the excitement over the Poincaré conjecture and Fermat's Last Theorem taught us that there really is a public appetite for deep mathematics. I think the public is prepared to be astonished by the mystery and the beauty of mathematics. Often when mathematicians try to speak to the press, there is a disconnection between their own motivations for their work, which are probably much closer to what the public could identify with, and how they express the mathematics, which tends to be in rather formal and technical terms.

Notices: *Any final thoughts?*

Arthur: I sometimes worry that every new president is going to feel an expectation that he or she create something new, a monument, that will be grafted onto the AMS. The motivation is of course good, and it is certainly the way I felt. In fact, I know that during my early days I had some pretty harebrained schemes! At times I must have made life difficult for John Ewing and Bob Daverman! John is the AMS executive director, and Bob is the AMS secretary. They are extraordinarily good at what they do, and it is a great privilege to serve with them. But the AMS president is first and foremost a public spokesperson for the AMS and, by extension, for mathematics itself. One important role for the AMS, as I mentioned before, is to be in subtle ways a moral support to mathematicians. The president of the AMS is in an ideal position to bring this out.

I am looking forward to Jim Glimm taking over as AMS president. He has some interesting ideas for the future of the AMS and a great deal of energy and dedication. There have been some really wonderful presidents in the past—I would mention my predecessor, David Eisenbud, to whom I am very grateful for helping me learn the job. And there have been others, going back ten or fifteen years, who, partly with the AMS staff and partly through their own efforts, have brought the AMS into a position now where it is an extremely well-run organization. Just look at publications, for example. We publish a number of journals, including one, *Journal of the AMS*, which is arguably the best—or the second or third best—mathematics journal in the world. This is the work of a democratically elected scientific society! We also publish other journals that are important, and they are all sold at reasonable prices. We also have Math Reviews, an extraordinary database used all over the world. These are things for which the world mathematical community relies on the AMS. I mention them to point out that the AMS really is a remarkable organization. There is no doubt room for improvement, but we should also not forget that we really do have something quite special.

I should say that I am also proud to be a member of the Canadian mathematical community. The Canadian Mathematical Society [CMS] works closely with the AMS. Canadian mathematics has really blossomed in the last thirty years. There are also some very good mathematicians in Mexico, and it is good to see relations developing among three North American societies: the AMS, the CMS, and the Mexican Mathematical Society [MMS]. The MMS invites two or three AMS representatives to come and speak every year at its annual meeting. There is also going to be a joint meeting next year between the AMS and the MMS in Mexico.

We collectively as mathematicians should be pretty excited about what's happening in our field. In the past ten years there have been two extraordinary mathematical breakthroughs. We have seen a proof of Fermat's Last Theorem, which, even though it has a very simple statement, uses some of the deepest mathematics ever discovered. We now have the Poincaré and geometrization conjectures apparently resolved, with a union of analysis and geometry and topology that would have been absolutely unheard of thirty years ago. These both—with apologies to Andrew Wiles and Grisha Perelman!—now belong to all of us. We should not lose sight of the fact that these are remarkable times in mathematics. The AMS is a part of it all. It plays a major role in helping all mathematicians—not only its members, but mathematicians the world over—better serve their profession.

*Added in postscript: Of members who voted on the fellowship program, 63.2% were in favor, a figure that falls just short of the required two-thirds majority. Besides being very close, the vote was substantially larger than for any election in recent memory. My reading of the results is that the question will remain with us for some time. *—J.A., Dec. 2006.*

Interview with William Rundell

William Rundell served as director of the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) from the fall of 2002 until the summer of 2006, when he was succeeded by Peter March of the Ohio State University. Rundell has now returned to his home institution, Texas A&M University. What follows is the edited text of an interview with Rundell conducted in fall 2006 by *Notices* deputy editor Allyn Jackson.

Notices: *What was the budget climate like in the NSF when you went there in the fall of 2002?*

Rundell: The first year was an incredible roller coaster. Over the previous forty years, DMS had gone up roughly with NSF, but probably a percentage point or two behind per year. You see little blips of inspiration. For example, after the David Report [published in 1984] there was a little budget boost. After some of the experiments the DMS did in the early 1990s, there was a decline—they didn't sell well. But this was tinkering with percentages, not major structural changes. But with the Mathematical Sciences Priority Area being declared and with [then-NSF director] Rita Colwell's promotion of it starting in 2001, the DMS went from about US$100 million up to US$150 million at the start of 2002.

The [fiscal year] 2003 budget was waiting to be passed by Congress when I came in. There was a US$30 million request from NSF for the priority area, and in the Senate version of the bill someone had written in that DMS would only get a US$10 million dollar request rather than US$30 million. There was a big fight over this and an ensuing battle to try and restore the US$30 million dollars. For the first several months it wasn't clear whether we were getting the US$10 million or the US$30 million. But that got resolved positively, and we got the US$30 million increase, so the DMS budget was US$180 million.

In December 2002 the president signed the authorization bill to double the NSF'S budget in five years. This meant DMS surely would get at least the NSF average increase. We had already almost doubled the DMS budget, and in fact at the end of that next fiscal year it was going to be US$200 million. If we got the doubling after that, it would be US$400 million, and we would be in great shape. There was a sense of euphoria around the NSF that we had seen some good times, and they were going to get better.

You can achieve a doubling of the budget in five years with an increase of 15 to 18 percent per year. Instead, we got 2 percent. That burst the bubble. In subsequent years the NSF had a flat or declining budget. Things changed very quickly around the foundation. All the plans—you just saw them getting shelved. People were in the mode of, What can I cut?

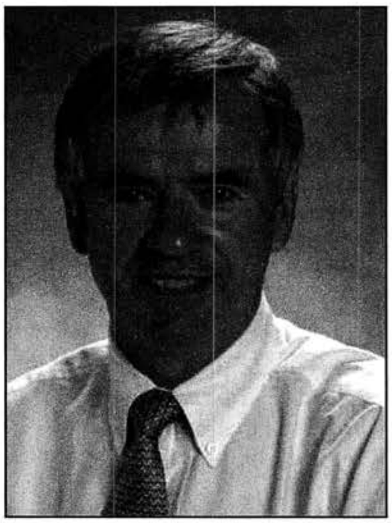
Notices: *How did DMS deal with these changes?*

Rundell: Well, it certainly was problematic. It did cramp us making new programs. So for example, I inherited VIGRE [Vertical Integration of Research and Education]. VIGRE was being run at a pace that was commensurate in the long term with probably a US$300 to US$400 million budget. It was a very popular program in the foundation and Congress. The DMS was tackling the obvious problem of how to get U.S. citizens into science, in particular hard sciences. We were at least trying to do something about the problem, and there was a certain sympathy for that. So to cut off VIGRE would be stupid, and yet we had a program that required an increasing budget for its sustainability at then-current levels but that was overgrown for the actual budget. I also knew that VIGRE shouldn't be sustained. VIGRE was there to transform, and after that had been achieved, it had to be mainstreamed. So I brought in the Research Training Groups, which are similar to VIGRE but done within a smaller group. I thought this could be a useful addition to VIGRE and possibly an answer to, what will VIGRE transform into? At that time I had no idea what the budgets were going to be like in future years. But there was no intent to cut the amount of money being spent on work force programs.

The DMS's move to put in a high-profile program to attract domestic talent into the discipline was a really, really important move. You can argue endlessly whether VIGRE was a good program or whether it was implemented well. But I think it's absolutely clear that the attempt to do something was viewed very positively.

Notices: *You did not cut the work force budget during this time. What did you cut in DMS?*

Rundell: Basically what we did was, we kept everything flat. I was an optimist, and I think we are probably going to see now better times ahead. It takes time to put programs in, and when the money does come, sometimes you have got to have an idea for grabbing it. To sit back and do nothing until good times come along isn't necessarily a good strategy. So a certain optimism has to be there.



William Rundell

But when I came in in 2002 the number of expansion programs already in place through the priority area was huge. We didn't need more programs as much as making sure the existing ones were working well. We were doing business with every single research directorate in the foundation, partly through the priority area, but partly just through regular business. We were working with NIH [National Institutes of Health]. The DMS interaction with NIH is by far the largest interaction that has ever taken place between the two agencies.

Notices: *You mean even between the NSF biology directorate and NIH?*

Rundell: Yes. When biology puts something together, it's a few million dollars, and it lasts for a fixed period. We have been running this for five years now, and we are going to continue it. The level of money has been around US$20 million, of which NIH has been putting in US$2 to our US$1. This is a huge program by almost any standards. During a visit to Congress, NIH director Elias Zerhouni gave three examples of NIH's innovation, and one of them was the interaction with DMS. So that is high value, and it's something that is a success.

Notices: *Most mathematicians believe PI grants are the most important part of the DMS. How did PI grants fare in this budget climate?*

Rundell: I'd rather not call them PI grants, although it is a good term. I would call them single-investigator grants. They include summer salary support, travel, sometimes graduate student support and visitor money. These are sometimes complicated grants. If you take any block of time from NSF's beginnings to now and you ask, what were the best years for DMS single-investigator grants or for senior researcher increases?, the answer is the period of 2001 through 2005.

Notices: *You mean in terms of numbers of PIs supported?*

Rundell: No—the amount of money in it. The number of single-investigator grants went up somewhat, maybe 10 percent. But the amount of money available in the grants went up considerably. Before that time, we were really cutting back on the amount of summer support. It was basically a month, maximum. We are now giving junior people two months, and senior people sometimes a month, but often a month and a half and even sometimes two months. We are much more likely to give generous travel, and we are giving money for bringing in visitors. The value of the grants went up enormously. The foundation had been worried not just about the lack of support for mathematics in general but about the low value of each grant. So in the priority area there were goals of increasing the money available globally to mathematics, about the work force, about interactions with other disciplines, and about funding grants at a better level. The next level of priority would be to increase the number of awards. But that was never one of the main priorities.

And remember inflation here is a huge factor. You view inflation costs as being 2 percent, right? But in fact the inflation costs that DMS was seeing were nearly 6 percent.

Notices: *Why?*

Rundell: The average raise in universities is 2 or 3 percent, but the stars are getting 6 or 7 percent raises. They are getting a 10 percent promotion raise, and if they move, they are getting a big hike in salary. These are the people we are funding. The single biggest thing we pay is single-investigator grant salaries—and you add on fringe benefits and indirect costs, which are prorated to the increase in salary. So the whole budget goes up basically as that block. We need in other words to double the budget every eleven or twelve years just to stay even.

One of the drivers of the priority area was to improve graduate student support. The numbers are difficult to come by, but I would say that essentially we doubled the amount of money spent on this. All of my predecessors and I worried enormously about what damage inactivity here was doing to U.S. mathematics. We knew that if we didn't do something for graduate student support, then we would not be able to attract the best students from abroad, and we would not send a good message to domestic students. And we will suffer in the long term.

If we had US$400 million, we would use part of it to enrich the grants, we would support more graduate students, we would support more postdocs, and we would manage to slightly increase the number of people supported. It would be nice for mathematicians to have the same level of support as chemists, biologists, computer scientists, and physicists—but not on US$200 million, not on US$300 million, and, to tell you the truth, not on US$400 million. The idea of spreading it like butter doesn't look like we are supporting the best stuff. We would be perceived as not making the decisions, but just giving it out almost like a charity.

Notices: *Few mathematicians get grants. Does this inspire apathy among people who feel they will never have a chance to get a grant? Does this apathy mean a lack of pressure to increase the budget for math?*

Rundell: Sure. It's a vicious circle. About half of DMS support goes to about twenty universities, three-quarters goes to forty universities, and so on down the line. That means that the stakeholders are relatively few in number. If we spread the money out, would it make a difference? Yes, but then the amount of money would be so insignificant it would not be on the radar map. But I think it is probably true that the mathematicians who get the money aren't pulling their weight for justifying us to get more. And on the other hand, those people who are disenfranchised have no incentive to do that.

We don't make the case. If you find a staffer on Capitol Hill who has a science background, I would guess there is a 50 percent chance the person is a physicist. I don't know what the chance is that the person is in mathematics, but it's less than 10 percent. The fact that a lot of information flow is coming through the physics community and is filtered by that perspective is on the long haul going to make a difference for that discipline. It's not just that we don't work Capitol Hill well enough. We don't work the whole process. Math departments in universities are notorious for not promoting themselves as well as they should. It goes beyond just federal funding. It's that the discipline doesn't promote its case well enough, whether at universities or for the funding situation.

So the problem isn't that the US$200 million budget is small. The problem is that we haven't been proactive in promoting the discipline, and that's why it's small. And it is criminally small. But I think the fault here is not the outsiders. We are in a situation where you have to promote yourself, and we just haven't done that effectively. We haven't done it effectively in a sustained way, the way others have.

Notices: *Some say that while the people who go to DMS are good and dedicated, they are not at the top of the field. How would you respond?*

Rundell: I am going to react strongly to the insinuation that the program officers aren't coming from a good research background. One of the things I worked at enormously hard was recruiting. We were not hiring people who we were not supporting. These are people who have a long history of support. We have got people who have been graduate chairs and chairs of departments, some of them very good departments. I don't think we need to get Fields Medalists to come in to be program officers. But we absolutely have been hiring people who not only are potentially fundable but have been funded by NSF. So the people making the decisions are on average quite a bit better than the people submitting proposals. They don't have to be at the very top of that list, but they are certainly better than the average submitting mathematician. And several of them have absolutely stellar records of research. You've got to print this in 24-point bold, that the people making decisions are people who have been successful.

It's very hard to recruit. In academia—and hiring at NSF is like hiring in academia—if hiring is not the hardest thing you are doing, you are not doing it well enough. It's going to be hard, because you are looking for better and better people all the time. One of the things I spent a lot of energy on at the NSF was to get every permanent program officer a window office, get everyone a nice office, and give them a lot more time to do their own work, and fairly generous travel money. The program officer environment is actually quite good, and the people we have been getting are really very good.

I had dealt with NSF a lot before going there. I had been on panels, I had a long history of NSF support for my own work, and I was a VIGRE PI. So I felt I knew NSF to some extent, and I felt very good about it. That's why I went. Did I feel better or worse about NSF after I left? The answer is, I felt even better. As an institution, it's absolutely without question the best funding agency on the planet. It's totally professional, and the dedication of the people really is high. And the quality of the people is much higher than the outsiders think.

You submit a proposal to NSF, and the level of justice you get is superb. DMS gets 2,700 proposals a year. I am not saying that every single one of those is handled superbly. That would be impossible. But the level of professionalism and the number of those proposals that are handled in an absolutely first-class way is astoundingly high. And I think the important factor is that there are good people. That's why it works.

2006 Annual Survey of the Mathematical Sciences

(First Report)

Report on the 2005–2006 New Doctoral Recipients Faculty Salary Survey

Ellen E. Kirkman, James W. Maxwell, and Colleen Rose

The First Report of the 2006 Annual Survey gives a broad picture of 2005–06 new doctoral recipients from U.S. departments in the mathematical sciences, including their employment status in fall 2006. The First Report also presents salary data for faculty members in U.S. departments of mathematical sciences in four-year colleges and universities. This report is based on information collected from two questionnaires distributed to departments in April 2006. A follow-up questionnaire was distributed to the individual new doctoral recipients in October 2006. This questionnaire will be used to update and revise results in this report, which are based on information from the departments that produced the new doctorates. Those results will be published in the Second Report of the 2006 Annual Survey in the August 2007 issue of the *Notices* of the AMS. Another questionnaire concerned with data on fall 2006 course enrollments, graduate students, and departmental faculty was distributed to departments in September 2006. Results from this questionnaire will appear in the Third Report of the 2006 Annual Survey in the November 2007 issue of the *Notices* of the AMS.

The 2006 Annual Survey represents the fiftieth in an annual series begun in 1957 by the American Mathematical Society. The 2006 Survey is under the direction of the Data Committee, a joint committee of the American Mathematical Society, the American Statistical Association, the Institute of Mathematical Statistics, the Society of Industrial and Applied Mathematics, and the Mathematical Association of America. The current members of this committee are Richard Cleary, Amy Cohen-Corwin, Donald M. Davis, Nicholas M. Ercolani, Abbe H. Herzig, Donald R. King, Ellen E. Kirkman (chair), David J. Lutzer, Peter March, James W. Maxwell (ex officio), Polly Phipps, David E. Rohrlich, and Henry Schenck. The committee is assisted by AMS survey analyst Colleen A. Rose. Comments or suggestions regarding this Survey Report may be directed to the committee.

Ellen E. Kirkman is professor of mathematics, Wake Forest University. James W. Maxwell is AMS associate executive director for special projects. Colleen A. Rose is AMS survey analyst.

Report on the 2005–2006 New Doctoral Recipients

This report presents a statistical profile of recipients of doctoral degrees awarded by departments in the mathematical sciences at universities in the United States during the period July 1, 2005, through June 30, 2006. It includes a preliminary analysis of the fall 2006 employment plans of 2005–06 doctoral recipients and a demographic profile summarizing characteristics of citizenship status, sex, and racial/ethnic group. All information came from the departments that awarded the degrees.

Table 1: Number of Departments Responding to Doctorates Granted Survey

Group I (Pu)	25 of 25 including 0 with 0 degrees
Group I (Pr)	22 of 23 including 0 with 0 degrees
Group II	52 of 56 including 0 with 0 degrees
Group III	67 of 75 including 11 with 0 degrees
Group IV	60 of 88 including 10 with 0 degrees
Group Va	19 of 21 including 1 with 0 degrees

See "Definitions of the Groups" on page 267.

Table 1 provides the departmental response rates for the 2006 Survey of New Doctoral Recipients. See page 267 for a description of the groups. No adjustments were made in this report for nonresponding departments.

This preliminary report will be updated in the Second Report of the 2006 Annual Survey using information gathered from the new doctoral recipients. The Second Report will appear in the August 2007 issue of the *Notices* of the AMS.

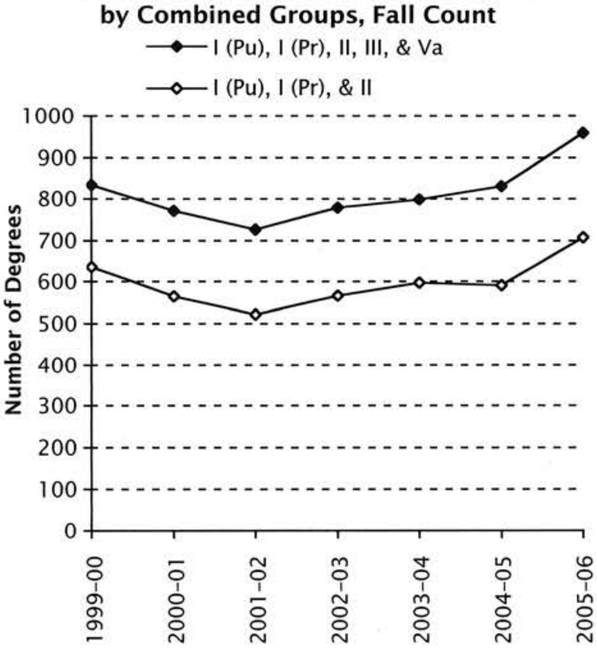
Changes in the Annual Survey occur over time, and these changes need to be considered when comparing results in this report to those in prior years. Information about changes that occurred in 1997 or later can be found in the First Report for the 2000 Annual Survey in the February 2001 issue of the *Notices* of the AMS.

In this First Report's tables referring to new doctoral recipients, "Fall" refers to results based on information about new doctoral recipients received from departments granting their degrees. This information is gathered in the first fall following the academic year in which the degrees were granted. "Final" refers to results based on supplemental information received from the new doctoral recipients themselves as well as additional new doctoral recipients not reported by departments in time for publication in the First Report. These

Table 2: New Doctoral Degrees Awarded by Group, Fall Count

Group	I (Pu)	I (Pr)	II	III	IV	Va	TOTAL
1996-97	297	187	228	132	197	72	1123
1997-98	306	174	264	129	213	77	1163
1998-99	292	152	241	136	243	69	1133
1999-00	256	157	223	132	284	67	1119
2000-01	233	129	203	125	237	81	1008
2001-02	218	139	164	124	222	81	948
2002-03	258	138	170	121	239	91	1017
2003-04	195	187	215	111	243	90	1041
2004-05	243	146	203	153	285	86	1116
2005-06	307	184	216	140	287	111	1245

Figure 1: New Doctoral Degrees Awarded by Combined Groups, Fall Count



Highlights

There were 1,245 new doctoral recipients reported for 2005-06 by departments responding in time for the 2006 First Report. This is the highest number ever reported.

All groups, except Group III, reported increased numbers of new doctorates. Group 1 (Pu) had the largest increase (64) (the highest number reported by this group since 1997-1998 (306)), and Group IV, while reaching a ten-year high, showed the smallest increase (2). Only 522 (42%) of the new doctoral recipients for 2005-06 are U.S. citizens.

Based on responses from departments alone, the fall 2006 unemployment rate for the 1,066 new doctoral recipients whose employment status is known is 4.4%, down from 7.3% for fall 2005.

Sixty new doctoral recipients hold positions at the institution that granted their degree, although not necessarily in the same department. This is 6% of the new doctoral recipients who are currently known to have jobs and 9% of those who have academic positions in the U.S. Fourteen new doctoral recipients have part-time positions.

The number of new doctoral recipients employed in the U.S. is 884, up 133 from last year. The number of new doctoral recipients employed in academic positions in the U.S. increased to 671 from 602 last year. This is the highest number reported in the last two decades.

Of the 884 new doctoral recipients taking positions in the U.S., 167 (19%) have jobs in business and industry; the number of new doctoral recipients taking jobs in business and industry oscillated in the late 1990s, declined during 2001-2003, and has increased for the last three consecutive years 2004-2006. The fall 2006 number is up 45% from fall 2005, and the fall 2006 number is 1 less than the fall 2001 number. The number of new doctoral recipients taking jobs in government is up 12 (35%) over fall 2005.

Among the 884 new doctoral recipients having employment in the U.S., 404 (46%) are U.S. citizens (up from 325 (43%) last year). The number of non-U.S. citizens having employment in the U.S. is 480, up 13% from 426 last year.

Among the 343 new doctoral recipients hired by U.S. doctoral-granting departments, 43% are U.S. citizens (up from 38% last year). Among the 328 having other academic positions in the U.S., 54% are U.S. citizens (up from 51% last year).

Of the 1,245 new doctoral recipients, 394 (32%) are females, up 64 from fall 2005. Of the 552 U.S. citizen new doctoral recipients, 143 (27%) are females, up 23 from fall 2005.

Among the 522 U.S. citizen new doctoral recipients, 3 are American Indian or Alaska Native, 34 are Asian, 17 are Black or African American, 17 are Hispanic or Latino, 3 are Native Hawaiian or Other Pacific Islander, 444 are White, and 4 are unknown; each of these numbers is the same or larger than last year's number.

Group IV produced 287 new doctorates, of which 134 (47%) are females, compared to all other groups combined, where 260 (27%) are females. In Group IV, 84 (29%) of the new doctoral recipients are U.S. citizens (while in the other groups 46% are U.S. citizens).

Three hundred ninety-six new doctorates had a dissertation in statistics/ biostatistics (331) or probability (65), a 6% increase over last year's number. The next highest number was in algebra and number theory with 184. Those with dissertations in statistics/biostatistics or probability accounted for 32% of the new doctorates in 2005-06.

Table 3: Full-Time Graduate Students in Groups I, II, III, & Va, Fall 1996 to Fall 2005

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total full-time graduate students	9476	9003	8791	8838	9637	9361	9972	10444	10707	10565
Female	2760	2691	2770	2766	3016	2899	3136	3215	3245	3111
% Female	29%	30%	32%	31%	31%	31%	31%	31%	30%	29%
% U.S. citizen	57%	55%	55%	53%	53%	49%	51%	54%	55%	56%
Total first-year graduate students	2443	2386	2458	2664	2839	2875	2996	2711	3004	2832
Female	795	836	859	866	879	1014	1038	902	983	851
% Female	33%	35%	35%	33%	31%	35%	35%	33%	33%	30%

(Data Reprinted from Table 6B in Third Report, 2005 Annual Survey)

results are published each August in the Second Report.

Doctoral Degrees Granted in 2005–06

Table 2 shows the number of new doctoral degrees granted by the different doctoral groups surveyed in the Annual Survey for the past ten years. The 1,245 new doctorates granted by these departments in 2005–06 is an increase of 129 from the fall count for 2004–05, and the highest number of new doctorates ever reported in a First Report. Figure 1 presents the trends in doctorates granted for Groups I (Pu), I (Pr), II, III, and Va combined and Groups I (Pu), I (Pr), and II combined.

The response rates were above 90% for all groups except Groups III and IV. Response rates increased in all groups, except Groups III and IV. Overall, five more departments responded in time for the First Report this year than responded last year.

The number 1,245 of new doctoral recipients is a preliminary count. A final count will appear in the Second Report in the August 2007 issue of the *Notices* of the AMS. Efforts continue to obtain data from as many of the nonresponding departments as possible.

From Table 2 we see that all groups, except Group III, showed an increase in the number of doctoral recipients from the previous year, but most of the increase (102) was in Group I (Pu) and Group I (Pr), combined. Group I (Pu) had the largest increase (64) (attaining the highest number of new doctorates reported by this group since 1997–1998 (306)), and Group IV, while reaching an eight-year high, showed the smallest increase (2). Group V had the largest percentage increase (29%).

Table 3 gives historical information about various types of full-time graduate students in Groups I, II, III, and Va combined. These data, gathered in the 2005 Departmental Profile survey, are reprinted from Table 6B of the Third Report of the 2005 Annual Survey (*Notices* of the AMS, December 2006). From this data we can see that total full-time graduate enrollment in the doctoral mathematics groups has been generally increasing since 1999, although it was down in fall 2005. Similarly, the number of first-year full-time graduate students declined in 2005 after steadily increasing since 1998. The number of full-time graduate students who are U.S. citizens has been increasing since 2002, and the number of non-U.S. citizens has been decreasing since 2003. The number of female full-time graduate students, which had been increasing since 2002, dropped 4% in 2005 The percentage of females among full-time graduate students in the combined mathematics groups has remained relatively stable over the 10-year period shown.

The 2005–06 numbers in Table 2 will be broken down in various ways, such as by sex, in later sections of this report. The names of the 1,245 new doctoral recipients are found on pages 264–82 of this issue of the *Notices*.

Figure 2: Percentage of New Doctoral Recipients Unemployed (as reported in the respective Annual Survey Reports 1994–2006)

Report	Fall	Final
1994–95	15.0%	11.0%
1995–96	9.4%	8.1%
1996–97	6.8%	3.8%
1997–98	7.2%	4.9%
1998–99	6.2%	4.7%
1999–00	4.6%	3.3%
2000–01	5.6%	3.7%
2001–02	4.3%	2.9%
2002–03	5.1%	5.0%
2003–04	5.7%	4.4%
2004–05	7.3%	3.9%
2005–06	4.4%	*

*To appear in the Second Report.
Note: Prior to 1998-99, the percentages include new doctoral recipients from Group Vb.

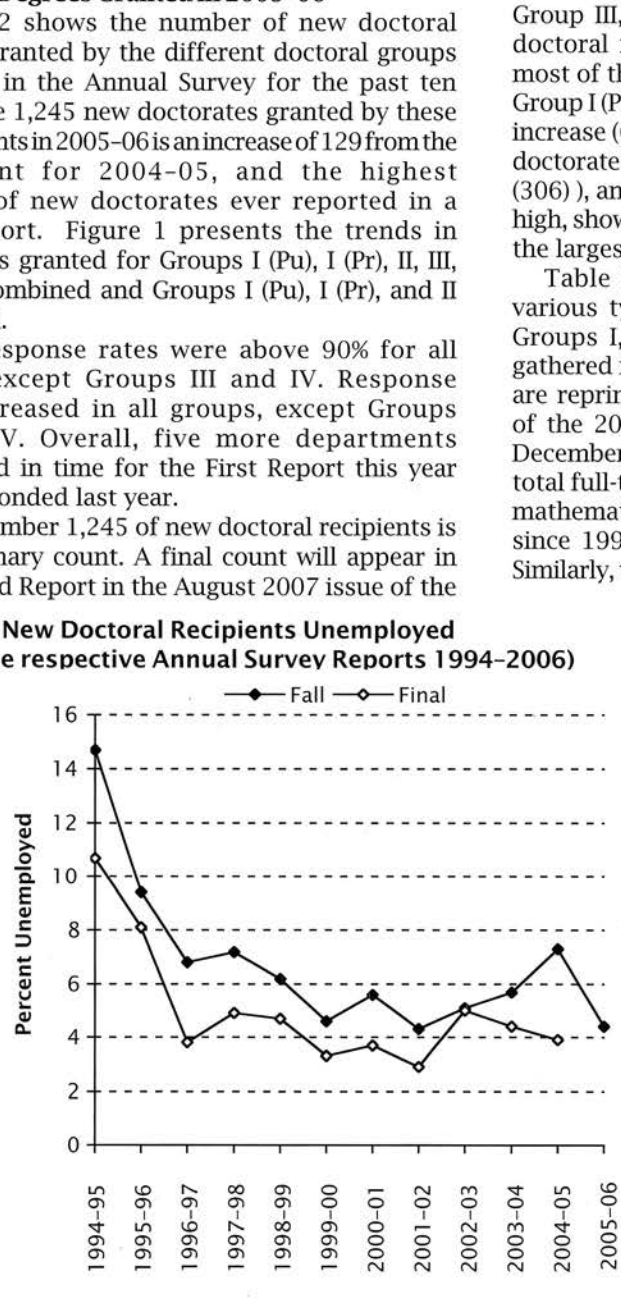


Table 4A: Employment Status of 2005–06 New Doctoral Recipients in the Mathematical Sciences by Field of Thesis

TYPE OF EMPLOYER	FIELD OF THESIS: Algebra/ Number Theory	Real, Comp., Funct., & Harmonic Analysis	Geometry/ Topology	Discr. Math./ Combin./ Logic/ Comp. Sci.	Probability	Statistics/ Biostat.	Applied Math.	Numerical Analysis/ Approxi-mations	Linear Nonlinear Optim./ Control	Differential, Integral, & Difference Equations	Math. Educ.	Other/ Unknown	TOTAL
Group I (Public)	17	8	9	7	0	1	9	6	1	13	1	0	**72**
Group I (Private)	17	3	18	2	7	3	9	4	1	11	0	0	**75**
Group II	17	15	5	5	4	2	5	4	3	10	0	0	**70**
Group III	4	2	5	5	2	10	5	3	0	7	2	0	**45**
Group IV	0	0	0	1	7	59	1	0	0	0	1	0	**69**
Group Va	0	0	0	1	1	1	4	4	1	0	0	0	**12**
Master's	12	3	4	6	3	13	2	3	0	7	3	0	**56**
Bachelor's	32	11	17	10	7	12	7	11	2	14	5	1	**129**
Two-Year College	2	2	0	0	0	2	0	0	1	2	2	0	**11**
Other Academic Dept.	2	5	2	6	3	45	19	5	1	6	2	1	**97**
Research Institute/ Other Nonprofit	8	0	4	2	0	10	5	1	1	4	0	0	**35**
Government	3	2	0	2	0	15	12	7	2	3	0	0	**46**
Business and Industry	8	9	5	8	14	88	22	5	3	5	0	0	**167**
Non-U.S. Academic	31	9	17	14	5	9	8	2	2	7	1	1	**106**
Non-U.S. Nonacademic	4	0	2	1	2	7	3	0	0	2	0	0	**21**
Not Seeking Employment	3	0	1	0	1	2	1	0	0	0	0	0	**8**
Still Seeking Employment	8	3	3	8	3	4	7	5	0	6	0	0	**47**
Unknown (U.S.)	9	5	7	4	2	14	19	3	1	8	2	0	**74**
Unknown (non-U.S.)*	7	4	7	2	4	34	21	13	3	9	0	1	**105**
TOTAL	**184**	**81**	**106**	**84**	**65**	**331**	**159**	**76**	**22**	**114**	**19**	**4**	**1245**
Column Subtotals Male	148	61	84	61	52	176	109	53	17	81	8	1	**851**
Column Subtotals Female	36	20	22	23	13	155	50	23	5	33	11	3	**394**

*Includes those whose status is reported as "unknown" or "still seeking employment".

Table 4B: Employment Status of 2005–06 New Doctoral Recipients in the Mathematical Sciences by Type of Degree-Granting Department

TYPE OF EMPLOYER	TYPE OF DOCTORAL DEGREE-GRANTING DEPARTMENT: Group I (Public) Math.	Group I (Private) Math.	Group II Math.	Group III Math.	Group IV Statistics	Group Va Applied Math.	TOTAL	Row Subtotals: Male	Female
Group I (Public)	33	19	14	1	0	3	**72**	58	14
Group I (Private)	27	34	4	0	3	7	**75**	62	13
Group II	28	13	17	3	2	7	**70**	52	18
Group III	5	4	8	19	6	3	**45**	30	15
Group IV	3	0	1	1	62	2	**69**	41	28
Group Va	1	3	0	0	0	8	**12**	7	5
Master's	7	3	21	18	6	1	**56**	37	19
Bachelor's	40	13	37	28	7	4	**129**	94	35
Two-Year College	3	1	2	2	0	3	**11**	9	2
Other Academic Dept.	10	9	12	14	44	8	**97**	61	36
Research Institute/ Other Nonprofit	8	9	7	0	7	4	**35**	17	18
Government	7	3	11	2	13	10	**46**	29	17
Business and Industry	27	14	19	9	80	18	**167**	101	66
Non-U.S. Academic	34	25	22	14	8	3	**106**	83	23
Non-U.S. Nonacademic	6	5	2	1	6	1	**21**	17	4
Not Seeking Employment	1	2	1	2	1	1	**8**	2	6
Still Seeking Employment	10	10	7	8	4	8	**47**	32	15
Unknown (U.S.)	24	6	14	10	14	6	**74**	53	21
Unknown (non-U.S.)*	31	11	17	8	24	14	**105**	66	39
TOTAL	**307**	**184**	**216**	**140**	**287**	**111**	1245	**851**	**394**
Column Subtotals Male	233	147	158	91	153	69	**851**		
Column Subtotals Female	74	37	58	49	134	42	**394**		

*Includes those whose status is reported as "unknown" or "still seeking employment".

Table 4C: Field of Thesis of 2005–06 New Doctoral Recipients by Type of Degree-Granting Department

TYPE OF DOCTORAL DEGREE-GRANTING DEPARTMENT	FIELD OF THESIS												TOTAL
	Algebra/ Number Theory	Real, Comp., Funct., & Harmonic Analysis	Geometry/ Topology	Discr. Math./ Combin./ Logic/ Comp. Sci.	Probability	Statistics/ Biostat.	Applied Math.	Numerical Analysis/ Approximations	Linear Nonlinear Optim./ Control	Differential, Integral, & Difference Equations	Math. Educ.	Other/ Unknown	
Group I (Public)	82	26	43	24	28	8	30	12	4	44	3	3	307
Group I (Private)	53	11	29	19	11	3	34	5	2	17	0	0	184
Group II	33	32	22	13	9	8	38	24	8	26	3	0	216
Group III	15	12	12	20	2	25	14	12	1	14	12	1	140
Group IV	0	0	0	0	6	272	9	0	0	0	0	0	287
Group Va	1	0	0	8	9	15	34	23	7	13	1	0	111
Column Total	184	81	106	84	65	331	159	76	22	114	19	4	1245

Table 5A: 2005–06 New Doctoral Recipients Employed in the U.S by Type of Degree-Granting Department

	Group						
Type of Employer in U.S.	I (Pu)	I (Pr)	II	III	IV	Va	TOTAL
Groups I, II, III, IV, and Va	99	73	44	24	73	30	343
Master's, Bachelor's, and 2-Year Colleges	50	17	60	48	13	8	196
Other Academic and Research Institutes	18	18	19	14	51	12	132
Government	7	3	11	2	13	10	46
Business and Industry	27	14	19	9	80	18	167
TOTAL	201	125	153	97	230	78	884

Table 5B: Number of New Doctoral Recipients Taking Positions in Business and Industry in the U.S. by Type of Degree-Granting Department, Fall 2002 to Fall 2006

	Group						
Year	I (Pu)	I (Pr)	II	III	IV	Va	TOTAL
Fall 2002	15	12	19	6	56	15	123
Fall 2003	19	13	5	8	45	7	97
Fall 2004	9	13	9	9	50	9	99
Fall 2005	5	9	14	15	64	8	115
Fall 2006	27	14	19	9	80	18	167

Table 5C: Number of New Doctoral Recipients Taking U.S. Academic Positions by Type of Degree-Granting Department, Fall 2002 to Fall 2006

	Group						
Year	I (Pu)	I (Pr)	II	III	IV	Va	TOTAL
Fall 2002	120	83	91	86	92	31	503
Fall 2003	123	76	117	60	118	40	534
Fall 2004	110	113	130	70	142	49	614
Fall 2005	131	88	130	83	131	39	602
Fall 2006	167	108	123	86	137	50	671

Table 5D: Academic Positions in U.S. Filled by New Doctoral Recipients by Type of Hiring Department, Fall 2002 to Fall 2006

	Group					
Year	I–III	IV	Va	M&B	Other	TOTAL
Fall 2002	213	46	7	138	99	503
Fall 2003	203	39	9	156	127	534
Fall 2004	222	63	17	154	158	614
Fall 2005	231	45	12	188	126	602
Fall 2006	262	69	12	185	143	671

Employment Plans of 2005–06 New Doctoral Recipients

Tables 4A, 4B, and 4C each provide a different cross-tabulation of the 1,245 new doctoral recipients in the mathematical sciences. These tables contain a wealth of information about these new doctoral recipients, some of which will be discussed in this report. Note that these tables give a breakdown by sex for type of employer, type of degree-granting department, and field of thesis. Keep in mind that the results in this report come from the departments giving the degrees and not from the degree recipients themselves. These tables will be updated using information from the doctoral recipients themselves and will appear in the 2006 Second Report in the August 2007 issue of the *Notices* of the AMS.

The last column (Total) in Table 4A can be used to find the overall unemployment rate. In this and other unemployment calculations in this report, the individuals whose employment status is not known (Unknown (U.S.) and Unknown (non-U.S.)) are first removed, and the unemployment fraction is the number still seeking employment divided by the total number of individuals left after the "Unknowns" are removed. The overall unemployment rate for these data is 4.4%. This figure will be updated later with information gathered from the individual new doctoral recipients. The figure for fall 2005 was 7.3%. Figure 2 shows how this unemployment rate compares with other years over the past decade. The unemployment rates, calculated using Table 4B, vary from group to group, with a high of 8.8% for Group Va and lows of 1.6% and 3.8% for Groups IV and II, respectively.

There are 884 new doctoral recipients employed in the U.S. Table 5A gives a breakdown of type of employer by type of degree-granting department for these 884 new doctoral recipients. Of these, 671 (76%) hold academic positions, 46 (5%) are employed by government, and 167 (19%) hold positions in business and industry.

In the First Report for 2004–05, there were 751 new doctoral recipients employed in the U.S., of which 602 (80%) held academic positions, 34 (5%) were in government, and 115 (15%) were in business and industry. The number of new doctoral recipients employed in the U.S. increased in all categories of Table 5A. "Business and Industry" showed the largest increase at 45%, and "Master's, Bachelor's and Two-Year Colleges" showed the smallest increase at 1%.

Table 5B shows the number of new doctoral recipients who took positions in business and industry by the type of department granting their degree for fall 2002 to fall 2006. The number of new doctoral recipients taking jobs in business and industry oscillated in the late 1990s, declined during 2001–2003, and has increased for the three consecutive years 2004–2006. The fall 2006 number is up 45% from fall 2005, and the fall 2006 number is 1 less than the fall 2001 number (168). The number of new doctoral recipients taking jobs in government is up 12 (35%) over fall 2005.

Among the 884 new doctoral recipients known to have employment in the U.S. in fall 2006, Group III has the smallest percentage taking jobs in business and industry at 9% and Group IV the highest at 35%.

Table 5C shows the number of new doctoral recipients who took academic positions in the U.S. by type of department granting their degree for fall 2002 to fall 2006. The number of new doctoral recipients taking academic employment in fall 2006 has increased 11%, reaching a 20-year high. Among the 884 new doctoral recipients employed in the U.S. in fall 2006, 76% have academic positions. This percentage is highest for Group III at 89% and lowest for Groups IV at 60%.

Table 5D shows the number of positions filled with new doctoral recipients for each type of academic employer. Increases in positions filled by new doctoral recipients were realized by all groups except Groups Va and M&B (combined). The biggest increases in hires of new doctorates into academic positions were hires in Group IV (53% increase) and in Group I(Pr) (50% increase). Hires of new doctorates into positions at research institutes increased 59%, from 22 in 2005 to 35 in 2006.

Table 5E: Females as a Percentage of 2005–06 New Doctoral Recipients Produced by and Hired by Doctoral-Granting Groups

	Group						
Percent	I (Pu)	I (Pr)	II	III	IV	Va	TOTAL
Produced	24%	20%	27%	35%	47%	38%	32%
Hired	19%	17%	26%	33%	41%	42%	27%

Table 5G: 2005–06 New Doctoral Recipients Having Employment in the U.S. by Type of Employer and Citizenship

	CITIZENSHIP		
U.S. EMPLOYER	U.S.	Non-U.S.	TOTAL
Academic	322	349	671
Groups I-Va	146	197	343
M, B, & 2-Year	127	69	196
Other Acad. & Research Inst.	49	83	132
Government, Business & Industry	82	131	213
TOTAL	**404**	**480**	**884**

Table 5F: Employment Status of 2005–06 New Doctoral Recipients by Citizenship Status

	CITIZENSHIP				
		NON-U.S. CITIZENS			
TYPE OF EMPLOYER	U.S. CITIZENS	Permanent Visa	Temporary Visa	Unknown Visa	TOTAL
U.S. Employer	404	50	410	20	884
U.S. Academic	322	34	301	14	671
Groups I, II, III, and Va	119	16	132	7	274
Group IV	27	6	34	2	69
Non-Ph.D. Department	162	10	116	5	293
Research Institute/Other Nonprofit	14	2	19	0	35
U.S. Nonacademic	82	16	109	6	213
Non-U.S. Employer	33	1	93	0	127
Non-U.S. Academic	32	1	73	0	106
Non-U.S. Nonacademic	1	0	20	0	21
Not Seeking Employment	4	1	3	0	8
Still Seeking Employment	30	4	13	0	47
SUBTOTAL	471	56	519	20	1066
Unknown (U.S.)	50	7	17	0	74
Unknown (non-U.S.)*	1	1	101	2	105
TOTAL	522	64	637	22	1245

*Includes those whose status is reported as "unknown" or "still seeking employment".

Table 6: Sex, Race/Ethnicity, and Citizenship of 2005–06 New Doctoral Recipients

	MALE					FEMALE					
		NON-U.S. CITIZENS					NON-U.S. CITIZENS				
RACIAL/ETHNIC GROUP	U.S. CITIZENS	Permanent Visa	Temporary Visa	Unknown Visa	Total Male	U.S. CITIZENS	Permanent Visa	Temporary Visa	Unknown Visa	Total Female	TOTAL
American Indian or Alaska Native	3	0	0	0	3	0	0	0	0	0	**3**
Asian	21	15	263	5	304	13	16	144	3	176	**480**
Black or African American	12	2	14	1	29	5	2	4	0	11	**40**
Hispanic or Latino	12	3	27	0	42	5	2	8	1	16	**58**
Native Hawaiian or Other Pacific Islander	3	0	1	0	4	0	0	1	0	1	**5**
White	324	14	114	4	456	120	9	52	4	185	**641**
Unknown	4	1	8	0	13	0	0	5	0	5	**18**
TOTAL	**379**	**35**	**427**	**10**	**851**	**143**	**29**	**214**	**8**	**394**	**1245**

In fall 2006, 60 new doctoral recipients held positions in the institution that granted their degree, although not necessarily in the same department. This represents 6.8% of new doctoral recipients who are currently employed in the U.S. and 9% of the U.S. academic positions held by new doctoral recipients. In fall 2005 there were 57 such individuals making up 6.5% of the new doctoral recipients who were employed at the time of the First Report. Fourteen new doctoral recipients have taken part-time positions in fall 2006 compared with 23 in fall 2005.

Information about 2005–06 Female New Doctoral Recipients

Tables 4A and 4B give male and female breakdowns of the new doctoral recipients in 2005–06 by Field of Thesis, by Type of Degree-Granting Department, and by Type of Employer.

Overall, 394 (32%) of the 1,245 new doctoral recipients in 2005–06 are female. In 2004–05, 330 (30%) of the new doctoral recipients were female. This percentage varies over the different groups, and these percentages are given in the first row of Table 5E. This year the percentage of females produced is highest again for Group IV at 47%, compared with 44% last year. While Group I (Pr) produced the lowest percentage again this year (20%), it is up from last year's percentage of 18%.

The second row of Table 5E gives the percentage of the new doctoral recipients hired who are female for each of the Groups I, II, III, IV, and Va. In addition, 34% of the new doctoral recipients hired in Group M, master's departments, are female; 27% of the new doctoral recipients hired in Group B, bachelor's departments, are female, up from 29% last year. This year, as well as last year, Group IV hired the highest percentage of women (41% this year and 42% last year).

The unemployment rate for female new doctoral recipients is 4.5%, compared to 4.4% for males and 4.4% overall.

The percentage of female new doctoral recipients within fields of thesis ranged from 20% in both algebra/number theory and probability, to 47% in statistics, and 58% in mathematics education.

Later sections in this First Report give more information about the female new doctoral recipients by citizenship and the female new doctoral recipients in Group IV.

Employment Information about 2005–06 New Doctoral Recipients by Citizenship and Type of Employer

Table 5F shows the pattern of employment within employer categories broken down by citizenship status of the new doctoral recipients.

The unemployment rate for the 522 U.S. citizens is 6.4% compared to 5.3% in fall 2005. The unemployment rate for non-U.S. citizens is 2.9%. This varies by type of visa. The unemployment rate for non-U.S. citizens with a permanent visa is 7.1%, while that for non-U.S. citizens with a temporary visa is 2.5%. Among U.S. citizens whose employment status is known, 86% are employed in the U.S. Among non-U.S. citizens with a permanent visa whose employment status is known, 89% have jobs in the U.S. (last year this percentage was 85%), while the similar percentage for non-U.S. citizens with a temporary visa is 79% (last year the percentage was 72%). The number of non-U.S. citizens having employment in the U.S. is 480, up 13% from 426 last year.

Table 5G is a cross-tabulation of the 884 new doctoral recipients who have employment in the U.S. by citizenship and broad employment categories, using numbers from Table 5F. Of the 884 new doctoral recipients having jobs in the U.S., 46% are U.S. citizens (up from 43% last year). Of the 343 new doctoral recipients who took jobs in U.S. doctoral-granting

Table 7: U.S. Citizen Doctoral Recipients, Fall Counts

Year	Total Doctorates Granted by U.S. Institutions	Total U.S. Citizen Doctoral Total	%
1980-81	839	567	68%
1985-86	755	386	51%
1990-91	1061	461	43%
1995-96*	1150	493	43%
1999-00	1119	537	48%
2000-01	1008	494	49%
2001-02	948	418	44%
2002-03	1017	489	48%
2003-04	1041	441	42%
2004-05	1116	433	39%
2005-06	1245	522	42%

*Prior to 1998-99, the counts include new doctoral recipients from Group Vb. In addition, prior to 1982-83, the counts include recipients from computer science departments.

departments, 43% are U.S. citizens (up from 38% last year). Of the 328 who took other academic positions, 54% are U.S. citizens (up from 51% last year). Of the 213 who took nonacademic positions, 38% are U.S. citizens. Of the 404 U.S. citizens employed in the U.S., 36% have jobs in a doctoral-granting department, 44% are in other academic positions, and 20% are in nonacademic positions. For the 480 non-U.S. citizens employed in the U.S., the analogous percentages are 41%, 32%, and 27% respectively.

Sex, Race/Ethnicity, and Citizenship Status of 2005-06 New Doctoral Recipients

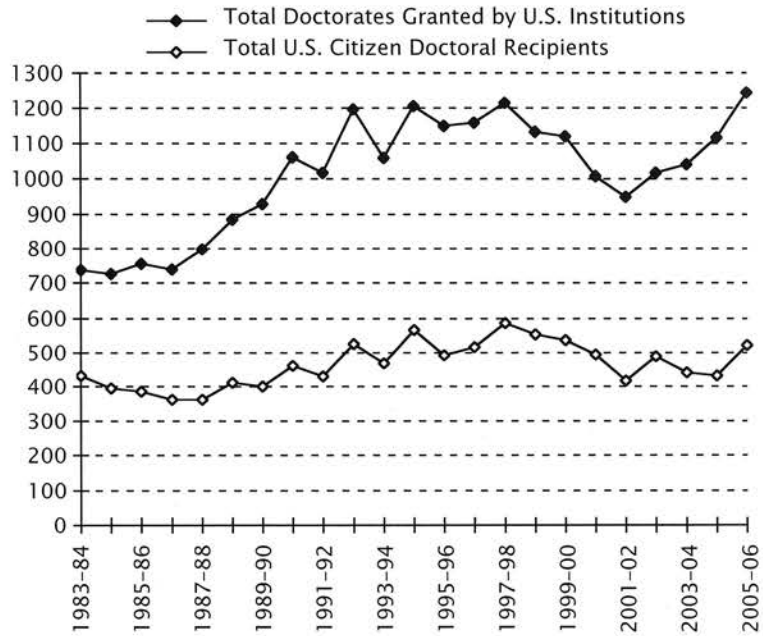
Table 6 presents a breakdown of new doctoral recipients according to sex, racial/ethnic group, and citizenship status. The information reported in this table was obtained in summary form from the departments granting the degrees.

Table 8: Sex of U.S. Citizen Doctoral Recipients, Fall Counts

Year	Total U.S. Citizen Doctoral Recipients	Male	Female	% Female
1980-81	567	465	102	18%
1985-86	386	304	82	21%
1990-91	461	349	112	24%
1995-96*	493	377	116	24%
1999-00	537	379	158	29%
2000-01	494	343	151	31%
2001-02	418	291	127	30%
2002-03	489	332	157	32%
2003-04	441	297	144	33%
2004-05	433	313	120	28%
2005-06	522	379	143	27%

*Prior to 1998-99, the counts include new doctoral recipients from Group Vb. In addition, prior to 1982-83, the counts include recipients from computer science departments.

Figure 3: U.S. Citizen Doctoral Recipients, Fall Counts



There were 522 (42%) U.S. citizens among the 1,245 new doctoral recipients in 2005-06. Among U.S. citizens, 3 are American Indian or Alaska Native (male), 34 are Asian (21 males and 13 females), 17 are Black or African American (12 males and 5 females), 17 are Hispanic or Latino (12 males and 5 females), 3 are Native Hawaiian or Other Pacific Islander (males), 444 are White (324 males and 120 females), and 4 are Unknown (males). Among non-U.S. citizens, there are 446 Asians, 23 Blacks or African Americans, 41 Hispanics or Latinos,

Figure 4: Females as a Percentage of U.S. Citizen Doctoral Recipients and Graduate Students, Fall Counts

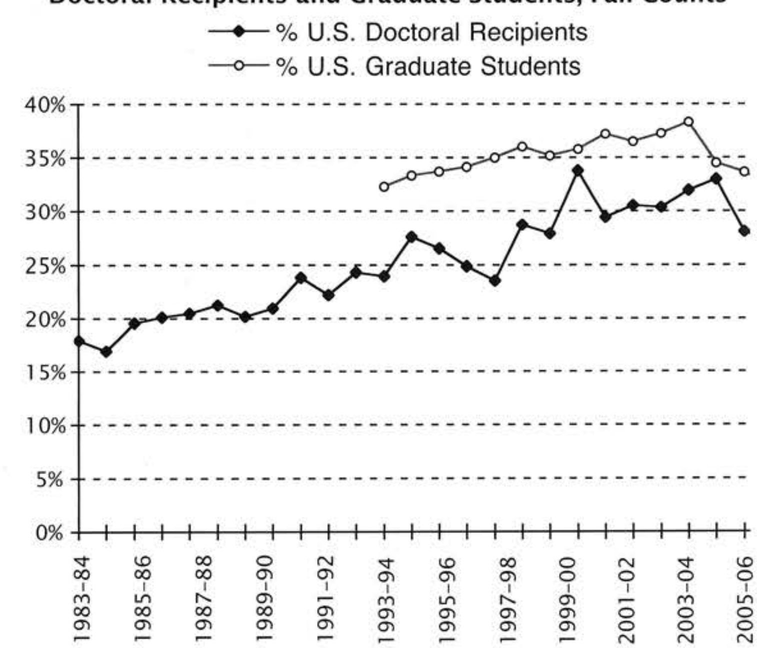


Table 9: Sex and Citizenship of 2005–06 New Doctoral Recipients by Type of Degree Granting Department

	GROUP												TOTAL	
	I (Pu)		I (Pr)		II		III		IV		Va			
CITIZENSHIP	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
U.S.	112	30	70	19	78	24	36	22	50	34	33	14	**379**	**143**
Non-U.S.	121	44	77	18	80	34	55	27	103	100	36	28	**472**	**251**
TOTAL	**233**	**74**	**147**	**37**	**158**	**58**	**91**	**49**	**153**	**134**	**69**	**42**	**851**	**394**

2 Native Hawaiian or Other Pacific Islander, 197 Whites, and 14 unknown. The total number in each ethnic group was up in 2006 over 2005, as well as the total number of American citizens of each ethnic group; e.g., the number of Black or Afro-American U.S. citizens increased from 14 to 17, and the number of Hispanic or Latino U.S. citizens increased from 12 to 17.

Table 7 (and Figure 3) gives the number of new U.S. doctoral recipients and the number of U.S. citizens back to 1980-81. The 522 U.S. citizen new doctoral recipients is down by 15 (3%) from 1999–00. The percentage of U.S. citizen new doctoral recipients has increased this year to 42% from 39% in fall 2005, while in both years the total number of doctorates granted increased.

Females make up 27% of the 522 U.S. citizens receiving doctoral degrees in the mathematical sciences in 2005–06. Last year this percentage was 28%. Among the 723 non-U.S. citizen new doctoral recipients, 35% (251) are female, up from last year's 31%.

Table 8 (and Figure 4) gives the historical record of U.S. citizen new doctoral recipients, broken down by male and female for past years, going back to 1980–81. The number of female U.S. citizen new doctoral recipients is down 15 (9%) from 158 in 1999–00 and down 24% from an all-time high of 187 in 1998–99. Figure 4 also displays the percentage of females among U.S. citizen (full-time) graduate students beginning in fall 1993. Recent increases in the number of U.S. citizen graduate students (see Table 3) are due to increases in the number of males, hence the declines in the percentage of females.

Table 9 gives a sex and citizenship breakdown of the new doctorates within each of the six groups of doctoral-granting departments. Among all 1,245 new doctoral recipients, 45% of the males and 36% of the females are U.S. citizens. Within the groups the percentage of the new doctoral recipients who are U.S. citizens is lowest in Group IV at 29% and highest in Groups I(Pr) and I (Pu), both at 48%. The number of U.S. citizen new doctoral recipients is lower than the number of non-U.S. citizen new doctoral recipients in all doctoral granting groups for 2005-06, with the exception of females in Group I(Pr).

2005–06 New Doctoral Recipients with Dissertations in Statistics/Biostatistics and Probability

Group IV contains U.S. departments (or programs) of statistics, biostatistics, and biometrics reporting a doctoral program. In the Annual Survey Reports, Group IV is referred to as the Statistics Group. In addition, other groups in the Annual Survey produce new doctoral recipients with dissertations in statistics/biostatistics or probability. The other groups produced 118 new doctoral recipients with dissertations in statistics/biostatistics or probability

Table 10: New Doctoral Recipients with Dissertations in Statistics/Biostatistics and Probability

			New Doctoral Recipients in Group IV				New Doctoral Recipients in Statistics/Biostatistics and Probability				New Doctoral Recipients Hired by Group IV	
Year	Depts Surveyed	Depts Responding (percent)	Total	Female (percent)	Jobs in Bus & Ind	Percentage Unemployed	Total	Group IV	Other Groups	Percentage Unemployed	Male	Female
1996–97	81	60 (74%)	197	74 (38%)	70	4.2%	292	187	105	5.1%	24	9
1997–98	82	59 (72%)	213	73 (34%)	70	3.2%	294	199	95	3.7%	25	10
1998–99	91	72 (79%)	243	87 (36%)	57	4.9%	320	240	80	5.8%	29	20
1999–00	89	75 (84%)	284	110 (39%)	79	2.4%	351	278	73	2.0%	24	22
2000–01	86	70 (81%)	237	98 (41%)	59	5.1%	289	221	68	5.3%	27	14
2001–02	86	72 (84%)	222	92 (41%)	56	6.0%	288	221	67	5.4%	31	15
2002–03	86	74 (86%)	239	98 (41%)	45	2.1%	302	234	68	3.3%	20	19
2003–04	87	65 (75%)	243	97 (40%)	50	3.0%	318	241	77	4.0%	48	15
2004–05	87	63 (72%)	285	126 (44%)	64	5.0%	374	283	91	5.0%	26	19
2005–06	88	60 (68%)	287	134 (47%)	80	2.0%	396	278*	118**	2.0%	41	28
Statistics	55	40 (73%)	211	88 (42%)	28	1.0%					29	15
Biostatistics	33	20 (61%)	76	46 (61%)	16	2.0%					12	13

* Of 278, there were 272 in statistics/biostatistics and 6 in probability. For complete details, see Table 4C.

** Of 118, there were 59 in statistics/biostatistics and 59 in probability. For complete details, see Table 4C.

in 2005–06 and have averaged 84.2 per year over the ten-yearperiod reported in Table 10. Information about these 118 new doctoral recipients and the 287 new doctoral recipients in Group IV is found in this section of the report.

Table 10 contains information about new doctoral recipients in Group IV as well as those with dissertations in statistics/biostatistics and probability in other groups for this year as well as for the past nine years. The last two rows of Table 10 give a split of the 2005–06 results between the 55 statistics departments and the 33 biostatistics and biometrics departments in Group IV. This year 396 new doctorates had a dissertation in statistics/ biostatistics (331) or probability (65), a 6% increase over last year's number. Those with dissertations in statistics/biostatistics and probability accounted for 32% of new doctorates in 2005–06. Quite a bit of the variation in numbers from year to year in Table 10 is due to the changes made in the departments in Group IV over the ten years and to the relatively low response rate for this group. At the time of the Second Report last year, 66 of 87 (75%) of Group IV departments had responded.

Group IV has 88 departments for 2005–06, 13 more than the next largest doctoral group. It contains 30% of all doctoral departments surveyed, and the 60 Group IV departments responding to the Annual Survey reported 287 new doctoral recipients, 23% of all new doctoral recipients in 2005–06. While this is the lowest percentage of responding Group IV departments since 1995–96 when it was 68%, it is the largest number of new doctoral recipients reported since 1999–00, when it was 284. The number of new doctoral recipients in Group IV is up 2 from the number reported at this time last year, while the number of departments responding is down 3 from the number responding by this time last year.

Because of its size, the data from Group IV have a large effect on the results when all doctoral groups are combined. Furthermore, Group IV results are often quite different from those for Groups I (Pu), I (Pr), II, III, and Va. Group IV results can mask important changes in the other doctoral groups. In the following paragraphs some of these differences are presented. The trends noted below have also been observed in past reports.

Group IV is producing a larger percentage of female doctorates than the other doctoral groups. Table 9 shows that for the Group IV new doctoral recipients, 134 of 287 (47%) are female, while 260 of 958 (27%) are female in the other doctoral groups. Among U.S. citizens, females accounted for 34 of the 84 (40%) Group IV new doctoral recipients, while for the other groups 109 of 438 (25%) were female. Overall, 143 of 522 (27%) U.S. citizen new doctoral recipients were female.

Group IV is producing a smaller percentage of U.S. citizen new doctorates than the other doctoral groups. In Group IV, 84 of 287 (29%) new doctoral recipients are U.S. citizens, while in other groups 438 of 958 (46%) are U.S. citizens. In Group IV, 100 (75%) of the 134 females were not U.S. citizens.

Group IV doctorates are more likely to take jobs in business and industry than those in other doctoral groups. Of the 230 new doctoral recipients from Group IV who found employment in the U.S., 80 (35%) took jobs in business or industry. From the other groups, 654 new doctoral recipients found employment in the U.S., of which 87 (13%) took jobs in business or industry.

Group IV doctorates have a lower unemployment rate than the other doctoral groups.The employment status for 249 Group IV new doctoral recipients is known, and 4 (1.6%) are unemployed. For the other groups, the employment status of 817 is known, and 43 (5.3%) are unemployed. Group IV is hiring a bigger percentage of females than the other doctoral groups. Twenty-eight of 69 (41%) new doctoral recipients hired by Group IV departments were female, down from last year's 42%, the lowest percentage of female hires reported since 1999–2000. The other doctoral groups reported that 65 of 274 (24%) new doctoral recipients hired were female, up from last year's 22%.

Group IV had 278 new doctoral recipients with fields of thesis in statistics/biostatistics (272) and probability (6), and the other doctoral departments had 118 with fields of thesis in statistics/biostatistics (59) and probability (59) (last year the other doctoral departments had 65 new doctorates in statistics and 26 in probability). The distribution of these degrees among the various groups can be found in Table 4C. The number of new doctoral recipients with theses in statistics/biostatistics and probability (396) is substantially larger than any other field, with algebra and number theory next with 184.

Table 11: Faculty Salary Response Rates

Department	Number	Percent
Group I (Public)	24 of 25	96
Group I (Private)	15 of 23	65
Group II	46 of 56	82
Group III	63 of 75	84
Group IV (Statistics)	36 of 54	62
Group IV (Biostatistics)	18 of 32	56
Group Va	10 of 19*	53
Group M	97 of 188	52
Group B	328 of 1036	32

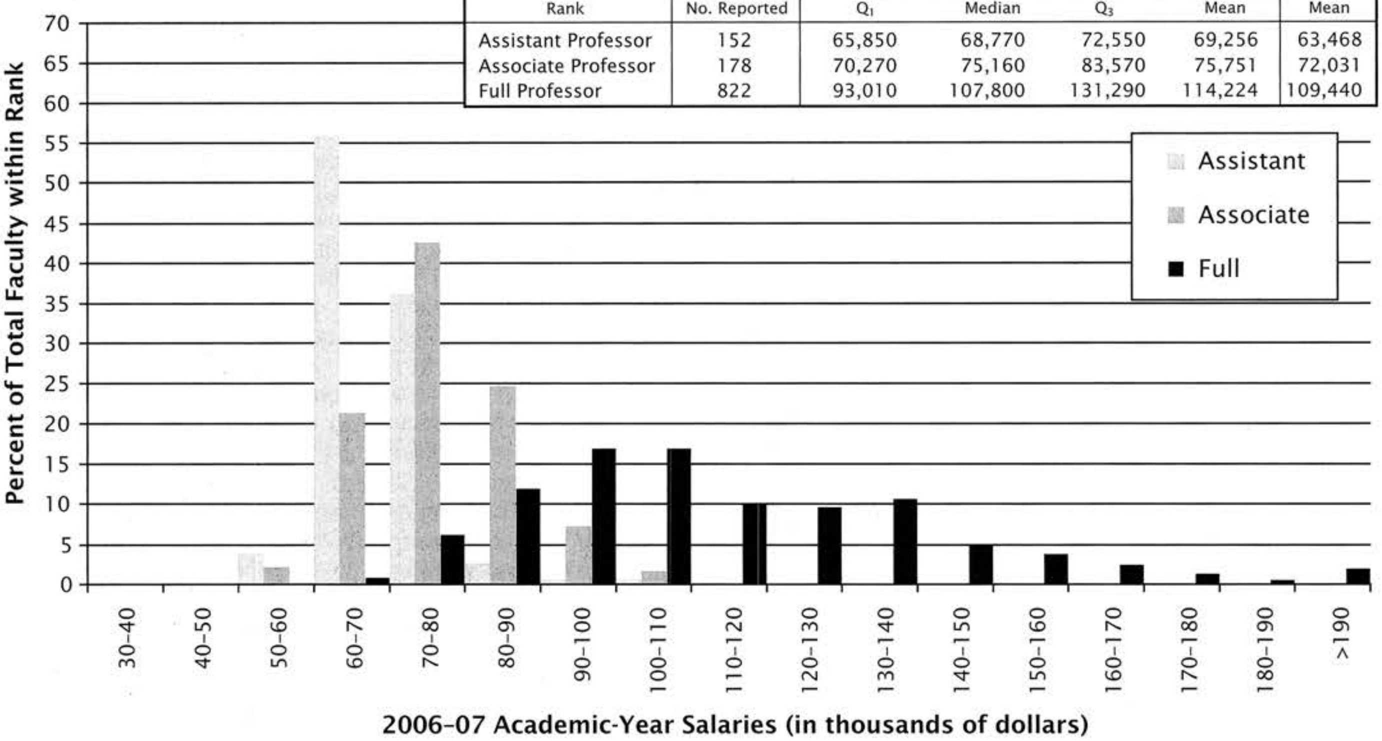
* The population for Group Va is slightly less than for the Doctorates Granted Survey, because two programs do not formally "house" faculty and their salaries.

Group I (Public) Faculty Salaries

Doctoral degree-granting departments of mathematics

24 responses out of 25 departments (96%)

	2006-07					2005-06
Rank	No. Reported	Q_1	Median	Q_3	Mean	Mean
Assistant Professor	152	65,850	68,770	72,550	69,256	63,468
Associate Professor	178	70,270	75,160	83,570	75,751	72,031
Full Professor	822	93,010	107,800	131,290	114,224	109,440

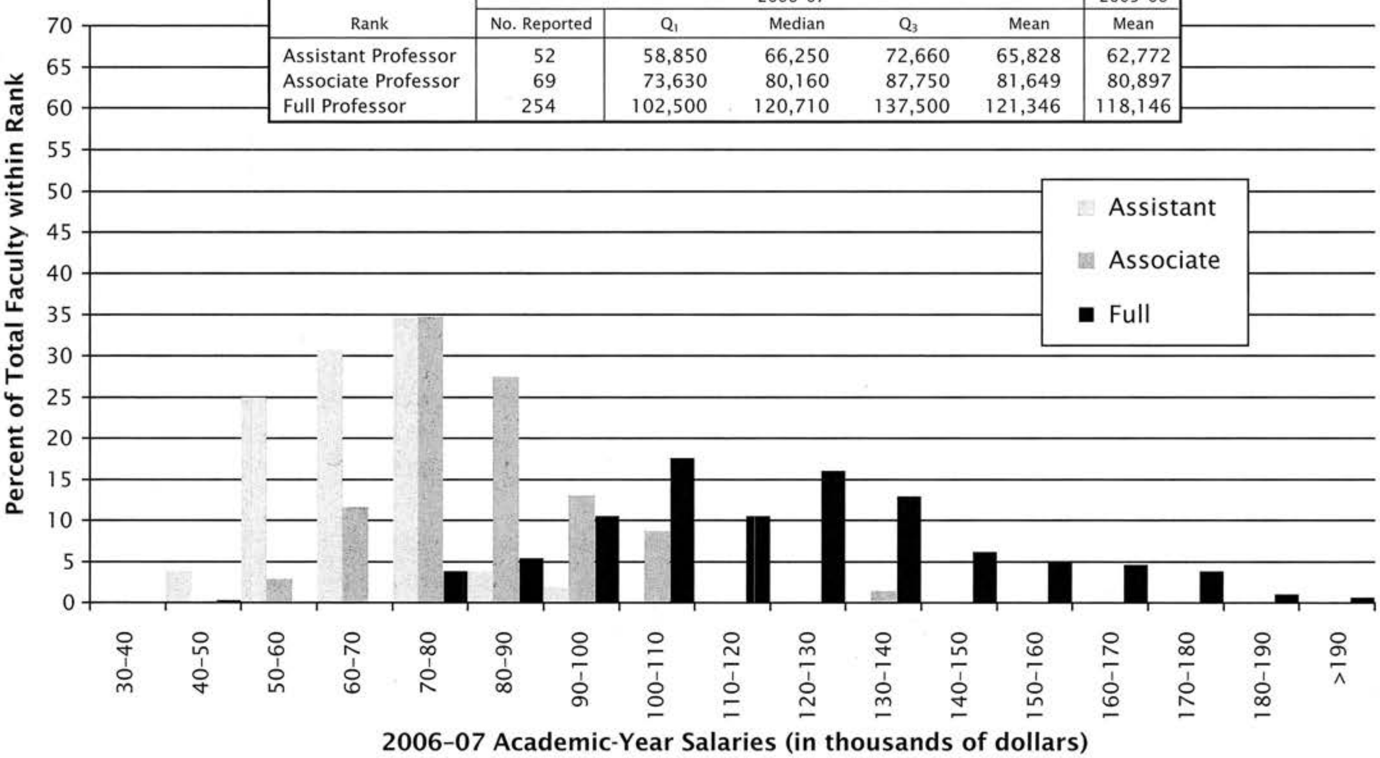


Group I (Private) Faculty Salaries

Doctoral degree-granting departments of mathematics

15 responses out of 23 departments (65%)

	2006-07					2005-06
Rank	No. Reported	Q_1	Median	Q_3	Mean	Mean
Assistant Professor	52	58,850	66,250	72,660	65,828	62,772
Associate Professor	69	73,630	80,160	87,750	81,649	80,897
Full Professor	254	102,500	120,710	137,500	121,346	118,146

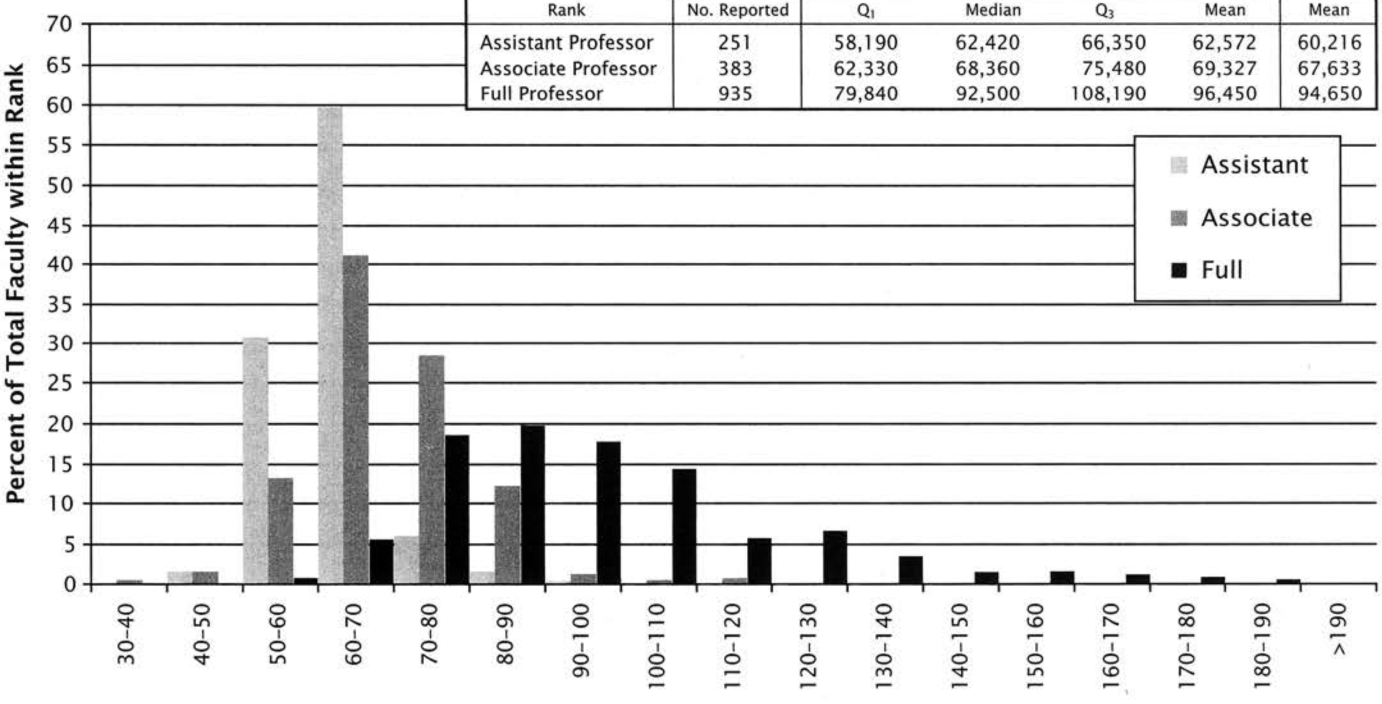


Group II Faculty Salaries

Doctoral degree-granting departments of mathematics

46 responses out of 56 departments (82%)

	2006-07					2005-06
Rank	No. Reported	Q_1	Median	Q_3	Mean	Mean
Assistant Professor	251	58,190	62,420	66,350	62,572	60,216
Associate Professor	383	62,330	68,360	75,480	69,327	67,633
Full Professor	935	79,840	92,500	108,190	96,450	94,650

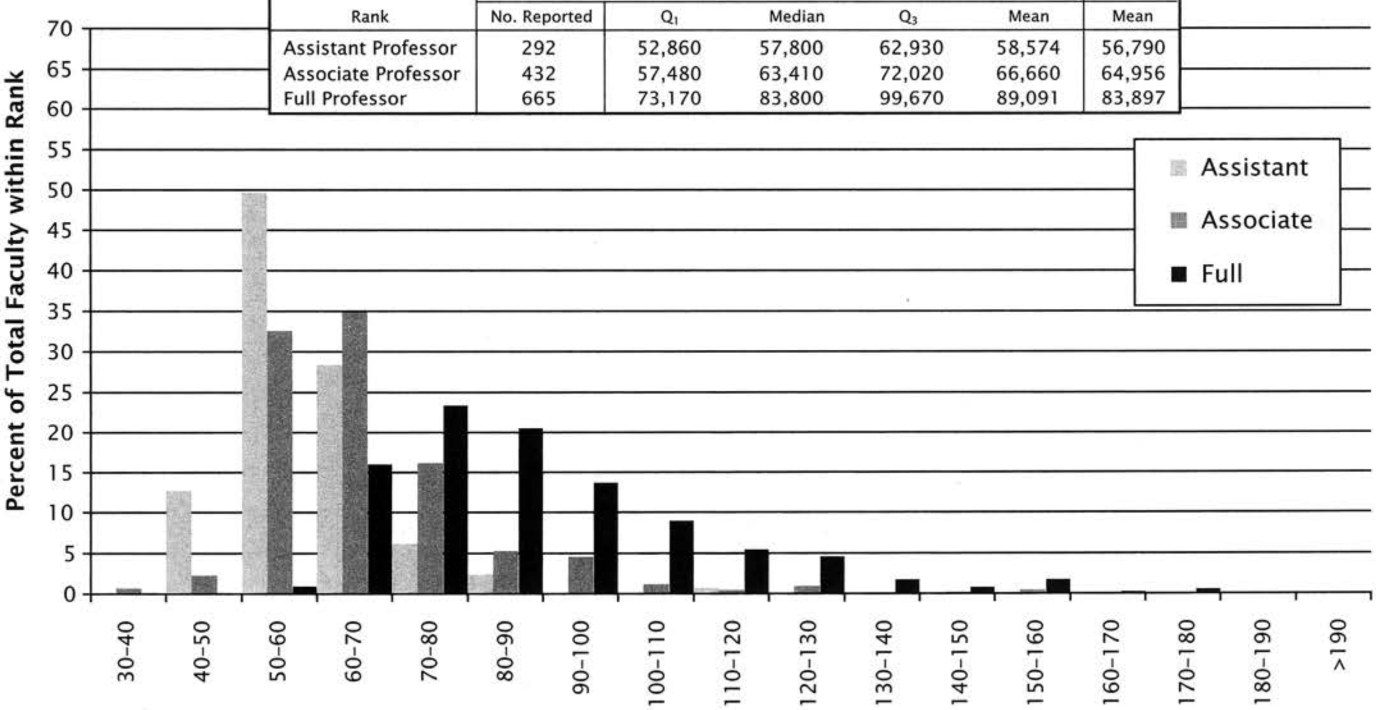


Group III Faculty Salaries

Doctoral degree-granting departments of mathematics

63 responses out of 75 departments (84%)

	2006-07					2005-06
Rank	No. Reported	Q_1	Median	Q_3	Mean	Mean
Assistant Professor	292	52,860	57,800	62,930	58,574	56,790
Associate Professor	432	57,480	63,410	72,020	66,660	64,956
Full Professor	665	73,170	83,800	99,670	89,091	83,897

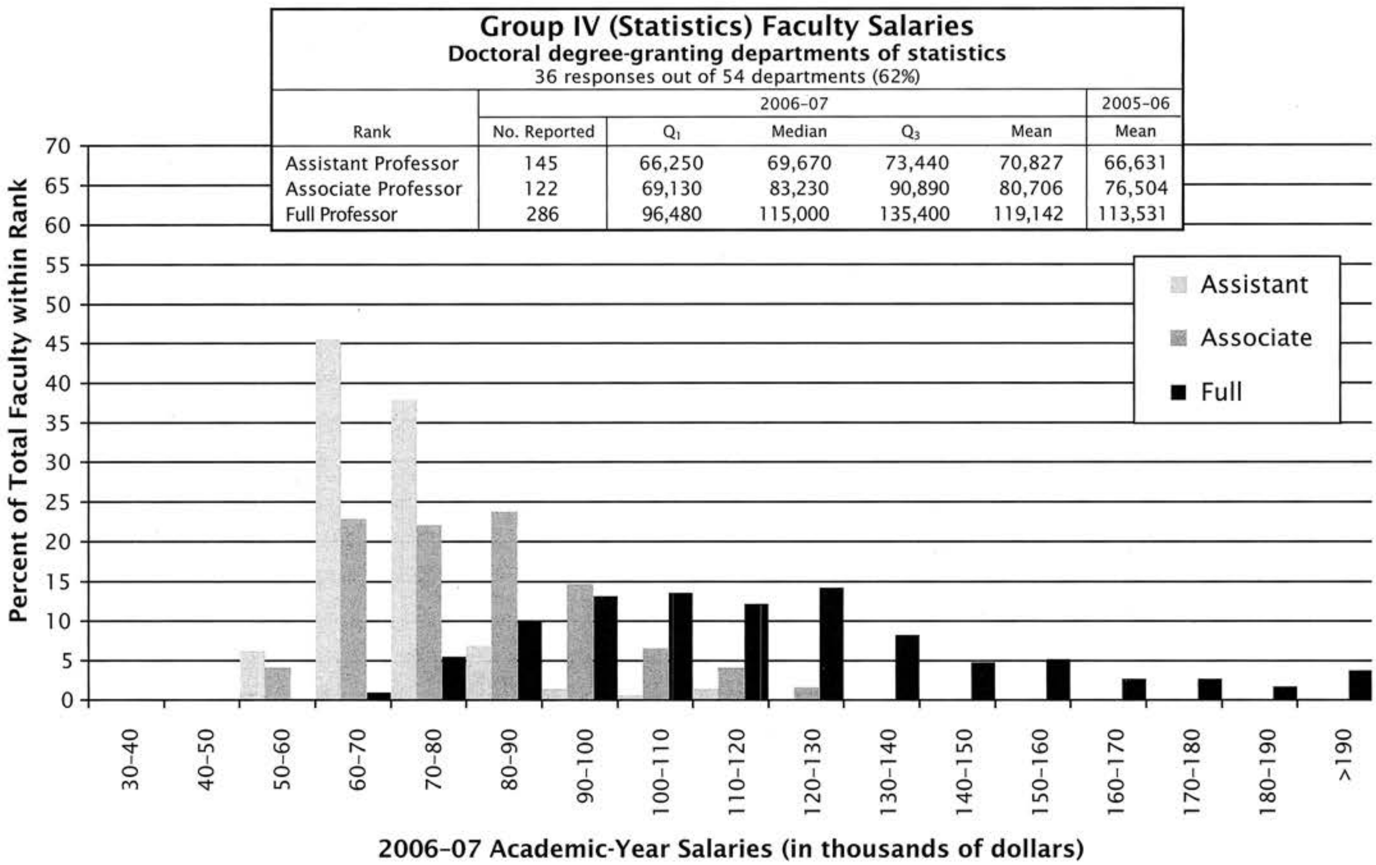


Group IV (Statistics) Faculty Salaries

Doctoral degree-granting departments of statistics

36 responses out of 54 departments (62%)

Rank	2006-07					2005-06
	No. Reported	Q_1	Median	Q_3	Mean	Mean
Assistant Professor	145	66,250	69,670	73,440	70,827	66,631
Associate Professor	122	69,130	83,230	90,890	80,706	76,504
Full Professor	286	96,480	115,000	135,400	119,142	113,531

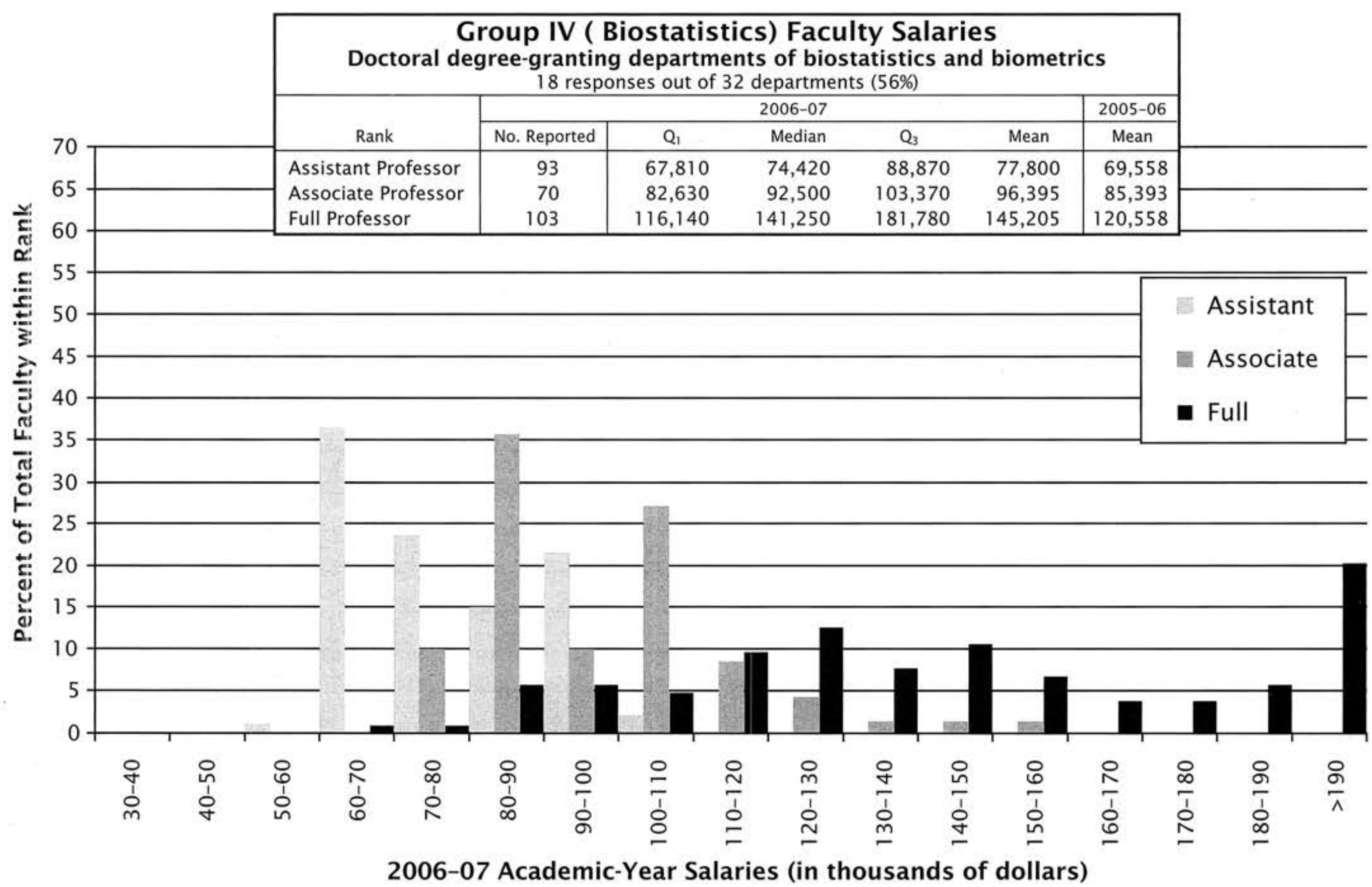


Group IV (Biostatistics) Faculty Salaries

Doctoral degree-granting departments of biostatistics and biometrics

18 responses out of 32 departments (56%)

Rank	2006-07					2005-06
	No. Reported	Q_1	Median	Q_3	Mean	Mean
Assistant Professor	93	67,810	74,420	88,870	77,800	69,558
Associate Professor	70	82,630	92,500	103,370	96,395	85,393
Full Professor	103	116,140	141,250	181,780	145,205	120,558

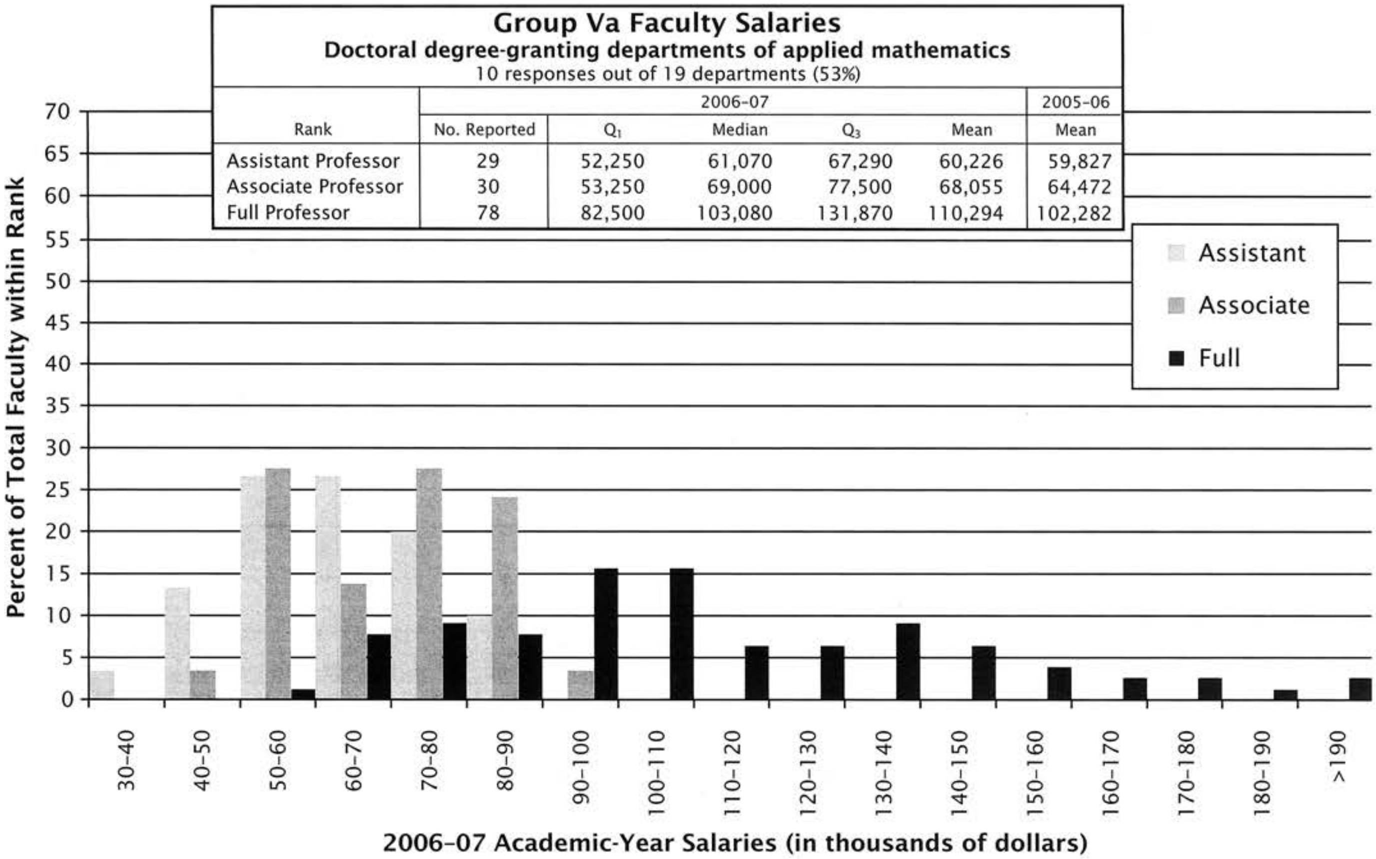


Group Va Faculty Salaries

Doctoral degree-granting departments of applied mathematics

10 responses out of 19 departments (53%)

Rank	2006-07 No. Reported	2006-07 Q_1	2006-07 Median	2006-07 Q_3	2006-07 Mean	2005-06 Mean
Assistant Professor	29	52,250	61,070	67,290	60,226	59,827
Associate Professor	30	53,250	69,000	77,500	68,055	64,472
Full Professor	78	82,500	103,080	131,870	110,294	102,282

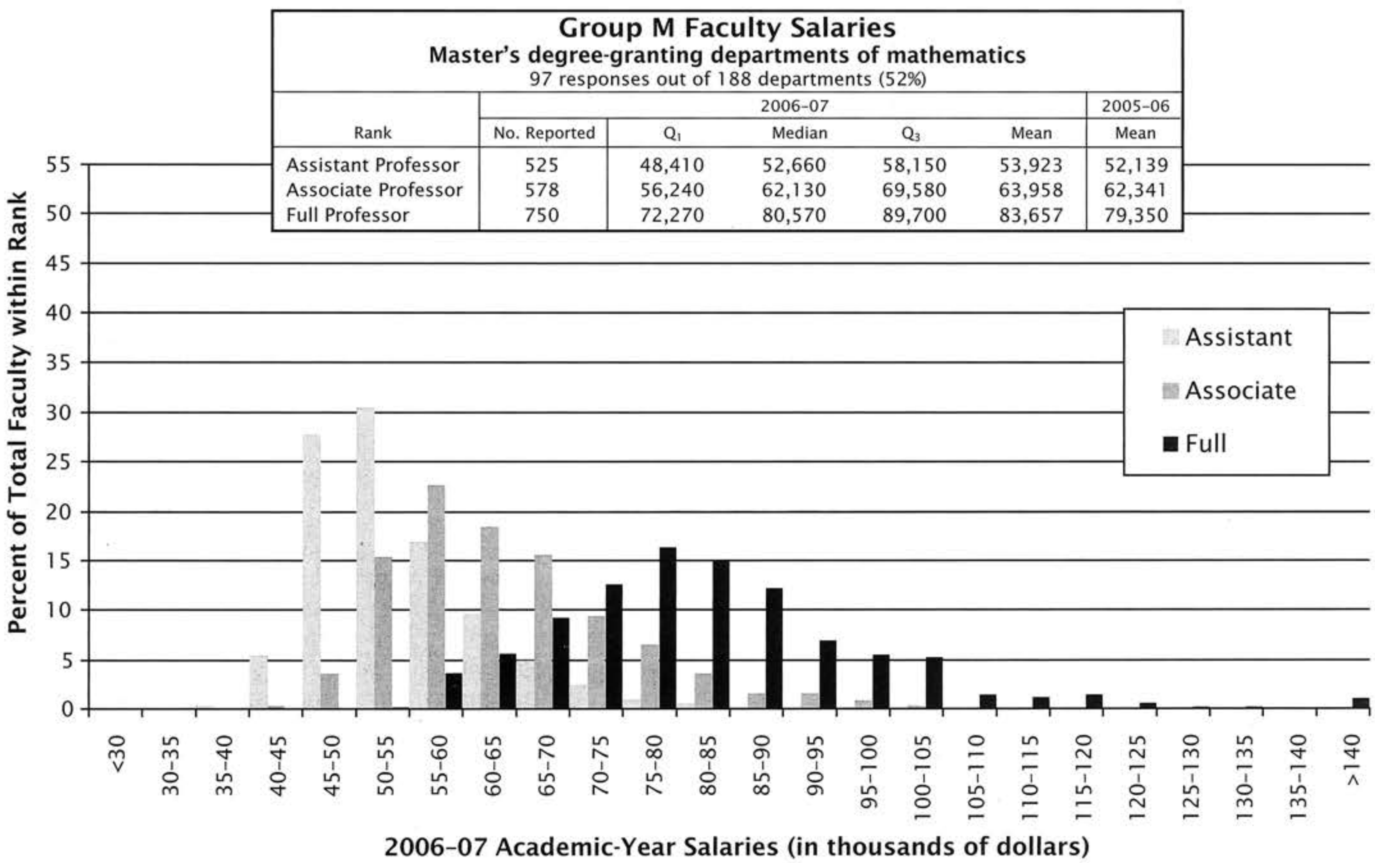


Group M Faculty Salaries

Master's degree-granting departments of mathematics

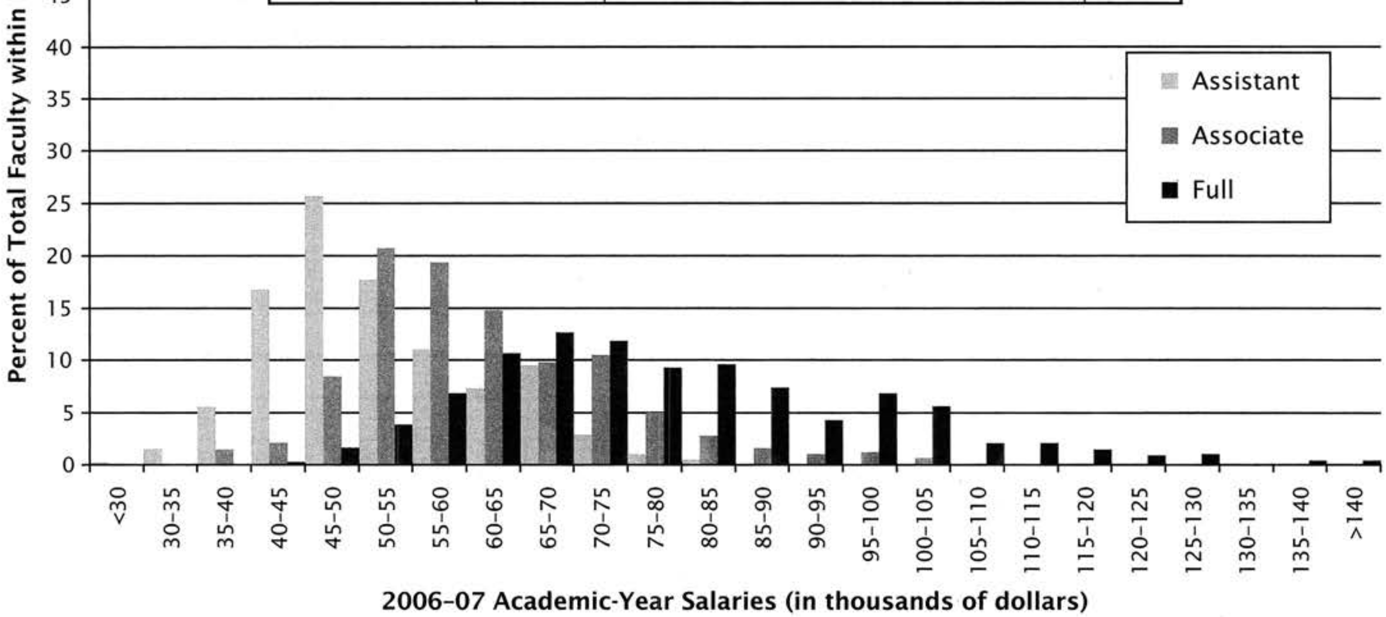
97 responses out of 188 departments (52%)

Rank	2006-07 No. Reported	2006-07 Q_1	2006-07 Median	2006-07 Q_3	2006-07 Mean	2005-06 Mean
Assistant Professor	525	48,410	52,660	58,150	53,923	52,139
Associate Professor	578	56,240	62,130	69,580	63,958	62,341
Full Professor	750	72,270	80,570	89,700	83,657	79,350



Group B Faculty Salaries
Bachelor's degree-granting departments of mathematics
328 responses out of 1036 departments (32%)

	2006-07					2005-06
Rank	No. Reported	Q_1	Median	Q_3	Mean	Mean
Assistant Professor	858	45,170	50,070	58,350	51,880	48,808
Associate Professor	873	53,090	59,400	68,950	61,640	58,293
Full Professor	954	65,600	76,060	90,650	79,277	76,289



Faculty Salary Survey

The charts on the following pages display faculty salary data for Groups I (Pu), I (Pr), II, III, IV (Statistics), IV (Biostatistics), Va, M, and B: faculty salary distribution by rank, mean salaries by rank, information on quartiles by rank, and the number of returns for the group. Salaries are reported in actual (unadjusted) dollars. Results reported here are summaries based on the departments who responded to this portion of the Annual Survey. This is the fourth year that salary information has been reported separately for statistics departments and biostatistics and biometrics departments in Group IV.

Table 11 provides the departmental response rates for the 2005 Faculty Salary Survey. Departments were asked to report for each rank the number of tenured and tenure-track faculty whose 2005–06 academic-year salaries fell within given salary intervals. Reporting salary data in this fashion eliminates some of the concerns about confidentiality but does not permit determination of actual quartiles. Although the actual quartiles cannot be determined from the data gathered, these quartiles have been estimated assuming that the density over each interval is uniform.

Since departments in Groups I, II, and III were changed in 1995–96 (see definitions of the groups on page 267), comparisons are possible only to the last ten years' data. In addition, prior to the 1998 survey Groups Va and Vb were reported together as Group V. When comparing current and prior year figures, one should keep in mind that differences in the set of responding departments may be a significant factor in the change in the reported mean salaries.

Previous Annual Survey Reports

The 2004 First, Second, and Third Annual Survey Reports were published in the *Notices* of the AMS in the February, August, and September 2005 issues respectively. These reports and earlier reports, as well as a wealth of other information from these surveys, are available on the AMS website at `www.ams.org/employment/surveyreports.html`.

Acknowledgments

The Annual Survey attempts to provide an accurate appraisal and analysis of various aspects of the academic mathematical sciences scene for the use and benefit of the community and for filling the information needs of the professional organizations. Every year, college and university departments in the United States are invited to respond. The Annual Survey relies heavily on the conscientious efforts of the dedicated staff members of these departments for the quality of its information. On behalf of the Annual Survey Data Committee and the Annual Survey Staff, we thank the many

secretarial and administrative staff members in the mathematical sciences departments for their cooperation and assistance in responding to the survey questionnaires.

Other Data Sources

American Association of University Professors, *The Annual Report on the Economic Status of the Profession 2004–2005*, Academe: Bull. AAUP (April 2005), Washington, DC.

American Statistical Association, *Business, Industry, and Government 2005 Salary Survey.* [http://www.amstat.org/publications/amsn/2005/highlights10-1.pdf] Revised November 2005. (Published in *AMSTATNEWS*, October 2005, Issue #340.)

______, *2005–2006 Salary Report of Academic Statisticians.* [http://www.amstat.org/publications/amsn/2005/highlights12-2.pdf]

Commission on Professionals in Science and Technology, *Professional Women and Minorities*, 15th ed., CPST, Washington, DC, 2004.

______, *Salaries of Scientists, Engineers, and Technicians: A Summary of Salary Surveys*, 21st ed., CPST, Washington, DC, 2004.

______, *Employment of Recent Doctoral Graduates in S&E: Results of Professional Society Surveys*, CPST, Washington, DC, 1998.

______, *Employment Outcomes of Doctorates in Science and Engineering: Report of a CPST Workshop*, CPST, Washington, DC, 1998.

Conference Board of the Mathematical Sciences, *Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States: Fall 2000 CBMS Survey*, American Mathematical Society, Providence, RI, 2002.

______, *Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States: Fall 1995 CBMS Survey*, MAA Reports No. 2, 1997.

National Opinion Research Center, *Doctorate Recipients from United States Universities: Summary Report 2005*, Survey of Earned Doctorates, Chicago, IL, 2006.

National Research Council, *Strengthening the Linkages between the Sciences and the Mathematical Sciences*, National Academy Press, Washington, DC, 2000.

______, *U.S. Research Institutes in the Mathematical Sciences: Assessment and Perspectives*, National Academy Press, Washington, DC, 1999.

National Science Board, *Science and Engineering Indicators—2006* (NSB 06-01), National Science Foundation, Arlington, VA, 2006.

National Science Foundation, *U.S. Doctorates in the 20th Century* (NSF 06-319), Arlington, VA, 2006

______, *Characteristics of Doctoral Scientists and Engineers in the United States: 2003* (NSF 06-329), Detailed Statistical Tables, Arlington, VA, 2006.

______, *Graduate Students and Postdoctorates in Science and Engineering: Fall 2004* (NSF 06-325), Arlington, VA, 2006.

Definitions of the Groups

As has been the case for a number of years, much of the data in these reports 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.*[1] These rankings update those reported in a previous study published in 1982.[2] Consequently, the departments which now compose Groups I, II, and III differ significantly from those used prior to the 1996 survey.

The subdivision of the Group I institutions into Group I Public and Group I Private was new for the 1996 survey. With the increase in number of the Group I departments from 39 to 48, the Annual Survey Data Committee judged that a further subdivision of public and private would provide more meaningful reporting of the data for these departments.

Brief descriptions of the groupings are as follows:

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/employment/.

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[1]Research-Doctorate Programs in the United States: Continuity and Change, *edited by Marvin L. Goldberger, Brendan A. Maher, and Pamela Ebert Flattau, National Academy Press, Washington, DC, 1995.*

[2]*These findings were published in* An Assessment of Research-Doctorate Programs in the United States: Mathematical and Physical Sciences, *edited by Lyle V. Jones, Gardner Lindzey, and Porter E. Coggeshall, National Academy Press, Washington, DC, 1982. The information on mathematics, statistics, and computer science was presented in digest form in the April 1983 issue of the* Notices *of the AMS, pages 257–67, and an analysis of the classifications was given in the June 1983* Notices *of the AMS, pages 392–3.*

Mathematics People

Sujatha Awarded ICTP/IMU Ramanujan Prize

RAMDORAI SUJATHA of the Tata Institute of Fundamental Research has been awarded the 2006 Srinivasa Ramanujan Prize for Young Mathematicians from Developing Countries by the Abdus Salam International Centre for Theoretical Physics (ICTP) and the International Mathematical Union (IMU). Sujatha was honored for her work on the arithmetic of algebraic varieties and her contributions to noncommutative Iwasawa theory.

The Ramanujan Prize is funded by the Niels Henrik Abel Memorial Fund with the cooperation of the International Mathematical Union and is designed to honor researchers under forty-five years of age who have conducted outstanding research in developing countries. The prize carries a cash award of US$10,000 and a travel allowance to visit ICTP to deliver a prize lecture.

—From an ICTP announcement

NSF CAREER Awards Made

The Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) has honored eleven mathematicians in fiscal year 2006 with Faculty Early Career Development (CAREER) awards. The NSF established the awards to support promising scientists, mathematicians, and engineers who are committed to the integration of research and education. The grants run from four to five years and range from US$150,000 to US$400,000 each. The 2006 CAREER grant awardees in the mathematical sciences and the titles of their grant projects follow.

ANNA GILBERT, University of Michigan, Ann Arbor: Modeling and Analysis of Data from Massive Graphs; MARK HUBER, Duke University: Perfect Sampling Techniques for High-Dimensional Integration; KIRAN KEDLAYA, Massachusetts Institute of Technology: Cohomological Methods in Algebraic Geometry and Number Theory; DAN KNOPF, University of Texas, Austin: Investigating Ricci Flow Singularity Formation; IRINA MITREA, University of Virginia: Spectral Theory for Singular Integrals, Validated Numerics and Elliptic Problems in Non-Lipschitz Polyhedra: Research and Outreach; MARTIN MOHLENKAMP, Ohio University: Toward Direct Numerical Solution of the Multiparticle Schrödinger Equation; ELCHANAN MOSSEL, University of California, Berkeley: Applications of Probability Theory in Computer Science, Social Choice, Biology, and Statistics; ALEXANDER POSTNIKOV, Massachusetts Institute of Technology: Algebraic Combinatorics and Its Applications; BENJAMIN SUDAKOV, Princeton University: Methods and Challenges in Discrete Mathematics; VAN VU, Rutgers University: Sharp Concentration and Probabilistic Methods; and CHONGCHUN ZENG, Georgia Institute of Technology: Perturbation Problems in PDE Dynamics.

—Elaine Kehoe

Mathematics Opportunities

National Academies Research Associateship Programs

The Policy and Global Affairs Division of the National Academies is sponsoring the 2007 Postdoctoral and Senior Research Associateship Programs. The programs are meant to provide opportunities for Ph.D., Sc.D., or M.D. scientists and engineers of unusual promise and ability to perform research at more than 100 research laboratories throughout the United States and overseas.

Full-time associateships will be awarded for research in the fields of mathematics, chemistry, earth and atmospheric sciences, engineering, applied sciences, life sciences, space sciences, and physics. Most of the laboratories are open to both U.S. and non-U.S. nationals and to both recent doctoral recipients and senior investigators.

Amounts of stipends depend on the sponsoring laboratory. Support is also provided for allowable relocation expenses and for limited professional travel during the period of the award.

Awards will be made four times during the year, in February, May, August, and November. The deadline for application materials to be postmarked or for electronic submissions for the February 2007 review is **February 1, 2007.**

For further information and application materials, see the National Academies website at `http://www7.nationalacademies.org/rap/` or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; `rap@nas.edu`.

—From an NRC announcement

News from the CRM Montreal

The Centre de Recherches Mathématiques (CRM) in Montreal, Canada, has announced its thematic program for the semester running from January to June 2007. Devoted to recent advances in combinatorics optimization, it will be organized by F. Bergeron, S. Brlek, P. Leroux, and C. Reutenauer, all of the University of Quebec at Montreal (UQAM).

The semester will begin (January 19–21, 2007) with a miniworkshop, Algebraic Combinatorics Meets Inverse Systems, organized by F. Bergeron, K. Dalili (Dalhousie University,), S. Faridi (Dalhousie University), and A. Lauve (UQAM). Five workshops will be held, four of which will be preceded by a school. The schedule follows.

February 12–16, 2007: School on Statistical Mechanics and Combinatorics.

February 19–23, 2007: Workshop on Combinatorial Problems Raised by Statistical Mechanics. Organizers: M. Bousquet-Mélou (University of Bordeaux), P. Leroux (UQAM), T. Guttmann (University of Melbourne), and A. Sokal (New York University).

March 5–9, 2007: School on Combinatorics on Words.

March 12–16, 2007: Workshop on Recent Progress in Combinatorics on Words. Organizers: S. Brlek (UQAM), C. Reutenauer (UQAM), and B. Sagan (Michigan State University).

April 30–May 4, 2007: School on Macdonald Polynomials.

May 7–11, 2007: Workshop on Combinatorial Hopf Algebras and Macdonald Polynomials. Organizers: M. Aguiar (Texas A&M University), F. Bergeron (UQAM), N. Bergeron (York University), M. Haiman (University of California, Berkeley), and S. van Willigenburg (University of British Columbia).

May 21–25, 2007: School on Algebraic Geometry and Algebraic Combinatorics.

May 28–June 1, 2007: Workshop on Interactions between Algebraic Combinatorics and Algebraic Geometry. Organizers: F. Bergeron (UQAM), A. Geramita (Queen's University), A. Knutson (University of California, San Diego), R. Vakil (Stanford University), and S. Faridi (Dalhousie University).

June 11–22, 2007: Real, Tropical, and Complex Enumerative Geometry. Organizers: V. Kharlamov (University of Strasbourg) and R. Pandharipande (Princeton University).

The Aisenstadt Lecturer will be Richard Stanley (Massachusetts Institute of Technology).

Besides the thematic program, a number of activities will take place at the CRM during this period.

A conference Groups and Symmetries: From the Neolithic Scots to John McKay will be held from April 27–30, 2007, in honor of four decades of contributions by John McKay. The organizers are J. Harnad (Concordia University) and P. Winternitz (CRM).

A short program Moduli Spaces and Related Topics will be held June 4–15, 2007, at the CRM, organized by D. Korotkin and M. Bertola. The conference Fractals in Engineering VI, organized by F. Nekka and J. Lévy Véhel, will be held July 4–6, 2007, at the CRM. A conference on Banach Algebras will be held July 4–12, 2007, at Laval University; organizers are T. J. Ransford and D. Jakobson. The Workshop on Statistical Methods for Modeling Dynamic Systems will be held July 9–13, 2007, at the CRM, organized by J. Ramsay.

For more information on the lecturers at various events and on the support available for visitors, graduate students, and postdoctoral fellows, see `http://www.crm.umontreal.ca`.

—From a CRM announcement

Inside the AMS

New AMS Service for Students

Headlines & Deadlines for Students is a new service from the AMS that provides email notification of mathematics news and upcoming deadlines. These email notifications are issued about once a month and when there is special news. Imminent deadlines are included in these emails, which link to a Web page that's a centralized source of information relevant to students and faculty advisors at `http://www.ams.org/news-for-students/`. Sign up for the email service at `http://www.ams.org/news-for-students/signup`.

—*AMS announcement*

AMS Email Support for Frequently Asked Questions

A number of email addresses have been established for contacting the AMS staff regarding frequently asked questions. The following is a list of those addresses together with a description of the types of inquiries that should be made through each address.

abs-info@ams.org for questions regarding a particular abstract.

abs-submit@ams.org for information on how to submit abstracts for AMS meetings and MAA sessions at January Joint Mathematics meetings. Type HELP as the subject line.

acquisitions@ams.org to contact the AMS Acquisitions Department.

ams@ams.org to contact the Society's headquarters in Providence, Rhode Island.

amsdc@ams.org to contact the Society's office in Washington, DC.

amsmem@ams.org to request information about membership in the AMS and about dues payments or to ask any general membership questions; may also be used to submit address changes.

annualsurvey@ams.org for information or questions about the *Annual Survey of the Mathematical Sciences* or to request reprints of survey reports.

bookstore@ams.org for inquiries related to the online AMS Bookstore.

classads@ams.org to submit classified advertising for the *Notices*.

cust-serv@ams.org for general information about AMS products (including electronic products), to send address changes, place credit card orders for AMS products, or conduct any general correspondence with the Society's Customer Services Department.

development@ams.org for information about giving to the AMS, including the Epsilon Fund.

eims-info@ams.org to request general information about *Employment Information in the Mathematical Sciences* (EIMS). For ad deadlines and rates go to `http://www.ams.org/eims`.

ejour-submit@ams.org to submit papers to *Representation Theory* and *Conformal Geometry and Dynamics*. Each submission must be accompanied by the journal template. A copy of the template is available by sending email to: `http://ejour-submit@ams.org`. Put the word TEMPLATE in the subject field of the email message. To get additional help, put the word HELP in the subject field in a separate mail message.

emp-info@ams.org for information regarding AMS employment and career services.

eprod-support@ams.org for technical questions regarding AMS electronic products and services.

era-submit@ams.org for authors to submit research announcements to *Electronic Research Announcements of the AMS*.

mathcal@ams.org to send information to be included in the "Mathematics Calendar" section of the *Notices*.

mathrev@ams.org to submit reviews to *Mathematical Reviews* and to send correspondence related to reviews or other editorial questions.

meet@ams.org to request general information about Society meetings and conferences.

meetreg-request@ams.org to request email meeting registration forms.

meetreg-submit@ams.org to submit completed registration forms.

mmsb@ams.org for information or questions about registration and housing for the Joint Mathematics Meetings (Mathematics Meetings Service Bureau).

msn-support@ams.org for technical questions regarding MathSciNet.

notices@ams.org to send correspondence to the managing editor of the *Notices*, including items for the news columns. The editor (`notices@math.ou.edu`) is the person to whom to send articles and letters. Requests for permission to reprint from the *Notices* should be sent to reprint-permission@ams.org (see below).

notices-ads@ams.org to submit paid display ads electronically for the *Notices*. (Hard copy of the ad should also be faxed or sent via postal mail.)

notices-booklist@ams.org to submit suggestions for books to be included in the "Book List" in the *Notices*.

notices-letters@ams.org to submit letters and opinion pieces to the *Notices*.

notices-whatis@ams.org to comment on or send suggestions for topics for the "WHAT IS...?" column in the *Notices*.

paoffice@ams.org to contact the AMS Public Awareness Office.

president@ams.org to contact the president of the American Mathematical Society.

prof-serv@ams.org to send correspondence about AMS professional programs and services.

pub@ams.org to send correspondence to the AMS Publication Division.

pub-submit@ams.org to submit accepted electronic manuscripts to AMS publications (other than *Abstracts*). See `http://www.ams.org/submit-book-journal` to electronically submit accepted manuscripts to the AMS book and journal programs.

reprint-permission@ams.org to request permission to reprint material from Society publications.

sales@ams.org to inquire about reselling or distributing AMS publications or to send correspondence to the AMS Sales Department.

secretary@ams.org to contact the secretary of the Society.

statements@ams.org to correspond regarding a balance due shown on a monthly statement.

tech-support@ams.org to contact the Society's typesetting Technical Support Group.

textbooks@ams.org to request examination copies or inquire about using AMS publications as course texts.

webmaster@ams.org for general information or for assistance is accessing and using the AMS website.

—*AMS announcement*

Reference and Book List

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

Contacting the *Notices*

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

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

The electronic-mail addresses are notices@math.ou.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 405-325-7484 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

January 2007: Nominations for Maria Mitchell Women in Science Award. See http://www.mmo.org/category.php?cat_id=14, or contact the Maria Mitchell Women in Science Award Committee, Maria Mitchell Association, 4 Vestal Street, Nantucket, MA 02554; telephone 508-228-9198.

January 10, 2007: Applications for AAUW Selected Professions Fellowships. See http://www.aauw.org/fga/fellowships_grants/selected.cfm or contact the AAUW Educational Foundation, Selected Professions Fellowships, P.O. Box 4030, Iowa City, IA 52243-4030.

January 15, 2007: Applications for AMS-AAAS Mass Media Summer Fellowships. See http://www.aaas.org/programs/education/MassMedia/ or contact Stacey Pasco, Manager, Mass Media Program, AAAS Mass Media Science and Engineering Fellows Program, 1200 New York Avenue, NW, Washington, DC 20005; telephone 202-326-6441; fax 202-371-9849; email: spasco@aaas.org. Further information is also available at http://www.ams.org/government/massmediaann.html and through the AMS Washington Office, 1527 Eighteenth Street, NW, Washington, DC 20036; telephone 202-588-1100; fax 202-588-1853; email: amsdc@ams.org.

January 25, 2007: Proposals for NSF Scientific Computing Research Environments for the Mathematical Sciences (SCREMS). See http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf05627.

Where to Find It

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

January 31, 2007: Applications for AMS Congressional Fellowship. See http://www.ams.org/government/congressfellowann.html or contact the AMS Washington Office at 202-588-1100, email: amsdc@ams.org.

February 1, 2007: Applications for National Academies Research Associateship Programs. See "Mathematics Opportunities" in this issue.

February 1, 2007: Applications for AWM Travel Grants and Mentoring Travel Grants. See http://www.awm-math.org/travelgrants.html; telephone 703-934-0163; email: awm@math.umd.edu; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

February 9, 2007: Applications for Newton Fellowships of the Math for America Foundation (MfA). See http://www.mathforamerica.org/.

February 16, 2007: Nominations for CMI Liftoff fellowships. See http://claymath.org/fas/liftoff_fellows/; telephone: 617-995-2600; email: nominations@claymath.org.

March 1, 2007: Applications for National Academies Christine Mirzayan Graduate Fellowships for the summer program. See http://www7.nationalacademies.org/policyfellows or contact The National Academies Christine Mirzayan Science and Technology Policy Graduate Fellowship Program, 500 5th Street, NW, Room 508, Washington, DC 20001; telephone: 202-334-2455; fax: 202-334-1667; email: policyfellows@nas.edu.

April 15, 2007: Applications for AMS "Math in Moscow" Scholarships for fall 2007. See http://www.mccme.ru/mathinmoscow or contact Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax +7095-291-65-01; email: mim@mccme.ru. For information and application forms for the AMS scholarships see http://www.ams.org/outreach/mimoscow.html or contact Math in Moscow Program, Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence RI 02904-2294; email: student-serv@ams.org.

May 1, 2007: Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html; telephone 703-934-0163; email: awm@math.umd.edu; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

June 1, 2007: Applications for National Academies Christine Mirzayan Graduate Fellowships for the fall program. See http://www7.nationalacademies.org/policyfellows or contact The National Academies Christine Mirzayan Science and Technology Policy Graduate Fellowship Program, 500 5th Street, NW, Room 508, Washington, DC 20001; telephone: 202-334-2455; fax: 202-334-1667; email: policyfellows@nas.edu.

June 5, 2007: Proposals for Enhancing the Mathematical Sciences Workforce in the Twenty-First Century. See http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf05595.

June 30, 2007: Nominations for 2007 Fermat Prize. See http://www.math.ups-tlse.fr/Fermat/.

October 1, 2007: Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html; telephone 703-934-0163; email: awm@math.umd.edu; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

MPS Advisory Committee

Following are the names and affiliations of the members of the Advisory Committee for Mathematical and Physical Sciences (MPS) of the National Science Foundation. The date of the expiration of each member's term is given after his or her name. The website for the MPS directorate may be found at http://www.nsf.gov/home/mps/. The postal address is Directorate for the Mathematical and Physical Sciences, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230.

Douglas N. Arnold (10/08)
Institute for Mathematics and its Applications
University of Minnesota

Lars Bildsten (10/07)
KITP
University of California, Santa Barbara

Cynthia J. Burrows (10/08)
Department of Chemistry
University of Utah

Claude R. Canizares (10/08)
Office of the Provost
Massachusetts Institute of Technology

Susan Coppersmith (10/07)
Department of Physics
University of Wisconsin

Larry R. Dalton (10/08)
Department of Chemistry
University of Washington

Sol M. Gruner (10/07)
Department of Physics
Cornell University

Rhonda Hughes (10/08)
Department of Mathematics
Bryn Mawr College

Iain M. Johnstone (10/09)
Department of Statistics
Stanford University

William L. Jorgensen (10/09)
Department of Chemistry
Yale University

David E. Keyes (10/09)
Department of Applied Physics and Applied Mathematics
Columbia University

Robert V. Kohn (10/07)
Courant Institute
New York University

Steven E. Koonin (10/07)
Chief Scientist
BP, plc

Theresa A. Maldonado (MPSAC/CEOSE Liaison) (10/09)
Department of Electrical and Computer Engineering
Texas A&M University

Dusa M. McDuff (10/09)
Department of Mathematics
Stony Brook University

Monica Olvera de la Cruz (10/08)
Department of Materials Science and Engineering
Northwestern University

Jose N. Onuchic (10/08)
Department of Physics
University of California San Diego

Eve Ostricker (10/07)
Department of Astronomy
University of Maryland, College Park

David W. Oxtoby (10/07)
Office of the President
Pomona College

Marcia J. Rieke (10/07)
Steward Observatory
University of Arizona

Ian M. Robertson (10/09)
Department of Materials Science and Engineering
University of Illinois, Urbana-Champaign

Elizabeth H. Simmons (10/07)
Department of Physics and Astronomy
Michigan State University

Winston O. Soboyejo (10/09)
Department of Mechanical and Aerospace Engineering
Princeton University

Robert Williams (10/09)
Space Telescope Science Institute

Michael Witherell (Chair) (10/08)
Department of Physics
University of California, Santa Barbara

Book List

The Book List highlights books that have mathematical themes and are aimed at a broad audience potentially including mathematicians, students, and the general public. When a book has been reviewed in the Notices, *a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. Suggestions for books to include on the list may be sent to* `notices-booklist@ams.org`.

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

Alan Turing's Automatic Computing Engine: The Master Codebreaker's Struggle to Build the Modern Computer, edited by B. Jack Copeland. Oxford University Press, June 2005. ISBN 0-198-56593-3.

Analysis and Probability: Wavelets, Signals, Fractals by Palle E. T. Jorgensen. Springer, September 2006. ISBN 0-387-29519-4.

Arthur Cayley: Mathematician Laureate of the Victorian Age, by Tony Crilly. Johns Hopkins University Press, December 2005. ISBN 0-801-88011-4.

The Artist and the Mathematician: The Story of Nicolas Bourbaki, the Genius Mathematician Who Never Existed, by Amir D. Aczel. Thunder's Mouth Press, August 2006. ISBN 1-560-25931-0.

A Beautiful Math: John Nash, Game Theory, and the Modern Quest for a Code of Nature, by Tom Siegfried. Joseph Henry Press, October 2006. ISBN 0-309-10192-1.

**Bourbaki, A Secret Society of Mathematicians*, Maurice Mashaal. AMS, June 2006. ISBN 0-821-83967-5.

Change Is Possible: Stories of Women and Minorities in Mathematics, by Patricia Clark Kenschaft. AMS, September 2005. ISBN 0-8218-3748-6.

The Coxeter Legacy: Reflections and Projections, edited by Chandler Davis and Erich W. Ellers. AMS, March 2006. ISBN 0-8218-3722-2.

Dark Hero of the Information Age: In Search of Norbert Wiener, by Flo Conway and Jim Siegelman. Basic Books, December 2004. ISBN 0-738-20368-8. (Reviewed May 2006.)

Decoding the Universe: How the New Science of Information Is Explaining Everything in the Cosmos, from Our Brains to Black Holes, by Charles Seife. Viking Adult, February 2006. ISBN 0-670-03441-X.

Descartes: A Biography, by Desmond Clarke. Cambridge University Press, March 2006. ISBN 0-521-82301-3.

The Equations: Icons of Knowledge, by Sander Bais. Harvard University Press, November 2005. ISBN 0-674-01967-9.

M. C. Escher's Legacy: A Centennial Celebration, edited by Doris Schattschneider and Michele Emmer. Springer, September 2005 (paperback edition). ISBN 3-540-20100-9.

The Essential Turing, edited by B. Jack Copeland. Oxford University Press, September 2004. ISBN 0-198-25080-0. (Reviewed November 2006.)

Euclid in the Rainforest: Discovering Universal Truths in Logic and Math, by Joseph Mazur. Pi Press, October 2004. ISBN 0-131-47994-6.

Euler through Time: A New Look at Old Themes, by V. S. Varadarajan. AMS, June 2006. ISBN 0-8218-3580-7.

**Evolutionary Dynamics: Exploring the Equations of Life*, by Martin Nowak. Belknap Press, September 2006. ISBN 0-674-02338-2.

**The Fabulous Fibonacci Numbers*, by Alfred S. Posamentier and Ingmar Lehmann. Prometheus Books, February 2007. ISBN 1-591-02475-7.

Fearless Symmetry: Exposing the Hidden Patterns of Numbers, by Avner Ash and Robert Gross. Princeton University Press, May 2006. ISBN 0-691-12492-2. (Reviewed in this issue.)

**From Cosmos to Chaos: The Science of Unpredictability*, by Peter Coles. Oxford University Press, August 2006. ISBN 0-198-56762-6.

From Zero to Infinity: What Makes Numbers Interesting, by Constance Reid. Fiftieth anniversary edition, A K Peters, February 2006. ISBN 1-568-81273-6. (Reviewed in this issue.)

Gödel's Theorem: An Incomplete Guide to Its Use and Abuse, by Torkel Franzen. A K Peters, Ltd., May 2005. ISBN 1-568-81238-8.

**Great Feuds in Mathematics: Ten of the Liveliest Disputes Ever*, by Hal Hellman. Wiley September 2006. ISBN 0-471-64877-9.

Hiding in the Mirror: The Mysterious Allure of Extra Dimensions, from Plato to String Theory and Beyond, by Lawrence M. Krauss. Viking Adult, October 2005. ISBN 0-670-03395-2.

**How Mathematics Happened*, by Peter S. Rudman. Prometheus Books, October 2006. ISBN 1-591-02477-3.

Incompleteness: The Proof and Paradox of Kurt Gödel, by Rebecca Goldstein. W. W. Norton, February

2005. ISBN 0-393-05169-2. (Reviewed April 2006.)

Infinite Ascent: A Short History of Mathematics, by David Berlinski. Modern Library, September 2005. ISBN 0-679-64234-X.

The Infinite Book: A Short Guide to the Boundless, Timeless and Endless, by John D. Barrow. Pantheon, August 2005. ISBN 0-375-42227-7.

It's About Time: Understanding Einstein's Relativity, by N. David Mermin. Princeton University Press, September 2005. ISBN 0-691-12201-6.

John von Neumann: Selected Letters, edited by Miklós Rédei. AMS, November 2005. ISBN 0-8218-3776-1.

King of Infinite Space: Donald Coxeter, the Man Who Saved Geometry, by Siobhan Roberts. Walker and Company, September 2006. ISBN 0-802-71499-4.

The Lifebox, the Seashell, and the Soul: What Gnarly Computation Taught Me about Ultimate Reality, the Meaning of Life, and How to Be Happy, by Rudy Rucker. Thunder's Mouth Press, October 2005. ISBN 1-560-25722-9.

A Madman Dreams of Turing Machines, by Janna Levin. Knopf, August 2006. ISBN 1-400-04030-2.

The Man Who Knew Too Much: Alan Turing and the Invention of the Computer, by David Leavitt. Great Discoveries series, W. W. Norton, December 2005. ISBN 0-393-05236-2. (Reviewed November 2006.)

The Math Instinct: Why You're a Mathematical Genius (Along with Lobsters, Birds, Cats, and Dogs), by Keith Devlin. Thunder's Mouth Press, March 2005. ISBN 1-56025-672-9.

**Mathematics and Common Sense: A Case of Creative Tension*, by Philip J. Davis. A K Peters, October 2006. ISBN 1-568-81270-1.

More Mathematical Astronomy Morsels, by Jean Meeus. Willmann-Bell, 2002. ISBN 0-943396-743.

Musimathics: The Mathematical Foundations of Music, Volume 1, by Gareth Loy. MIT Press, September 2006. ISBN 0-262-12282-0.

Mystic, Geometer, and Intuitionist: The Life of L. E. J. Brouwer. Volume 2: Hope and Disillusion, by Dirk van Dalen. Oxford University Press, October 2005. ISBN 0-198-51620-7.

New Mexico Mathematics Contest Problem Book, by Liong-shin Hahn. University of New Mexico Press, November 2005. ISBN 0-8263-3534-9.

The Newtonian Moment: Isaac Newton and the Making of Modern Culture, by Mordechai Feingold. New York Library and Oxford University Press, December 2004. ISBN 0-195-17735-5.

Not Even Wrong: The Failure of String Theory and the Continuing Challenge to Unify the Laws of Physics, by Peter Woit. Jonathan Cape, April 2006. ISBN 0-224-07605-1.

Once Upon Einstein, by Thibault D'Amour. A K Peters, March 2006. ISBN 1-568-81289-2.

The Pea and the Sun: A Mathematical Paradox, by Leonard M. Wapner. A K Peters, April 2005. ISBN 1-568-81213-2. (Reviewed October 2006.)

Piano Hinged Dissections: Time to Fold!, by Greg Frederickson. A K Peters, October 2006. ISBN 1-56881-299-X.

Piero della Francesca: A Mathematician's Art, by J. V. Field. Yale University Press, August 2005. ISBN 0-300-10342-5.

PopCo, by Scarlett Thomas. Harvest Books, October 2005. ISBN 0-156-03137-X. (Reviewed February 2006.)

**Prince of Mathematics: Carl Friedrich Gauss*, by M. B. W. Tent. A K Peters, January 2006. ISBN 1-568-81261-2.

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

Reality Conditions: Short Mathematical Fiction, by Alex Kasman. Mathematical Association of America, May 2005. ISBN 0-88385-552-6. (Reviewed August 2006.)

Reflections: V. I. Arnold's Reminiscences, by V. I. Arnold. Springer, April 2006. ISBN 3-540-28734-5.

The Road to Reality: A Complete Guide to the Laws of the Universe, by Roger Penrose. Knopf, February 2005. ISBN 0-679-45443-8. (Reviewed June/July 2006.)

The Secret Life of Numbers: 50 Easy Pieces on How Mathematicians Work and Think, by George G. Szpiro. Joseph Henry Press, March 2006. ISBN 0-309-09658-8.

Shadows of Reality: The Fourth Dimension in Relativity, Cubism, and Modern Thought, by Tony Robbin. Yale University Press, March 2006. ISBN 0-300-11039-1.

The Shoelace Book: A Mathematical Guide to the Best (and Worst) Ways to Lace Your Shoes, by Burkard Polster. AMS, June 2006. ISBN 0-8218-3933-0. (Reviewed December 2006.)

Stalking the Riemann Hypothesis: The Quest to Find the Hidden Law of Prime Numbers, by Dan Rockmore. Pantheon, April 2005. ISBN 0-375-42136-X. (Reviewed September 2006.)

Symmetry and the Monster: The Story of One of the Greatest Quests of Mathematics, by Mark Ronan. Oxford University Press, May 2006. ISBN 0-192-80722-6. (Reviewed in this issue.)

The Three Body Problem, by Catherine Shaw. Allison and Busby, March 2005. ISBN 0-749-08347-6. (Reviewed October 2006.)

The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next, by Lee Smolin. Joseph Henry Press, October 2006. ISBN 0-309-10192-1.

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

Yearning for the Impossible: The Surprising Truths of Mathematics, by John Stillwell. A K Peters, May 2006. ISBN 1-568-81254-X.

Doctoral Degrees Conferred

2005–2006

ALABAMA

Auburn University (4)

MATHEMATICS AND STATISTICS

Bailey, Bradley, Related covering properties

Sindelrova, Petra, An example on moveable approximations of a minimal set in a continuous flow.

Turner, David, Coefficient space properties and a Schur algebra generalization.

Yan, Wen, Generalization of Ky Fan-Amir-Moez-Horn-Mirsky's result on the eigenvalues and real singular values of a matrix.

University of Alabama, Birmingham (3)

MATHEMATICS

Brouwer, Gaston, Green's functions from a metric point of view.

Lian, Jinguo, Pattern formation for some systems of nonlinear differential equations.

Zhang, Hongkun, Statistical properties of chaotic billiards.

University of Alabama, Huntsville (1)

MATHEMATICS

Wang, Yan, Acquisition numbers and competition-acquisition number.

University of Alabama, Tuscaloosa (11)

INFORMATION SYSTEMS STATISTICS AND MANAGEMENT SCIENCE

Cai, Biao, Evaluation of Gini S mean difference, mean deviation, and quasi-range as estimators of sigma for the performance of Shewhart x-bar control charts.

Haynie, James Brandon, Progressively phased bridge inspection process.

Kim, Young-il, Multivariation SPC for batch processes.

Mysore, Shrikanth, Three essays in scheduling.

Saithanu, Kidakan, Neural networks and multivariate quality control.

Shaltayev, Dmitriy, The value of market information in serial supply chains with Markov-modulated demand.

Watkins, Wade, An efficient search for identifying unobservable factors.

MATHEMATICS

Gong, Minqing G., Waiting time in a combined FCFS and STF queue.

Jun, Younbai, Domain decomposition algorithms for solving parabolic partial differential equations.

Rogers, Frank D., Optimal choices in an LFR system.

Ryang, Dohyoung, Finitely generated groups acting eometrically on generalized hyperbolic spaces.

ARIZONA

Arizona State University (3)

MATHEMATICS AND STATISTICS

Al-Sulami, Hamed Hamdan, C^*-algebras for boundary actions of abelian-by-cyclic groups.

Clark, Phil, The emergence of a classroom community of practice into mathematical structures course.

Lopez-Cruz, Roxana, Structured SIS epidemic models with applications to HIV epidemic.

University of Arizona (11)

MATHEMATICS

Belnap, Jason, Putting TAs into context: Understanding the graduate mathematics teaching assistant.

Leitner, Frederick, Deformation theory of noncommutative formal group in positive characteristics.

Pawloski, Robert, Computing the cohomology ring and Ext-algebra of group algebras.

PROGRAM IN APPLIED MATHEMATICS

Chitnis, Nakul, Using mathematical models in controlling the spread of malaria.

Espinola-Rocha, Jesus Adrian, Short-time asymptotic analysis of the Manakov system.

Forgoston, Eric, Initial-value problem for perturbations in compressible boundary layers.

Kano, Patrick, Development and analysis of high accuracy numerical methods for computational optics.

Linfoot, Andy, A case study of multi-threaded Buchberger normal form algorithm.

Schofield, Samuel, Dynamics of laminar jets in stratified fluids.

Soneson, Joshua, Optical pulse dynamics in nonlinear and resonant non-composite media.

Soterwood, Jeanine, Model and analysis of provider-user games.

CALIFORNIA

California Institute of Technology (9)

APPLIED AND COMPUTATIONAL MATHEMATICS

Demanet, Laurent, Curvelets, wave atoms and wave equations.

Goulet, David, Mathematical models of the developing *C. elegans* hermaphrodite gonad.

Luo, Wuan, Wiener chaos expansions and numerical solutions of stochastic partial differential equations.

Strinopoulos, Theofilos, Upscaling immiscible two-phase flows in an adaptive frame.

CONTROL AND DYNAMICAL SYSTEMS

Shadden, Shawn, A dynamical systems approach to unsteady systems.

The above list contains the names and thesis titles of recipients of doctoral degrees in the mathematical sciences (July 1, 2005, to June 30, 2006) reported in the 2006 Annual Survey of the Mathematical Sciences by 222 departments in 164 universities in the United States. Each entry contains the name of the recipient and the thesis title. The number in parentheses following the name of the university is the number of degrees listed for that university. A supplementary list containing names received since compilation of this list will appear in a summer 2007 issue of the *Notices*.

MATHEMATICS

Gealy, Matthew, On the Tamagawa number conjecture for motives attached to modular forms.

Liu, Xiaoyu, On divisible codes over finite fields.

Navilarekallu, Tejaswi, On the equivariant Tamagawa number conjecture.

Sorensen, Claus, Level-raising for GSp(4).

Claremont Graduate University (7)

SCHOOL OF MATHEMATICAL SCIENCES

Bui, Minh, Linear phase orthogonal filter bank construction with applications to image and geometric approximations.

Cepeda-Rizo, Juan, Solid and fluid mechanics: Case studies in electronic packaging.

De Pass, Monica, Wavelet feature extraction of high-range resolution radar profiles using generalized Gaussian distributions for automated target recognition.

Fedorchuk, Katherine, Condensed history methods for Monte Carlo solutions of photon transport problems.

Longhini, Patrick, Nonlinear dynamics design and operation of advanced magnetic sensors.

Teng, Ying, Modeling and simulation of aeroserroelastic control with multiple control surfaces using μ-method.

Wong, Chao-Jen, The embedding method for simulation for enzyme kinetics and transfer in sessile hydrogel drop.

Stanford University (6)

STATISTICS

Han, Jiarui, Dynamic portfolio management.

Li, Jingyang, Contributions to Bayesian survival analysis.

Schwartzman, Armin, Random ellipsoids and false discovery rates: Statistics for diffusion tensor imaging data.

Xing, Haipeng, Change-point stochastic regression models with applications to econometric time series.

Zhang, Nancy, Change-point models and sequence alignments: Statistical problems of genomics.

Zou, Hui, Some perspectives of sparse statistical modeling.

University of California, Berkeley (33)

BIOSTATISTICS

Birkner, Merrill, Statistical hypothesis testing and application to biological data.

Machekano, Rhoderick, Statistical complications of infectious disease data: Machine learning, causal inference and multiple testing.

Sinisi, Sandra, Data-adaptive prediction with the deletion/substitution/addition algorithm.

Wang, Yan, Statistical methods for evaluating linkage disequilibrium using length of haplotype sharing.

MATHEMATICS

Borooah, Gautam, Clean conditions and incidence rings.

Diesl, Alexander, Classes of strongly clean rings.

Dorsey, Thomas, Cleanness and strong cleanness of rings of matrices.

Dugas, Alexander, Stable equivalences of finite dimensional algebras: Relative homology and lifting problems.

Eriksson, Nicholas, Algebraic combinatorics for computational biology.

Farjoun, Yossi, Nucleation, growth, and coarsening: A global view on aggregation kinetics.

Fertig, Ron, Almost rational torsion points on Abelian varieties.

Gracia-Saz, Alfonso C., The symbol of a function of a pseudodifferential operator.

Grigsby, Elisenda, Knot floer homology in cyclic branched covers.

Grossman, Pinhas, Intermediate subfactors with small index.

Hough, J. Ben, Asymptotic results for zeros of diffusing Gaussian analytic functions.

Huggins, Bonnie, Fields of moduli and fields of definition of curves.

Kim, Walter, Ramification points on the eigencurve and the two variable symmetric square p-adic L-function.

Lim, Chu-Wee, Decomposition of spaces of cusp forms over Q and variants of Partial Nim.

Menta, Rajan, Supergroupoids, double structures, and equivariant cohomology.

Mesyan, Zachary, On endomorphism rings of infinite direct sums of modules.

Nielsen, Pace, The exchange property for modules and rings.

Okunev, Pavel, Renormalization methods with applications to spin systems and finance.

Palamarchuk, Konstantin, The 6-vertex model in statistical mechanics.

Rinker, Mark, Height functions, maps to the integers, and the Whitehead graph of a finite presentation.

Woo, Alexander, Ideals of the polynomial ring generated by irreducible symmetric group representations and Ellingsrud-Strømme.

Xia, Jianlin, Fast direct solvers for structured linear systems of equations.

STATISTICS

Chen, Chao, Topics on random forests.

Guha, Apratim, Analysis of dependence structures of hybrid stochastic processing using mutual information.

Hammond, Alan, Two models of probability theory: Brownian fluctuations and a kinetic limit.

Krishnapur, Manjunath, Zeros of random analytic functions.

McAuliffe, Jon, Statistical methods for comparing genomes.

Pete, Gábor, Dependent percolation critical exponents, anchored isoperimetry and random walks.

Zhao, Peng, Regularization: Sparsity, structure and computation.

University of California, Davis (9)

MATHEMATICS

Cheng, Ching-hsiao, Navier-Stokes equations interacting with a nonlinear elastic shell.

Deka, Lipika, Fermionic formulas for unrestricted Kostka polynomials and superconformal characters.

Johnson, Jesse, Heegaard splittings, the curve complex and the points complex.

Larripa, Kamila, Mathematical models of the cytoskeleton.

McAllister, Tyrrell, Applications of polyhedral geometry to computational representation theory.

Safnuk, Bradley, Intersection theory on the moduli space of curves.

Smith, Noel, Boundary interpolating trigonometric transforms and applications.

Wilson, Robin, Knots with infinitely incompressible Seifert surfaces.

Zhao, Jucheng, Efficient approximations: Overcome boundary effects.

University of California, Los Angeles (34)

BIOSTATISTICS

Comulada, Warren, Two-part longitudinal multivariate models for sex, drugs, and teratology.

Gadallah, May Mokhtar Aly, Combing aggregated and individual level data to estimate individual level parameters variance, covariance, and slope coefficient.

Lemus, Hector, Bayesian state space modeling of heterogeneous multivariate longitudinal data.

Li, Ning, Joint analysis of longitudinal measurements and competing risk failure time data.

Siddique, Juned, Multiple imputation using an iterative hot-deck with distance based donor selection.

Wu, Tongtong, A partial linear semiparametric additive risks model for two-stage design survival studies.

Zhao, Yu, Additive risk regression for survival data from two-stage designs.

Zhou, Kefei, A unified approach to nonparametric comparisons of receiver operating characteristics curves for longitudinal and clustered data.

MATHEMATICS

Bueti, John, A bound for the (n,k) maximal function via incidence combinatorics.

Cai, Shuang, Algebraic connective K-theory: A simple definition and its consequences.

Feigon, Brooke, Periods and relative trace formulas for GL(2) in the local setting.

Folsom, Amanda, Modular units.

Gilette, Alan, Image inpainting using phase-field method.

He, Lin, Applications and generalizations of the iterative refinement method.

Khamsemanan, Nirattaya, Estimation of Nielsen numbers.

Kim, Yon Seo, Localization method as a universal approach to the Gromov-Witten theory.

Klein, Silvius, Spectral theory for discrete, quasi-periodic Schrödinger operators.

Le, Triet, A study of image segmentation and decomposition in a variational approach.

Lee, Catherine, The effect of smoothness and derivative conditions on the fixed point sets of smooth maps.

Leung, Shing-Yu, Applications of the level set method to geometrical optics, transmission tomography, image processing and crystal growth modeling.

Lieu, Linh, Contribution to problems in image restoration, decomposition, and segmentation by variational methods and PDEs.

Ouellette, Keith, On the Fourier inversion formula for reductive adèlic groups.

Park, Frederick, Total variation and duality for blind image.

Peterson, Jesse, 1-cohomology and rigidity in Π_1 factors.

Schubert, Claus, New u-invariants of quadratic forms and function fields of good forms of height two.

Sze, Nang Keung, Multilevel optimization for VLSI circuit placement.

Thiyanaratnam, Pradeep, Modeling and simulation of electrodisposition in 2 and 3 dimensions.

Visan, Monica, The defocusing energy-critical nonlinear Schrödinger equation in dimensions five and higher.

Xu, Jinjun, Iterative regularization and nonlinear inverse scale space methods in image restoration—interactive regularization and nonlinear inverse scale space methods in image restoration.

STATISTICS

He, Yan, Missing data imputation for tree-based models.

Huang, Wehua, Methods to extract rare events.

Maciuca, Romeo, MCMC analysis: First hitting times, visiting scheme, and auxiliary variables.

Veen, Alejandro, Some methods of assessing and estimating point processes models for earthquake occurrences.

Zheng, Ming, ChIP-chip: Data, model and analysis.

University of California, Riverside (3)

MATHEMATICS

Bartels, Tobias, Higher gauge theory, 2-bundles.

Hernandez, Lisa, On the girth of a knot.

Pearse, Erin, Complex dimensions of self-similar systems.

University of California, San Diego (13)

MATHEMATICS

Cecil, Mathew S., The Taylor map on complex path groups.

Emmons, Caleb J., Higher order integral Stark-type conjectures.

Fenwick, Jennifer E., A survey of meshing algorithms and a multi-purpose mesh generator.

Fleming, Thomas R., Generalized link homotopy invariants.

Horton, Matthew D., Ihara zeta functions of irregular graphs.

Kang, Weining, An invariance principle for semimartingale reflecting Brownian motions (SRBMs) in domains with piecewise smooth boundaries.

Lee, Jason, Topics in combinatorial game theory: Partizan versions of Nim, the hypercube description and results on computation in the field of numbers.

Lim, Poon Chuan Adrian, Path integrals on a compact manifold with non-negative curvature.

Miceli, Brian, A rook theory model for product formulas and poly-Stirling numbers.

Newland, Derek, Kernels in the Selberg trace formula on $\mathbb{T}_k$ and distributions of the zeroes of the Ihara-zeta function.

Pendergrass, Cayley, Just-infinite algebras and an extension of a theorem of Herstein.

Winkelmann, Beate M., Finite dimensional optimization methods and their application to optimal control with PDE constraints.

Wu, Lei, Random inscribed polytopes.

University of California, Santa Barbara (13)

MATHEMATICS

Ham, Ji-Young, The minimal dilatations of 4 and 5 braids.

Lichtenstein, Eric, Divisors for elliptic curves satisfying Zagier's conjecture.

Pavone, Christopher, The spectral scale of a self-adjoint operator in a semifinite von Neumann algebra.

Roybal, Roger, A reproducing kernel condition for indeterminacy in the multidimensional moment problem.

Sittinger, Brian, Recurrence formulae for the coefficients of modular forms and functions.

Tomova, Madlena, Compressing thin spheres in the complement of a link.

Wylie, William, On the fundamental group of noncompact manifolds with nonnegative Ricci curvature.

STATISTICS AND APPLIED PROBABILITY

Chernobai, Anna, Contributions to modeling of operational risk in banks.

Frame, Samuel, Some contributions to semi-supervised learning.

Grebeck, Michael, Application of stochastic programming and stable distributions to asset liability management.

Lei, Xiaofang, Bayes nets: A generalized variable elimination algorithm and applications to classification.

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University of Northern Colorado (3)

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University of Connecticut, Storrs (5)

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University of Delaware (2)

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DISTRICT OF COLUMBIA

American University (3)

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Florida Atlantic University (2)

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GEORGIA

Clark Atlanta University (1)

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Emory University (7)

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Georgia Institute of Technology (7)

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University of Hawaii (1)

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IDAHO

Idaho State University (2)

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ILLINOIS

Illinois Institute of Technology (1)

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Illinois State University (2)

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INDIANA

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IOWA

Iowa State University (11)

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KANSAS

Kansas State University (6)

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University of Kansas (4)

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KENTUCKY

University of Kentucky (3)

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LOUISIANA

Louisiana State University (11)

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Louisiana Technology University (4)

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MARYLAND

Johns Hopkins University (10)

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Harlim, John, Errors in the initial conditions for numerical weather prediction: A study of error growth patterns and error reduction with ensemble filtering.

Hauck, Cory, Entropy-based moment closures in semiconductor models.

Howard, Benjamin, Matroids and geometric invariant theory of torus actions on flag spaces.

Jiminez, William, Riemannian submersions and Lie groups.

Kim, Sunhee, Stimulating risk neutral stochastic processes with a view to pricing exotic options.

Lawton, Sean, $SL(3,C)$-character varieties and RP^2-structures on a trinion.

Li, Feiyue, Modeling and solving several important variants of the vehicle routing problem.

McClendon, David, Orbit discontinuities and topological models for Borel semiflows.

Mekchay, Khamron, Convergence of adaptive finite element methods.

Peterson, Elisha, Trace diagrams, representations, and low dimensional topology.

Rohde, Gustav, Registration methods for quantitative imaging.

Romero, Juan, Generalized multiresolution analysis: Construction and measure theoretic characterization.

Skufca, Joseph, Understanding a chaotic saddle with focus on a 9-variable model of planar Couette flow.

Truman, Christopher, Turaev torsion of manifolds with boundary.

Tsou, Hsiao-Hui (Sophie), Factor analysis of cross-classified data.

Wu, Xianfang, Stochastic volatility with Levy processes: calibration and pricing.

Xiao, Yue, Leveraged Levy processes as models for stock prices.

Xiong, Yupei, The minimum labeling spanning tree problem and some variants.

Zhang, Bing, A new Levy-based short rate model for the fixed income market and its estimation with particle filter.

MASSACHUSETTS

Boston University (5)

MATHEMATICS AND STATISTICS

Beck, Margaret, Topics in stability theory for partial differential equations.

Chua, David, Statistical analysis for whole networks.

Diniz Behn, Cecilia, A mathematical model of network dynamics governing sleep-wake behavior in mice.

Kao, Mei-fang, Bayesian modeling of nonrandom drop-outs in longitudinal data analysis.

Torres-Ardila, Fabian, Chern-Simons forms in infinite dimensions.

Boston University School of Public Health (2)

BIOSTATISTICS

Li, Jiang, Modeling of silent events and evaluation of biomarkers in a prospective study with scheduled follow-up.

Posner, Michael, Propensity scores: When are they needed and methods of implementation.

Brandeis University (7)

MATHEMATICS

Chang, Seunghwan, Extensions of rank one (φ, Γ)-modules.

Cheong, Daewoong, Quantum cohomology rings of Lagrangian and orthogonal Grassmannians and Vafa-Intriligator type formulas.

Feldman, Ophir, Actions of finite type Artin groups on R-trees.

Ghosh, Anish, Dynamics or homogeneous spaces and Diophantine approximation on manifolds.

Pande, Aftab, Local constancy of eigenforms.

Petersen, Thomas Kyle, Descents, peaks and P-partitions.

Romano, Bruce, On Stark's conjecture for octahedral representations.

Harvard University (36)

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Forsberg White, Laura, Statistical methods for the detection and quantification of infectious disease epidemics.

Goodman, Melody, Statistical methods for community-based cancer interventions and health disparities research.

Griffin, Beth Ann, Inference for failure time data subject to interrupted hazards to interval censoring.

Gryparis, Alexandros, Bayesian semiparametric regression methods with application to environmental epidemiology.

Guo, Yu, Statistical issues in microarray data analysis, array-to-array normalization, empirical Bayes batch effect adjustment, and Pearson's correlation coefficient in the context of replicated experiments.

Harezlak, Jaroslaw, Using functional regression models to analyze longitudinal data.

Karamitis Nikolov, Margaret, Statistical methods for assessing source-specific health effects of air pollution.

Murphy, Amy, Novel methodologies for genetic association testing.

Najita, Julie, Statistical issues in the design and analysis of developmental toxicity studies.

Ruan, Ping (Kathryn), Methodology for failure time data with missing cause of failure or dependent censoring.

Schumi, Jennifer, Resampling-based methods for multiple hypothesis testing.

Soh, Chang-Heok, Bias-reduction in variable selection and the analysis of competing risks with missing covariant values with right-censored data.

Szwarc, Suzanne, Statistical models for fertility-related issues in adjuvant treatment for breast cancer.

Tchetgen Tchetgen, Eric, Statistical methods for robust inference in causal and missing data models.

Vanderweele, Tyler, Contributions to the theory of causal directed acyclic graphs.

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Drinea, Eleni, Lower bounds for the capacity of channels with I.I.D. deletions and insertions.

Gal, Ya'akov, Reasoning about rationality and beliefs.

Li, Jr-Shin, Control of inhomogeneous ensembles.

Ng, Brenda, Factored inference for efficient reasoning of complex dynamic systems.

Nguyen, Minh-Huyen, Zero knowledge and efficient provers.

Shan, Chung-Chieh, Linguistic side effects.

Viola, Emanuele, The complexity of hardness amplification and derandomization.

Yuan, Haidong, Geometry, optimal control and quantum computing.

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Bainbridge, Matthew, Euler characteristics of Teichmüller curves in genus two.

Cautis, Sabin, Extending families of curves: Monodromy and applications.

Chmutova, Tatyana, Representations of the symplectic reflection algebras and of the rational Cherednik algebras.

Herzig, Florian, The weight in a Serre-type conjecture for tame n-dimensional Galois representations.

Kim, Namhoon, Algebraic aspects of operator products and generalizations of vertex algebras.

Kumar, Abhinav, $K3$ surfaces of high rank.

Matsen, Erick, Analysis of probabilistic models of evolution.

Petrakiev, Ivan, On zero-dimensional schemes with special Hilbert functions.

Schein, Michael, Weights of Galois representations associated to Hilbert modular forms.

Sena-Dias, Rosa, Estimated transversality and rational maps.

Wu, Chun-Chun, On the geometry of superstring with torsion.

Yoshida, Teruyoshi, Weight spectral sequence and Hecke correspondence on Shimura varieties.

Yu, Jeng-daw, On ordinary $K3$ surfaces over Fp.

Massachusetts Institute of Technology (23)

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Ackerman, Nathanael, Quantifier rank spectrum of L-infinity-omega.

Angeltveit, Vigleik, Noncommutative ring spectra.

Chan, Alice, Models of high rank for weakly scattered theories.

Chu, Kevin, Asymptotic analysis of extreme electrochemical transport.

Fok, Pak-Wing, Simulations of axisymmetric stepped surfaces with a facet.

Goddard, Christina, Improving a bounding result for weakly-scattered theories.

Harmon, Dion, New bounds on optimal binary search trees.

Heluani, Reimundo, Super symmetric vertex algebras and supercurves.

Hill, Michael, Computational methods for higher real K-theory with applications to tmf.

Hopkinson, John, Universal polynomials in λ-rings and the K-theory of the infinite loop space tmf.

Hu, David, The hydrodynamics of water-walking insects and spiders.

Kamenova, Ljudmila, Hyper-Kaehler fibrations and Hilbert schemes.

Kim, Boguk, Three-dimensional solitary waves in dispersive wave systems.

Lam, Fumei, Traveling salesman path problems.

Liu, Fu, Contributions to the theory of Ehrhart polynomials.

Malon, Christopher, The p-adic local Langlands conjecture.

Santoro, Bianca, Asymptotic expansion of complete Ricci-flat metrics on open manifolds.

Solomon, Jake, Intersection theory on the moduli space of the holomorphic curves with Lagrangian boundary conditions.

Stephens, Benjamin, Thread-wire surfaces.

Tenner, Bridget, The combinatorics of reduced decompositions.

Vener, David, Rocking and rolling down an incline: The dynamics of nested cylinders on a ramp.

Vera, Daniel, Topological Hochschild homology of twisted group algebras.

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Northeastern University (3)

MATHEMATICS

Nathanson, Michael, Local discrimination and quantum channel capacities.

Perez, Joe, L^2 Fredholm property $\bar{\partial}$ Neumann problem on strongly pseudoconvex G-manifolds.

Wickramasinghe, Irosha, Relative conditional complexity of compression for authorship attribution of texts.

University of Massachusetts, Amherst (2)

MATHEMATICS AND STATISTICS

Costeniuc, Marius, Ensemble equivalence and phase transitions for general models in statistical mechanics and for the Curie-Weiss-Potts model.

Tsagkarogiannis, Dimitrios, Mathematical strategies for the coarse-graining of interacting particle systems.

Worcester Polytechnic Institute (1)

MATHEMATICS AND SCIENCE

Simonis, Joseph, Inexact Newton methods applied to underdetermined systems.

MICHIGAN

Central Michigan University (2)

MATHEMATICS

Al-Sharawi, Ziyad, Periodic discrete dynamical systems.

Pararai, Mavis, Measurement errors in generalized Poisson regression model.

Michigan State University (15)

MATHEMATICS

Dai, Zhewei, Local regularization for the autoconvolution problem.

Danielson, Christopher, Walking a straight line: Introductory discourse on linearity in classrooms and curriculum.

Demirkoparan, Hasan, Pure Azimuthal shearing deformations for an extended class of elastic materials that are characterized by a microstructurally motivated internal balance principle.

Feng, Peng, Pattern information in some nonlinear systems.

Han, Jianlong, Nonlocal Cahn-Hilliard equation.

Lee, Jungho, The deformations of a curved rod.

Li, Peijun, Inverse medium scattering for electromagnetic wave propagation.

Park, Tae-Wan, The existence of global solutions of a variational nonlinear wave equation.

Wu, Dongsheng, Geometric properties of anisotropic Gaussian random fields.

Zhou, Guangyu, On a class of nonlocal evolution equations.

STATISTICS AND PROBABILITY

Wang, Li, Semilinear stochastic differential equations in Hilbert spaces driven by non-Gaussian noise and their asymptotic properties.

Wu, Mingxin, Trimmed and Winsorized estimators.

Xue, Lan, Additive coefficient modeling via marginal integration and polynomial spline smoothing.

Yi, Tingting, Some inference problems for interval censored data.

Zhang, Hui, Resampling methods for adaptive designs.

Michigan Technical University (2)

MATHEMATICS AND SCIENCE

Alqaraleh, Sahar Mubarak, Variational principles for linear and nonlinear mixtures: New derivations and application to bilinear materials and yield behavior.

Khan, Aktar, Numerical methods for elliptic inverse problems with interior data.

Oakland University (1)

MATHEMATICS AND STATISTICS

Xia, Zhengzhi, Some contributions to multiple comparison methods for longitudinal data and general linear mixed effects models.

University of Michigan (30)

BIOSTATISTICS

Andrei, Adin-Cristian, Nonparametric and semiparametric censored survival analysis of correlated times to event and their sequelae.

He, Yulei, Multiple imputation for continuous non-normal missing data.

Li, Mingyao, Statistical methods in gene mapping of complex diseases.

Liu, Dawei, Semiparametric regression for multi-dimensional data: Kernel machines and mixed-effects models.

Long, Qi, Emerging issues in causal inference for intervention trials.

Yuan, Ying, Model-based estimates of the finite population mean for two-stage cluster samples with nonresponse.

Zhou, Honghong, Case-control studies with longitudinal covariates.

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Andrei, Alina, The parameter space of quadratic polynomial maps on C^2.

Berger, Tobias, The Eisenstein ideal for imaginary quadratic fields.

Bird, Erik, A proof of existence of particle-like solutions to Einstein-Dirac equations.

Blekherman, Grigoriy, Convex geometry of orbits.

Brown, Jim, Saito-Kurokawa lifts, L-values for GL2, and congruences between Siegel modular forms.

Chindris, Calin, The cone of effective weights for quivers and Horn type problems.

Chivoret, Sebastien, Properties of multiple stochastic integrals with respect to fractional Brownian motion and applications to nonlinear filtering.

Choi, Jungmin, Partial hedging in financial markets with a large agent.

Ciupe, Stanca, Development and applications of mathematics tools in models of infectious diseases and biological phenomenon.

Dietz, Geoffrey, Closure operations in positive characteristic and big Cohen-Macaulay algebras.

Fiore, Thomas, Pseudo limits, bi-adjoints, and pseudo algebras: Categorical foundations of conformal field theory.

Forde, Jonathan, Delay differential equation models in mathematical biology.

Gao, Peng, N-level density of the low lying zeros of quadratic Dirichlet L-functions.

Hering, Milena, Syzygies of toric varieties.

Lorenz, William, A self-adaptive random walk algorithm to identify genetic epistatic effects.

Mihalcea, Constantin, Equivariant quantum cohomology of homogeneous spaces.

Peters, Han, Non-autonomous complex dynamical systems.

Shastry, Sreekar, The Drinfeld modular Jacobian $J_1(n)$ has connected fibers.

Teitler, Zachariah, Multiplier ideals of line arrangements.

Wolfe, Alexandre, Asymptotic invariants of graded systems of ideals and linear systems on projective bundles.

STATISTICS

Hu, Jennifer, Modeling variation in functional responses with applications in human motion analysis.

Lawrence, Earl, Flexicast network delay tomography.

Wang, Xiao, Nonparametric inference with applications to dark matter estimation in astronomy and degradation modeling in reliability.

Wayne State University (1)

MATHEMATICS

Song, Qingshuo, Numerical methods for control and games of regime-switching diffusion systems: Algorithms, analysis, and computations.

Western Michigan University (3)

MATHEMATICS

Escuadro, Henry, Detectable colorings of graphs.

Fox, Joseph, Nilpotent orbits on infinitesimal symmetric spaces.

Stockero, Shari, The effect of using video cases of mathematics teaching on preservice teachers' development of a reflective stance towards teaching.

MINNESOTA

University of Minnesota-Twin Cities (25)

DIVISION OF BIOSTATISTICS, SCHOOL OF PUBLIC HEALTH

Li, Bingbing, Sample size calculation in survival trials accounting for time dependent dynamics of noncompliance and risk.

Liu, Xuan, Latent variable models for multivariate spatial data.

Lu, Haolan, Measuring the complexity of generalized linear hierarchical models and Bayesian areal wombling for boundary analysis.

Reich, Brian, Sample size calculations with correlated binary data and multiple treatments.

SCHOOL OF MATHEMATICS

Anand, Akash, An efficient high-order numerical algorithm for scattering by 3-dimensional "thin structures".

Celiker, Fatih, Discontinuous Galerkin methods for structural mechanics.

Cheh, Jeongoo, Symmetry pseudogroups of differential equations.

Chen, Min-Hung, High order Runge-Kutta discontinuous Galerkin methods for computational electromagnetics.

Dong, Hongjie, On some problems related to the regularity theory for second-order elliptic-parabolic equations and their numerical approximations.

Du, Dapeng, Three regularity results related to the Navier-Stokes equations.

Ecevit, Fatih, Integral equation formulations of acoustic and electromagnetic scattering problems: High-frequency asymptotic expansion and convergence of multiple scattering interations.

Hoft, Thomas, An inverse problem in nondestructive evaluation of spotwelds.

Kim, Dayoon, Partial differential equations in Sobolev spaces with or without weights.

Ponomarenko, Mariya, Error estimates and adaptivity in approximation of functions by artificial neural networks.

Rogness, Jonathan, Homological and homotopical algebra of exact couples.

Turc, Catalin, High-order integral equation methods for high-frequency rough surface scattering applications.

Weng, Pangyen, On Sobolev spaces of divergence-free vector fields and their applications.

SCHOOL OF STATISTICS

Bennie, Barbara, Optimal bidding strategies for a non-durable consumer good with cyclic production.

Gregas, Matthew, A semi-parametric approach to intensity curve estimation with applications to neuroscience.

Huang, Yu-Min, Hypotheses with multiple linear inequality constraints.

Sheng, Jun, Methods for comparing two crossing hazard functions.

Sun, Jingran, Image segmentation for cDNA microarray data based on local polynomial kernel smoothing.

Wang, Junhui, Topics in large margin supervised and semi-supervised learning.

Wang, Lifeng, On L 1-norm multi-class support vector machines: Methodology, theory and applications.

Yoo, Jae Keun, Optimal sufficient dimension reduction for the multivariate conditional mean in multivariate regression.

MISSISSIPPI

Mississippi State University (1)

MATHEMATICS AND STATISTICS

Wattanataweekul, Hathaikarn, Convex analysis and flows in infinite networks.

University of Mississippi (5)

MATHEMATICS

Anderson, Joe, Reconnected binary matroids and graphs.

Cotwright, Carla, Clones and minors in matroids.

Sanford, Alice, Cycle spectra, automorphic uniqueness, and isomorphism.

Williams, Bryan, Large circuit pairs in matroids.

Wilson, Adrian, Graph groupoids and their topology.

MISSOURI

University of Missouri-Columbia (13)

MATHEMATICS

Arutyunyants, Georgiy, Combinatorial methods in harmonic analysis.

Brown, James (Ryan), Complex and almost-complex structures on six dimensional manifolds.

Diestel, Geoffrey, Bilinear Littlewood-Paley theory and square function estimates.

Jakab, Tunde, Parabolic layer potentials and initial boundary value problems in Lipschitz cylinders with data in Besov spaces.

Kucherenko, Tamara, The absolute functional calculus for sectorial operators.

Nguyen, Phuc, Potential theory and harmonic analysis methods for quasilinear and Hessian equations.

Sansing, Christopher, Directional time-frequency analysis with applications.

Yaskin, Vladyslav, Applications of the Fourier transform to convex geometry.

Yaskina, Maryna, Topics in functional analysis and convex geometry.

STATISTICS

Duty, Paul, Improving the delta method for nonlinear functions.

Park, Do Hwan, Semiparametric and nonparametric methods for the analysis of longitudinal data.

Sheng, Junfeng, Diagnosis, selection, and multiple comparisons in the mixed modeling framework.

Zhang, Song, Bayesian hierarchical models and applications in cancer analysis.

University of Missouri-Rolla (2)

MATHEMATICS AND STATISTICS

Rueck, Florian, Bootstrap prediction intervals for multivariate time series.

Ye, Yi (Derek), Statistical methods for the analysis of aerosol concentration data.

University of Missouri-St. Louis (2)

MATHEMATICS AND COMPUTER SCIENCE

Ndao, Rokhaya, Subdivision schemes for the design and rendering of 3D surfaces.

Wurdack, Karen, Hierarchical Kalman filtering.

Washington University (9)

ELECTRICIAL AND SYSTEMS ENGINEERING

Day, Theodore, Applications of operations research to medical informatics and systems.

Du, Xiuxia, Detection of visual input and control mechanism in the visual cortex of turtles.

Fischer, Brian, A model of the computations leading to a representation of auditory space in the midbrain of the barn owl.

Huang, Yong, A decomposition and selection method for solving VRPSTW and DEA applications.

Joseph, Jenner, Bio-inspired encoding of images with spatiotemporal cortical activity waves and information recovery via dynamical modeling.

MATHEMATICS

Lim, Wang Q., Wavelets with composite dilation and their applications.

Opela, David, Extensions and dilations of N-tuples of Hilbert space operators.

Traub, Cynthia, Topological effects related to minimum weight Steiner triangulations.

Zeng, Zemin, Set theoretic complete intersections and torsion cycles.

MONTANA

Montana State University-Bozeman (1)

MATHEMATICAL SCIENCES

Hasenbank, Jon, The effects of a framework for procedural understanding on college algebra students' procedural skill and understanding.

University of Montana - Missoula (2)

MATHEMATICAL SCIENCES

Luttman, Aaron, A three-dimensional variational approach to video segmentation.

Whitmire, Jane, The use of computer manipulatives in building integrated concrete understandings in secondary mathematics education.

NEBRASKA

University of Nebraska-Lincoln (4)

MATHEMATICS

Bartley, Katherine, Decoding algorithms for algebraic geometric codes over rings.

James, Justin, Some decision problems in group theory.

Langdon, Jennifer, Asymptotic behavior of linear dynamic equations on a time scale.

STATISTICS

Hooks, Tisha, Design and analysis of experiments in the presence of spatial correlation.

NEW HAMPSHIRE

Dartmouth College (1)

MATHEMATICS

Stemkoski, Lee, The Selberg trace formula for cocompact arithmetic groups in $SL(3, R)$.

University of New Hampshire (1)

MATHEMATICS AND STATISTICS

Montiel, Mariana, The process of integration and the concept of integral: How does success with applications and comprehension of underlying notions such as accumulation relate to students' mathematical ability.

NEW JERSEY

New Jersey Institute of Technology (3)

MATHEMATICAL SCIENCES

Lahiri, Soumi, Linear and log-linear models based on generalized inverse sampling scheme.

Tseluiko, Dimitri, Mathematical problems arising in interfacial electrohydrodynamics.

Zorych, Ivan, A Bayesian approach to wireless location problems.

Princeton University (5)

MATHEMATICS

Chen, Szu-Yu (Sophie), Boundary value problems of fully nonlinear equations in conformal geometry.

Ciperiani, Mirela, Solvable points on genus one curves.

Jorati, Hadi, Singular kernels adapted to curved flags.

Silberman, Lior, Arithmetic quantum chaos on locally symmetric spaces.

Wu, Ming-Yih, Stochastic Bouissinesq equations and the infinite dimensional Malliavin calculus.

Rutgers University, New Brunswick (11)

MATHEMATICS

Apagodu, Moa, The sharpening of Wilf-Zeilberger theory.

Enciso, Germán, Monotone input/output systems and biological applications.

Ganguly, Satadal, Large sieve inequalities and application to counting modular forms of weight one.

Holowinsky, Roman, Shifted convolution sums and quantum unique ergodicity.

Jin, Qinian, Curvature prescribing problems in hyperbolic space and conformal geometry.

Kong, Liang, A mathematical study of open-closed conformal field theories.

Mikula, Richard, The Weingarten curvature problem: Prescribing Gauss-Kronecker curvature on group invariant convex hypersurfaces.

Nacin, David, Structural properties of algebras arising from pseudoroots.

Radomirovic, Sasa, Cusp forms over function fields and modular symbols.

Vatter, Vincent, The enumeration and structure of permutation classes.

Weininger, Nicholas, Correlation properties of discrete probability models.

Stevens Institute of Technology (3)

MATHEMATICAL SCIENCES

Cho, Hong-Ray, An introduction to counter groups.

Rekeda, Ludmyla, Statistical tests for stochastic dominance.

Von Dohlen, Paul, Novel approaches to particle-tracking simulations for time dependent velocity fields.

NEW MEXICO

New Mexico State University, Las Cruces (5)

MATHEMATICAL SCIENCES

Li, Baokun, Estimation on random set data and skew normal distribution.

Moyo, Lloyd, Codomains for the Cauchy-Riemann operator, Laplace operator and the product Laplace operator in the context of the S-convolution.

Obiedat, Hamed, Topological characterizations of the Schwartz space and the Beurling-Bjorck space.

Weaver, Christopher, Modeling social systems processes found in text corpora through windowed latent semantic analysis and simulation of concept refreshment events.

Yasein, Mohammad, Polynomial and finite-type invariants of theta-curves.

University of New Mexico (3)

MATHEMATICS AND STATISTICS

Marquez-Lago, Tatiana, Numerical estimation of progesterone transcription in the EGFR pathway.

Vlaicu, Irina, Weak turbulence theory for coasting beams with Schottky noise.

Xu, Ling, Bayesian methods for computing populations with multimodal distributions.

NEW YORK

City University of New York, Graduate Center (8)

MATHEMATICS

Allen, David, On the homotopy of toric spaces with applications to the homotopy groups of certain manifolds.

Bocchi, Timothy, Prescribed mean curvature graphs in hyperbolic space.

Gouraige, Rony, Z-classes in central simple algebras.

Jitsukawa, Toshiaki, Stallings foldings and subgroups of free groups.

Lee, Jaewoo, Infinitely often dense bases and geometric structure of sumsets.

Majidi-Zolbanin, Mahdi, Splitting of vector bundles on punctured spectrum of regular local rings.

Markowsky, Gregory, The derivative of intersection local time in the plane.

Ulrich, James, Öre revisited: An algorithmic investigation of the simple commutator promise problem.

Clarkson University (1)

MATHEMATICS AND COMPUTER SCIENCE

Vasileva, Irina, Force inversion in floating plate dynamics.

Columbia University (21)

BIOSTATISTICS

Chen, Mei-Yin, Two stage stepwise procedures for dose finding in clinical trials with a biological endpoint.

Tian, Hong, Variance estimation of the cross validation estimator of the generalization error.

Yang, Yuqing, Some statistical methods for diagnostic accuracy with correlated data.

MATHEMATICS

Alyurov, Mikhail, Aloff-Wallach spaces: Volumes, curvatures, injectivity radii.

Freiermuth, Hans Georg, On partial compactifications of the space of framed vector bundles on the projective plane.

Kawamuro, Keiko, Algebraic crossing number and braid index.

Lamberson, Peter John, Splice type singularities and iterated branched cyclic covers.

Laza, Radu, Deformations of singularities and variations of GIT quotients.

Martens, Johan, Instanton counting through non-Abelian localization.

Ording, Philip, On knot Floer homology of satellite $(1, 1)$ knots.

Phan, Jeffrey, Order properties of monomial ideals and their free resolutions.

Zuehlke, John, Some Diophantine equations with complex exponents.

STATISTICS

Kardaras, Konstantinos, The numeraire portfolio and arbitrage in semimartingale models of financial markets.

Kerman, Jouni, An integrated framework for Bayesian graphical modeling, inference, and prediction.

Liang, Yu, Joint modeling and analysis of longitudinal observations and observation times.

Pal, Soumik, On capital requirements and optimal strategies to achieve acceptability.

Shnaidman, Michael, New approaches to modelling and analyzing recurrent event time data.

Xu, Jinfeng, Parameter estimation, model selection and inferences in $L1$-based linear regression.

Young, Fanesca, Discriminating between common risk factors and a causal relationship in familial co-aggregation studies.

Zhang, Daqing, Marginal quantile methods for censored multiple event times.

Zhang, Xi, Estimating the mixing proportion in a semi-parametric mixture model from censored time-to-event data.

Cornell University (25)

CENTER FOR APPLIED MATHEMATICS

Blais, Marcel, Liquidity and modelling the stochastic supply curve for a stock price.

Boyle, Katharyn, Risk minimization hedging methods using options.

Carey, Varis, A posteriori error estimation for the finite element method via local averaging.

Franco, Maria Mercedes, Existence and regularity of minimizers for a one-dimensional elasticity problem without convexity.

Goel, Sharad, Estimating mixing times: Techniques and applications.

Martin, Carla, Higher-order Kronecker properties and tensor decompositions.

Rodriguez, Jesus, Forward models and options in electricity markets.

Small, Tara, Modeling tradeoffs in intermittent connectivity networks.

MATHEMATICS

Belk, Maria, Applications of stress theory: Realizing graphs and Kneser-Poulsen.

Berestycki, Nathanaël, Phase transitions for the distance of random walks and applications to genome rearrangement.

Gibson, Lee, The number of sites visited by a random walk on an infinite graph.

Haiduc, Radu, Horseshoes in the forced van der Pol equation.

Hamblen, Spencer, Lifting n-dimensional Galois representations.

Hardin, Christopher, The Horn theory of relational Kleene algebra.

Kemp, Todd, Hypercontractivity in noncommutative holomorphic spaces.

Mermin, Jeffrey, Lexicographic ideals.

Montalban, Antonio, Beyond the arithmetic.

Morris, Steve, Four- and six-dimensional nilmanifolds and symplectic forms.

Roeder, Roland, Topology for the basins of attraction of Newton's method in two complex variables.

Sayit, Hasanjan, Realistic no arbitrage conditions.

Slavnov, Serguei, Semantic investigations of linear logic.

Thacker, John, Property of Brownian and random walk loop soups.

Trujillo Ferreras, José Antonio, The random walk loop soup and the expected area of the Brownian loop in the plane.

Woodroofe, Russ, Shelling the coset poset.

Zeng, Yan, Compensator of stopping time and its application to finance.

Courant Institute, New York University (11)

MATHEMATICS

Azer, Karim, A one-dimensional model of blood flow in arteries with friction, convection and unsteady Taylor diffusion based on the Womersley velocity principle.

Griffith, Boyce, Simulating the blood-muscle-valve mechanics of the heart by an adaptive and parallel version of the immersed boundary method.

Isaacson, Samuel, Stochastic reaction-diffusion methods for modeling gene expression and spatially distributed chemical kinetics.

Lisi, Samuel, Applications of symplectic geometry to Hamiltonian systems.

Liu, Kai Ju, A trainable graph combination scheme for belief propagation.

Neylon, Tyler, Sparse solutions for linear prediction problems.

Raj, Arjun, Stochastic processes in cell biology.

Schaffrin, Helga, An optimization approach to sea ice dynamics.

Tu, Xuemin, BDDC domain decomposition algorithms: Methods with three levels and for flow in porous media.

Vladimirski, Boris, Modeling and analysis of spontaneous electrical episodic activity in the developing nervous system by means of a heterogeneous excitatory network of spiking neurons with slow synaptic depression and reduced mean-field models.

Walker, Ryan, A two-dimensional coupled model for ice shelf-ocean interaction.

Rensselaer Polytechnic Institute (11)

MATHEMATICAL SCIENCES

Banks, Jeffrey, A high resolution Godurov method for high-speed mutli-material flows.

Castronovo, Emilio, A comparative study of Lagrangian stochastic models for oceanic transport.

Dediu, Sava, Recovering inhomogeneities in a waveguide using eigensystem decomposition.

Farwell, Kristin, Gomory cutting planes using exact arithmetic.

Glackin, James, Solving bi-level linear programs using multiple objective linear programming.

Koch, Gretchen, Simulating the min system in Escherichia coli: Two models of oscillating polymer chains.

Maserumule, Rebecca, On the linear stability analysis of the wetting front in the Vandose zone.

Pokorni, Boris, On the dynamics and intermittancy in the numerical model of gravity surface water waves.

Roe-Dale, Rachel, Quantitative models in cancer chemotherapy.

Xiang, Zhi, Multiple-response latent analysis (MLA).

Xie, Gang, Smoothness analysis of subdivisions in nonlinear and geometrical settings.

State University of New York, Albany (1)

MATHEMATICS AND STATISTICS

McCollum, Joseph, Random walks on the dihedral group and abelian groups.

State University of New York, Binghamton (4)

MATHEMATICS AND SCIENCE

Florez, Rigoberto, Four studies in the geometry of biased graphs.

Kong, Fanhui, Asymptotic properties of Buckley-James estimator.

Salazar-Diaz, Olga, Thompson's group V from a dynamical viewpoint.

Wang, Yishi, Some new tests for normality.

State University of New York, Buffalo (2)

MATHEMATICS

Cheon, Younhwan, Some enumeration problems for cryptographic Boolean functions.

Mohammed-Awel, Jemal Said, Deterministic and stochastic models of development of resistance to genetically modified pesticidal crops.

State University of New York, Stony Brook (32)

APPLIED MATHEMATICS AND STATISTICS

Ahn, Kwangmi, Quantifying the percent increase in minimum sample size of linear trend tests resulting from SNP genotyping errors in genetic association studies.

Baek, Inyoung, Optimal designs for potential missing trials in multiple-objective dose response studies.

Chung, Sohae, Bone image analysis: Quantifying topological change in bone under uniform erosion.

Duan, Tao, A power study of a two sample likelihood ratio test in the presence of mixtures.

Dutta, Srabasti, Supernovae and hydrodynamic instabilities.

Fan-Orzechowski, Xiaofei, Applications of Lovász's theta and Lagrangian functions to certain deterministic and stochastic optimization problems.

Genethliou, Dora, Statistical approaches to electric load forecasting.

Han, Guowen, Analysis of multiscale molecular dynamics algorithms for simulating biomolecules.

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Syracuse University (2)

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University of Rochester (2)

MATHEMATICS

Chen, Rui, Heat equation with white or fractional noise potentials.

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NORTH CAROLINA

Duke University (10)

INSTITUTE OF STATISTICS AND DECISION SCIENCE

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University of North Carolina at Charlotte (2)

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OHIO

Air Force Institute of Technology (2)

MATHEMATICS AND STATISTICS

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Bowling Green State University (6)

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Case Western Reserve University (1)

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Ohio State University, Columbus (27)

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Ohio University, Athens (1)

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University of Cincinnati (1)

MATHEMATICAL SCIENCES

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University of Toledo (4)

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OKLAHOMA

Oklahoma State University, Stillwater (1)

MATHEMATICS

Zhu, Xinyun, Finite representations of a quiver arising from string theory.

University of Oklahoma (2)

MATHEMATICS

Stone, Andrea, A psychometric analysis of the statistics concept inventory.

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OREGON

Oregon State University (3)

STATISTICS

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Monleon, Vicente, Regression calibration and maximum likelihood inference for measurement error.

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University of Oregon (5)

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Amende, Bonnie, G-irreducible subgroups of type A.

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PENNSYLVANIA

Bryn Mawr College (2)

MATHEMATICS

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Jordan, Jill, Generating family invariants for Legendrian links of unknots.

Carnegie Mellon University (16)

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Hilden, Sean, Allocation of risk capital via intra-firm trading.

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Lehigh University (4)

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Pennsylvania State University, University Park (16)

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Emelianenko, Maria, Multilevel and adaptive methods for some non-linear optimization problems.

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Luu, Viet-Trung, A large-scale approach to K-homology.

Matsnev, Dmitry, The Baum-Connes conjecture and group actions on affine buildings.

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Tyurina, Yulia, Skew embeddings and immersions of manifolds into Euclidean spaces in codimension two.

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Wang, Xiaoqiang, Phase field models and simulations of vesicle bio-membranes.

Temple University (7)

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University of Pennsylvania (8)

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University of Pittsburgh (5)

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Kim, Jeongeun, Parameter estimation in stochastic volatility models with missing data using particle methods and the EM algorithm.

Ren, Lulu, Parameter estimation for latent mixture models with applications to psychiatry.

RHODE ISLAND

Brown University (20)

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Chou, Ching-Shan, High order residual distribution conservative finite difference WENO schemes for steady state problems on non-smooth meshes.

Costanzino, Nicola, Existence and stability of nonlinear wave structures in one and several space dimensions.

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Hoffman, Aaron, Crystallographic pinning for traveling waves in lattice differential equations: Generic properties and higher codimensional phenomena.

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Kanevsky, Alex, High order implicit-explicit Runge-Kutta time-integration methods and applications and time-consistent filtering in spectral methods.

Lurati, Laura, Topics in spectral methods: Coping with uncertainty and the Gibbs phenomenon.

Madiman, Mokshay, Topics in information theory, probability and statistics.

Redd, Thomas, Measures of ergodicity, mixing, and transport in 2D maps and flows.

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Ha Quang, Minh, Reproducing kernel Hilbert spaces in learning theory.

Hur, Mikyoung Vera, Steady water waves with vorticity.

Jiang, Yongbin, Weil-étale topologies over local rings.

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University of Rhode Island (1)

MATHEMATICS

Quinn, Eugene, On the boundedness character of third-order rational difference equations.

SOUTH CAROLINA

Clemson University (5)

MATHEMATICAL SCIENCES

Lin, Wei, Statistical inference for single-index models.

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Medical University of South Carolina (3)

BIOSTATISTICS, BIOINFORMATICS, AND EPIDEMIOLOGY

Chen, Yian, Optimal DNA microarray design.

Jenkins, Ruth, Internet access of electronic medical record research data.

Travis, Penny, Drinking water source, sewage disposal, and risk of Helleobacter pylori in US/Mexico border children.

University of South Carolina (4)

MATHEMATICS

Ding, Yabin, Multiscale ELLAM methods for transient advection-diffusion equations with highly oscillatory coefficients.

Jin, Xiaohua (Teresa), Real number graph labelings with distance conditions.

Wang, Hua, Subtrees of trees, Wiener index and related problems.

Wu, Jianfeng, Connecting relation algebras to forcing.

TENNESSEE

University of Memphis (5)

MATHEMATICAL SCIENCES

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Liu, Henry, Recent extremal problems in combinatorics.

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University of Tennessee, Knoxville (4)

MATHEMATICS

Cathey, Matthew, Packings of conformal preimages of circles.

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Mirani, Mozhgan, Classical trees and ultrametric spaces.

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TEXAS

Baylor University (5)

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Feng, Amy, Bayesian evaluation of surrogate endpoints.

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Dussaud, Eric, Velocity analysis in the presence of uncertainty.

Hartsfield, Jane, A quantitative study of neuronal calcium signaling.

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Southern Methodist University (2)

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Texas A&M University (22)

MATHEMATICS

Copeland, Dylan, Negative-norm least-squares methods for axisymmetric Maxwell equations.

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Henderson, Troy, Causal equivalence of frames.

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McDonald, Terry, Piecewise polynomial functions on a planar region: Boundary constraints and polyhedral subdivisions.

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Hintze, Christopher, Modeling correlation in binary count data with application to fragile site identification.

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Munoz Maldonado, Yolanda, Mixed models, posterior means and penalized least squares.

Qian, Yi, Topics in multiple hypotheses testing.

Ren, Haobo, Functional inverse regression and reproducing kernel Hilbert space.

Schumann, Keith, Resampling confidence regions and test procedures for second degree stochastic efficiency with respect to a function.

Shin, Hyejin, Infinite dimensional discrimination and classification.

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Bandulasiri, Ananda, Statistical shape analysis in medical imaging.

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Chen, Baili, Mathematical models of motion detection in the fly's visual cortex.

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Holsapple, Raymond, Computational issues in autonomous control of unmanned air vehicles.

Hume, Casey, A sharp bound for the fourth coefficient for bounded convex functions.

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McCormack, Robert, Multi-host and multipatch mathematical epidemic models for disease emergence with applications to hantavirus in wild rodents.

Navaratna, Menaka, Statistics of random eigenvalues of large dynamical systems in biology and engineering.

Palamakumbura, Rathnamali, Control of solutions in MEMs actuator arrays.

Sugathadasa, Manjula, Affine and projective shape analysis with application.

University of Houston (7)

MATHEMATICS

Hay, Damon, Noncommutative topology and peak interpolation for operator algebras.

Leite, Maria, Homogeneous three-cell networks.

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Myers, Richard, Numerically consistent approximations for optimal control problems applied to stiff chemical systems.

Pacull, Francois, A numerical study of the immersed boundary method.

Pati, Arati, Numerical simulation of incompressible viscous flow with moving boundaries.

Svyatskiy, Daniil, Discretization methods and iterative solvers for diffusion equation on unstructured polyhedral meshes.

University of North Texas (4)

MATHEMATICS

Al-Haddad, Shemsi, Generic algebras and Kazhdan-Lusztig theory for monomial groups.

Bryant, Ross, A computation of partial isomorphism on ordinal structures.

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University of Texas, Arlington (4)

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INSTITUTE FOR COMPUTER ENGINEERING AND SCIENCE

Branets, Larisa, A variational grid optimization method based on a local cell quality metric.

Eslinger, Owen, Discontinuous Galerkin finite element methods applied to two-phase, air-water flow problems.

Kolos, Sergey, Risk management in energy markets.

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Kaplan, Jennifer, Factors in statistics learning: Developing a dispositional attribution model to describe the development of statistical proficiency.

Lalin, Matilde, Some relations of Mahler measure with hyperbolic volumes and special values of L-functions.

Macasieb, Melissa, Derived arithmetic Fuchsian groups of genus two.

Masri, Riad, Some applications of classical modular forms to number theory.

McKinnie, Kelly, Non-cyclic and indecomposable p-algebras.

McReynolds, David Ben, Cusps of arithmetic orbifolds.

Nolen, James, Reaction-diffusion fronts in inhomogeneous media.

University of Texas, Dallas (4)

MATHEMATICAL SCIENCES

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Lasater, Lena, Inverse problems of electromagnetic obstacle scattering and the method of lines.

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Zhou, Weihua, Generalized spatial U-quantiles: Theory and applications.

UTAH

Brigham Young University (1)

MATHEMATICS

Woodruff, Benjamin, Statistical properties of Thompson's group and random pseudo manifolds.

University of Utah (4)

MATHEMATICS

Caspers, Renate, Asymptotic theory for GARCH-M processes.

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Clay, Matthew, Deformation spaces of G-trees.

Shimomoto, Kazuma, Frobenius map in mixed characteristic.

VIRGINIA

Old Dominion University (2)

MATHEMATICS AND STATISTICS

Huabsomboon, Pallop, Implicit level set method for firespread model.

Samyono, Widodo, Hessian matrix-free Lagrange-Newton-Krylov-Schur-Schwarz methods for elliptic inverse problems.

University of Virginia (5)

MATHEMATICS

Higginbottom, Ryan, The nilpotent filtration in group cohomology.

Kent, Deborah, Benjamin Peirce and the promotion of research-level mathematics in America: 1830–1880.

Martini, Laura, Political and mathematical unification: Algebraic research in Italy, 1850–1914.

Valenti, Erin, On an infinite elastica: Local well-posedness of the initial value problem and stability of solitary waves.

Yang, Jack, A new approach to the modeling of correlation credit derivatives.

Virginia Polytechnic Institute and State University (3)

MATHEMATICS

Conrad, Emery, Bifurcation analysis and qualitative optimization of models of biochemical regulatory networks with applications to circadian rhythms.

Potter, Dustin, A combinatorial approach to scientific exploration of gene expression data: An integrative method using formal concept analysis for the comparative analysis of microarray data.

Stigler, Brandylin, An algebraic approach to reverse engineering with an application to biochemical networks.

WASHINGTON

University of Washington (21)

Applied Mathematics

Gkioulekas, Elef, The Nastrom-Gage energy spectrum of the atmosphere, proposed theoretical explanations and the double cascade theory.

Heuett, Willie, New methods for modeling large-scale biochemical networks.

Meza, Rafael, Some extensions and applications of multistage carcinogenesis models.

Reluga, Timothy, Some results on temporal and spatial heterogeneity in theoretical ecology.

Biostatistics

Janes, Holly, Adjusting for covariate effects in biomarker studies using the subject-specific threshold ROC curve.

Qin, Li-Xuan, The clustering of regression models method with applications in gene expression data.

Shepherd, Bryan, Causal inference in HIV vaccine trials: Comparing outcomes in a subset chosen after randomization.

Mathematics

Couperus, Peter, Combinatorial problems on abelian Cayley graphs.

Frigyik, Bela, Injectivity and stability of generalized X-ray transforms on curves.

Helliwell, Dylan, Boundary regularity for conformally compact Einstein metrics in even dimension.

Lind, Joan, The geometry of Loewner evolution.

Littig, Peter, Schubert varieties and the homology ring of the loop space of a compact Lie group.

O'Shea, Edwin, Toric algebra and the weak perfect graph theorem.

White, David, Processes with inert drift.

Statistics

Bailer, Heiko, Robust estimation of factor models in finance.

Basu, Saonli, Allele-sharing methods for linkage detection using extended pedigrees.

Chaudhuri, Sanjay, Using the structure of d-connecting paths as a qualitative measure of the strength of dependence.

Jager, Leah, Goodness-of-fit statistics based on phi-divergences.

Maathuis, Marloes, Nonparametric estimation for current status data with competing risks.

Scheet, Paul, An efficient and flexible model for patterns of population genetic variation.

Stewart, William, Alternative models for estimating genetic maps from pedigree data.

Washington State University (4)

Mathematics

Alvarado, Francisco, A nonlinear stability analysis of rhombic optical pattern formation in an atomic sodium vapor ring cavity.

Griffin, Kent, Solving the principle minor assignment problem and related computations.

Loveless, Andrew, Extensions in the theory of Lucas and Lehmer pseudoprimes.

Zhou, Huajun, Multivariate compound point processes with drifts.

WEST VIRGINIA

West Virginia University (5)

Mathematics

Millán Millán, Andrés, Applications of the covering property axiom.

Ou, Yongbin, Maximum size t-cross-intersecting families with degree conditions.

Shao, Yehong, Claw-free graphs and line graphs.

Simon Romero, Likin, Hyperspace graph of connected subgraphs.

Xue, Fei, Asymptotic solutions of almost diagonal differential and difference equations.

WISCONSIN

Marquette University (1)

Mathematics, Statistics and Computer Science

Kirova Yordanova, Roumyana, Markov chain decomposition and characterization of hypertensive blood pressure with application to linkage analysis.

Medical College of Wisconsin (2)

Biostatistics

Lu, Leiyan, Explained variation in survival analysis and hypothesis testing for current leukemia-free survival.

Zhang, Xu, Inference for cumulative incidence function with right censored and/or left truncated competing risks data.

University of Wisconsin, Madison (15)

Mathematics

Bisgard, James, Momoclinic and heteroclinic orbits for Hamiltonian systems.

Carracino, Christine, Estimates for the Szego kernel on a non-pseudoconvex domain.

Charalambides, Marios, Stable spectral methods with no spurious eigenvalues.

Davis, Joshua, Degenerate relative Gromov-Witten invariants and symplectic sums.

Dwyer, Chris, Twisted equivariant K-theory for proper actions of discrete groups.

Jenkins, Michael, Equivalences of holomorphic mappings in one and several complex variables.

Kent, Thomas, Decidability and definability in the σ_2^0-enumeration degrees.

McQuistan, Michael, Relativized character degree problems.

Ramsamooj, Neil, Gromov-Witten invariants of a $K3$ fibration.

Rushto, Joshua, Small-ball estimates and accompanying LIL for alpha-stable and related processes.

Swisher, Holly, Asymptotics and congruence properties for Stanley's partition function, and a note on a theorem of Koike.

Temple, Kathryn, Particle representations for measure-valued processes with interactions and exit measures.

Weinberg, Aaron, A framework for analyzing objects in mathematical discourse.

Wiesner, Emilie, Translation functors and the Shapovalov determinant.

Vega, Ramiro de la, Homogeneity properties on compact spaces.

WYOMING

University of Wyoming (2)

Mathematics

Fleming, Patrick, Projective planes and related topics.

Kim, In-Jae, Spectral properties of combinatorial classes of matrices.

AMERICAN MATHEMATICAL SOCIETY

From the AMS Public Awareness Office...

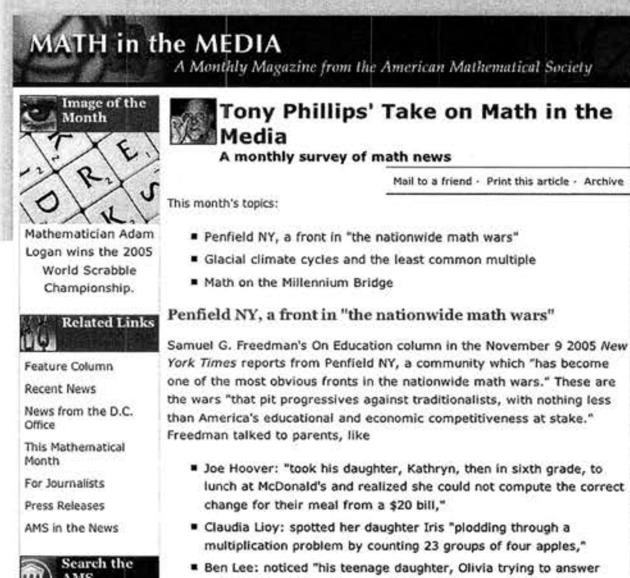
MATH in the MEDIA
www.ams.org/mathmedia

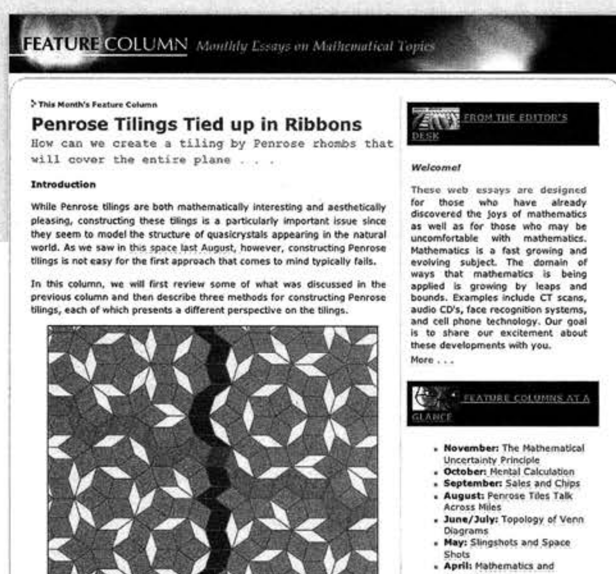
FEATURE COLUMN
www.ams.org/featurecolumn

Math in the Media and the **Feature Column** offer easy access to a wealth of information about current mathematics and its applications.

Math in the Media is a great way to keep abreast of math news as reported in newspapers and general science magazines. The collection—*Tony Phillips' Take on Math in the Media, Math Digest,* and *Reviews* of books, plays, and films with mathematical themes—is a centralized repository of articles in the media about mathematics.

The Feature Column is a series of essays on various mathematical topics—such as voting, Penrose tiles, cosmology, and networks—written by David Austin, Bill Casselman, Joe Malkevitch, and Tony Phillips.





2006 Election Results

In the elections of 2006 the Society elected a vice president, a trustee, five members at large of the Council, three members of the Nominating Committee, and two members of the Editorial Boards Committee. Terms for these positions are three years beginning on 1 February 2007 and ending on 31 January 2010, except for the trustee, whose term is for five years ending on 31 January 2012. Members elected to the Nominating Committee begin serving immediately, and their terms end on 31 December 2009. The Society also voted on a proposal to initiate an AMS Fellows Program.

Vice President

Elected as the new vice president is **Robert L. Bryant** from Duke University.

Trustee

Reelected as trustee is **Carol Saunders Wood** from Wesleyan University.

Members at Large of the Council

Elected as new members at large of the Council are

Robert L. Devaney from Boston University

Frank S. Quinn from Virginia Polytech Institute and State University

Marjorie Senechal from Smith College

Katherine St. John from Lehman College and the Graduate Center, City University of New York

Francis Edward Su from Harvey Mudd College

Nominating Committee

Elected as new members of the Nominating Committee are

Thomas C. Hales from the University of Pittsburgh

Roger Howe from Yale University

Hema Srinivasan from the University of Missouri

Editorial Boards Committee

Elected as new members of the Editorial Boards Committee are

Eric Bedford from Indiana University at Bloomington

Irena Swanson from Reed College

Proposal for an AMS Fellows Program

The proposal to initiate an AMS Fellows Program was not approved.

2007 AMS Election

Nominations by Petition

Vice President or Member at Large

One position of vice president and member of the Council *ex officio* for a term of three years is to be filled in the election of 2007. The Council intends to nominate at least two candidates, among whom may be candidates nominated by petition as described in the rules and procedures.

Five positions of member at large of the Council for a term of three years are to be filled in the same election. The Council intends to nominate at least ten candidates, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

Petitions are presented to the Council, which, according to Section 2 of Article VII of the bylaws, makes the nominations. The Council of 23 January 1979 stated the intent of the Council of nominating all persons on whose behalf there were valid petitions.

Prior to presentation to the Council, petitions in support of a candidate for the position of vice president or of member at large of the Council must have at least fifty valid signatures and must conform to several rules and operational considerations, which are described below.

Editorial Boards Committee

Two places on the Editorial Boards Committee will be filled by election. There will be four continuing members of the Editorial Boards Committee.

The President will name at least four candidates for these two places, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

The candidate's assent and petitions bearing at least 100 valid signatures are required for a name to be placed on the ballot. In addition, several other rules and operational considerations, described below, should be followed.

Nominating Committee

Three places on the Nominating Committee will be filled by election. There will be six continuing members of the Nominating Committee.

The President will name at least six candidates for these three places, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

The candidate's assent and petitions bearing at least 100 valid signatures are required for a name to be placed on the ballot. In addition, several other rules and operational considerations, described below, should be followed.

Rules and Procedures

Use separate copies of the form for each candidate for vice president, member at large, or member of the Nominating and Editorial Boards Committees.

1. To be considered, petitions must be addressed to Robert J. Daverman, Secretary, American Mathematical Society, 312 D Ayres Hall, University of Tennessee, Knoxville, TN 37996-1330 USA, and must arrive by 25 February 2006.
2. The name of the candidate must be given as it appears in the *Combined Membership List* (`www.ams.org/cml`). If the name does not appear in the list, as in the case of a new member or by error, it must be as it appears in the mailing lists, for example on the mailing label of the *Notices*. If the name does not identify the candidate uniquely, append the member code, which may be obtained from the candidate's mailing label or by the candidate contacting the AMS headquarters in Providence (amsmem@ams.org).
3. The petition for a single candidate may consist of several sheets each bearing the statement of the petition, including the name of the position, and signatures. The name of the candidate must be exactly the same on all sheets.
4. On the next page is a sample form for petitions. Petitioners may make and use photocopies or reasonable facsimiles.
5. A signature is valid when it is clearly that of the member whose name and address is given in the left-hand column.
6. The signature may be in the style chosen by the signer. However, the printed name and address will be checked against the *Combined Membership List* and the mailing lists. No attempt will be made to match variants of names with the form of name in the *CML*. A name neither in the *CML* nor on the mailing lists is not that of a member. (Example: The name Robert J. Daverman is that of a member. The name R. Daverman appears not to be.)
7. When a petition meeting these various requirements appears, the secretary will ask the candidate to indicate willingness to be included on the ballot. Petitioners can facilitate the procedure by accompanying the petitions with a signed statement from the candidate giving consent.

Nomination Petition for 2007 Election

The undersigned members of the American Mathematical Society propose the name of

____

as a candidate for the position of (check one):

- ☐ **Vice President**
- ☐ **Member at Large of the Council**
- ☐ **Member of the Nominating Committee**
- ☐ **Member of the Editorial Boards Committee**

of the American Mathematical Society for a term beginning 1 February, 2008

Return petitions by 26 February 2007 to:
Secretary, AMS, 312 D Ayres Hall, University of Tennessee, Knoxville, TN 37996-1330 USA

Name and address (printed or typed)	
	Signature
	Signature
	Signature
	Signature
	Signature
	Signature

Mathematics Calendar

The most comprehensive and up-to-date Mathematics Calendar information is available on the AMS website at `http://www.ams.org/mathcal/`.

February 2007

* 5–7 **KNAW Academy Colloquium "New Perspectives on Games and Interaction"**, Royal Netherlands Academy of Arts and Sciences, Amsterdam, The Netherlands.

Aims and Scope: The purpose of this colloquium is to encourage incipient interactions between the various disciplines thinking about games and interaction, and clarify their common concerns and potential for fruitful collaboration. The colloquium will focus on Information flow and reasoning in interaction; Complexity and computation of interaction; Evolution of stability through interaction; and consist of fifteen invited talks by international speakers that cover various aspects of games in logic, computer science, economics, and linguistics. Each talk will be followed by a commentary and discussion.

Invited speakers: Samson Abramsky (Oxford), Wiebe van der Hoek (Liverpool), Alexandru Baltag (Oxford)), Hans van Ditmarsch (Otago), Giacomo Bonanno (Davis CA), Jan van Eijck (Amsterdam/Utrecht), Adam Brandenburger (New York NY), Eric Pacuit (Amsterdam), Erich Grädel (Aachen), Jouko Väänänen (Amsterdam), Wilfrid Hodges (London), Francien Dechesne (Eindhoven), Natalia Komarova (Irvine CA), Jelle Zuidema (Amsterdam), Daniel Lehmann (Jerusalem), Ulle Endriss (Amsterdam), Ariel Rubinstein (Tel Aviv), Boudewijn de Bruin (Groningen), Dov Samet (Tel Aviv), Rineke Verbrugge (Groningen), Gabriel Sandu (Paris), Paul Dekker (Amsterdam), Brian Skyrms (Irvine CA), Gerhard Jäger (Bielefeld), Stef Tijs (Tilburg), Arantza Estevez Fernandez (Amsterdam), William Wadge (Victoria BC), Peter van Emde Boas (Amsterdam), Igor Walukiewicz (Bordeaux), Yde Venema (Amsterdam).

Information: email: `voorlichting@bureau.knaw.nl`; or `http://www.illc.uva.nl/KNAW-AC/`.

* 6–10 **28th Linz Seminar on Fuzzy Set Theory**, Bildungszentrum St. Magdalena, Linz, Austria.

Description: LINZ 2007 will be devoted to the mathematical aspects of "Fuzzy Sets, Probability and Statistics, Gaps and Bridges". The last ten years have witnessed a significant development of theoretical aspects of imprecise probabilities, as well as non-Bayesian approaches for uncertainty modelling, risk analysis and decision. These developments have created bridges between probability, fuzzy sets, and possibility theory.

Aim: The aim of this meeting is to discuss the synergy between these fields, as well as to lay bare important open questions.

Information: `http://www.flll.uni-linz.ac.at/research/linz2007/index.html`.

* 19–23 **School: Statistical Mechanics and Combinatorics**, Far Hills Inn and Centre de Recherches Mathématiques, Montréal, Québec, Canada.

Description: Workshop: *Combinatorial Problems Raised by Statistical Mechanics.* This workshop will include expository talks as well as presentations on current research on combinatorial problems raised by statistical mechanics. Topics of interest include: enumerative problems related to the classical models of statistical mechanics, algebraic methods related to functional equations, Mayer's theory and graph weights, Potts model on graphs, planar maps and 2-dimensional quantum gravity, Feynman diagrams, etc.

Goal: The goal of this mini-course is to introduce the basic methods of enumerative combinatorics and the concepts of Statistical Mechanics. The topics presented will include generating functions, combinatorial species, functional equations, asymptotics, classical models of statistical mechanics (polyominoes and animals, self-avoiding walks, gas models, Ising and Potts models, polymers and

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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 held in North America 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. Meetings held outside the North American area may carry more detailed information. In any case, 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/`.

percolation), thermodynamic limits, phase transitions and Tutte polynomials. The school is intended for graduate students, postdocs and researchers wishing to be introduced to these questions.
Information: email: paradis@crm.umontreal.ca.

March 2007

* 5–9 **School: Combinatorics on Words & Workshop on Recent Progress in Combinatorics on Words**, Centre de recherches mathématiques, Montréal, Québec, Canada.
Goal: The goal of this mini-course will be to introduce the basic methods of combinatorics on words. The topics will cover finite and infinite words, Sturmian words, patterns, codes, noncommutative series and polynomials. Lectures will be given by leading researchers in the field: tentatively Jean Berstel, Aldo de Luca, Christophe Reutenauer, and Bruce Sagan. This school is followed by the workshop on Recent Progress in Combinatorics on Words.
Information: email: paradis@crm.umontreal.ca; http://www.crm.umontreal.ca/Words_School07/index_e.shtml.

* 12–16 **Workshop on Recent Progress in Combinatorics on Words**, Centre de recherches mathématiques, Montréal, Québec, Canada.
Description: This workshop will include expository talks as well as presentations on current research highlighting the flow of ideas between combinatorics on words and several other fields of mathematics and theoretical computer science. In particular, we want to stress combinatorial, algebraic and algorithmic aspects, while underlying the manifold interactions with other fields, and particularly Number Theory, Theoretical Computer Science and Algebra.
Information: email: paradis@crm.umontreal.ca; http://www.crm.umontreal.ca/Words07/index_e.shtml.

* 19–23 **Motives and Algebraic Cycles, A Conference Dedicated to the Mathematical Heritage of Spencer J. Bloch**, Fields Institute, Toronto, Canada.
Information: http://www.fields.utoronto.ca/programs/scientific/06-07/homotopy/motives/.

* 22–23 **DIMACS Workshop on Auctions with Transaction Costs**, DIMACS Center, CoRE Bldg, Rutgers University, Piscataway, New Jersey.
Description: Auction theory has been an exciting area of research this past ten years because of the many complications that arise from asymmetric information and the way different auction rules aggregate that information. Auction theories dealing with transaction costs are now being developed, however, and this conference will bring together researchers working on them.
Organizers: Eric Rasmusen, Indiana University, erasmuse@indiana.edu; Michael Rothkopf, Rutgers University, rothkopf@rutcor.rutgers.edu; Tuomas Sandholm, Carnegie Mellon University, sandholm+@cs.cmu.edu.
Local Arrangements: Workshop Coordinator, DIMACS Center, workshop@dimacs.rutgers.edu, 732-445-5928.
Information: See http://dimacs.rutgers.edu/Workshops/Auctions/.

* 26–28 **Perspectives on Mathematical Practices 2007**, Vrije Universiteit Brussel, Brussels, Belgium.
Plenary speakers: David Corfield (Tübingen, Germany), José Ferreirós (Seville, Spain), Jens Høyrup (Roskilde, Denmark), Brendan Larvor (Hertfordshire, UK), Paolo Mancosu (Berkeley CA, US), Gianluigi Oliveri (Palermo, Italy), Yehuda Rav (Paris, France).
Contact: Perspectives on Mathematical Practices Conference, c/o Bart Van Kerkhove, Vrije Universiteit Brussel-CLWF, Pleinlaan 2, B-1050 Brussels, Belgium; clwf@vub.ac.be.

* 26–30 **Homotopy theory of schemes (March-April)**, Fields Institute, Toronto, Canada.
Information: http://www.fields.utoronto.ca/programs/scientific/06-07/homotopy/index.html.

* 30–April 1 **Texas Algebraic Geometry Symposium**, University of Texas, Austin, Texas.
Speakers: T. Bridgeland, L. Ein, Y. Hu, D. Huybrechts, J. Koll'ar, R. Lazarsfeld.
Information: email: benzvi@math.utexas.edu.

April 2007

* 10–14 **The Geometric Langlands Correspondence**, Mathematical Institute, Oxford, England.
Lecturer: Lectures by David Ben-Zvi, University of Texas at Austin.
Information: See http://www.maths.ox.ac.uk/~szendroi/langlands.html.

* 16–17 **4th Montreal Scientific Computing Days**, Centre de Recherches Mathématiques, Montréal, Quebec, Canada.
Short Courses: Randall LeVeque, University of Washington, USA, Finite-Volume Methods and Software for Hyperbolic PDEs and Conservation Laws; and Christoph Schwab, ETH Zurich, Switzerland, Numerical Methods for Operator Equations in High Dimensions.
Objective: The program includes two short courses offered by international experts, as well as a contributed poster session. Basing their decision upon the submitted abstracts for the posters, the organizers will invite a limited number of contributing authors to give a 15 minute oral presentation. Prizes will be awarded for the best poster and oral presentation. Students and post-doctoral researchers are especially encouraged to participate. Some financial support is available for out-of-town participants.
Fee: There is no fee to attend; however, registration is mandatory. For information on registration, to submit an abstract or apply for financial aid, please visit this site: http://www.crm.umontreal.ca/Comp07/index.shtml.
Deadline: The deadline for abstract submissions and financial aid requests is February 28, 2007.

* 21–26 **The First IPM Conference on Algebraic Graph Theory (AGT 2007)**, School of Mathematics, Institute for Studies in Theoretical Physics and Mathematics, Tehran, Iran.
Description: The conference will provide researchers working in Graph Theory and Combinatorics an opportunity to present accounts of their current research, to identify challenges for the disciplines to undertake, and to suggest new approaches to explore; it will serve to establish connections between both individual researchers and between research areas, and so will also promote collaboration and new research.
Invited Speakers: Richard Brualdi (University of Wisconsin-Madison, USA), Andries Brouwer (Einhoven University of Technology, The Netherlands), Peter Cameron (Queen Mary, University of London, UK), Drago Cvetkovic (Mathematical Institute SANU, Serbia), Chris Godsil (University of Waterloo, Canada), Ivan Gutman (University of Kragujevac, Serbia), Willem Haemers (Tilburg University, The Netherlands), Steve Kirkland (University of Regina, Canada), László Lovász (University of Washington, USA), Bojan Mohar (Simon Fraser University, Canada), Peter Rowlinson (University of Stirling, Scotland).
Information: http://www.ipm.ac.ir/agt2007.

* 22–27 **Industry workshop & short course: The mathematics of electricity supply and pricing**, Holiday Inn, Surfers Paradise, Queensland, Australia.
Overview: This week long event will consist of a short course, invited lectures and contributed talks on the mathematics of electricity demand and pricing. The topics likely to be addressed will be: Generation modelling; Network modelling; Demand side response, Load forecasting; Power system stability; Optimal load flow; Market design; Derivative pricing; Pool market modelling; GHG reduction;

Risk management; Game theory and bidding; Credit risk; Risk-return and efficient frontiers; Liquidity risk implications; Transfer pricing; Network pricing; Risk margins; Forecasting; Portfolio risk management,

Program: The program for the workshop and short course is available at http://www.amsi.org.au/Electricity_program.php.

Deadline: Abstracts for contributed 25-minute talks should be submitted by email to esp07@amsi.org.au by January 22, 2007. Abstracts should be no more than 400 words, Helvetica 12-point font, preferably in .doc or .rtf format. If you use other formats, please send, in addition, a converted .pdf file.

Information: email: gkeen@unimelb.edu.au.

*25–27 **International Conference on Nonlinear Analysis and Optimization**, Isfahan, Iran.

Aim: The main aim of this conference is to gather researchers on nonlinear analysis and optimization, stimulate scientific information on nonlinear analysis and optimization, and to discuss recent advances in theoretical and applicable aspects of these areas.

Tentative list of Main Speakers: F. Flores-Bazan, http://www.ing-mat.udec.cl/~fflores/, F. Giannessi, http://www.dm.unipi.it/~ricop/giannessi.html, N. Hadjisavvas, http://www.syros.aegean.gr/users/nhad/, D. T. Luc, http://www.puf.edu.vn/index.php?option=com_content&task=view&id=45&Itemi, J. E. Martinez-Legaz, http://pareto.uab.es/jemartinez/, A. Maugeri, B. Mordukhovich, http://www.math.wayne.edu/~boris/, P. Pardalos, http://www.ise.ufl.edu/pardalos/, J. P. Penot, http://lma.univ-pau.fr/membres/index.php, T. Rapcsak, http://www.oplab.sztaki.hu/rapcsak/pub_en.htm, M. Thera, http://www.unilim.fr/pages_perso/michel.thera/, X. M. Yang, X. Q. Yang, http://myweb.polyu.edu.hk/~mayangxq/index.htm.

Information: http://www.sci.ui.ac.ir/math/New/conference/index.html.

*30–May 4 **School: Macdonald Polynomials & Workshop: Combinatorial Hopf Algebras and Macdonald Polynomials**, Centre de recherches mathématiques, Montréal, Québec, Canada.

Goal: The goal of this mini-course is to introduce the basic methods of Hopf algebras and their interactions with algebraic combinatorics. The topics presented will include: Combinatorial Hopf algebras, symmetric and quasisymmetric functions, Macdonald polynomials and ties with group representation theory. The school is intended for graduate students, postdocs and researchers wishing to be introduced to these questions.

Information: email: paradis@crm.umontreal.ca.

May 2007

*2–5 **Foundations of the Formal Sciences VI (FotFS VI): Reasoning about probabilities and probabilistic reasoning**, Universiteit van Amsterdam, Amsterdam, The Netherlands.

Invited Speakers: Luc Bovens (London), David Corfield (Tübingen), Branden Fitelson (Berkeley CA), Maria Carla Galavotti (Bologna), Anne-Sophie Godfroy-Genin (Paris), Peter Grünwald (Amsterdam), Joe Halpern (Ithaca NY), Barteld Kooi (Groningen), Teddy Seidenfeld (Pittsburgh PA).

Special progicnet session: Jan-Willem Romeijn (Amsterdam), Greg Wheeler (Lisboa), Jon Williamson (Canterbury).

Information: http://www.math.uni-bonn.de/people/fotfs/VI/.

*7–11 **Instructional conference solution methods for Diophantine equations**, Lorentz Center, Leiden, The Netherlands.

Aim: The instructional conference is meant for advanced master students, Ph.D.-students and young post docs up to 35 years. The aim of the conference is to give an introduction to the techniques which are used today in solving Diophantine equations, coming from Diophantine approximation (linear forms in logarithms, hypergeometric method), p-adic analysis (Chabauty's method), and modular functions and Galois representations (Wiles' method).

Speakers: Lectures will be given by Mike Bennett (UBC, Vancouver), Nils Bruin (SFU, Vancouver), Yann Bugeaud (Univ. Strasbourg), and Samir Siksek (Univ. Warwick).

Information: http://www.lc.leidenuniv.nl/lc/web/2007/231/info.php3?wsid=231.

*7–11 **Workshop: Combinatorial Hopf Algebras and Macdonald Polynomials**, Centre de recherches mathématiques, Montréal, Québec, Canada.

Goal: The goal of this workshop is to take stock of ongoing work and of the many rich problems that still need to be addressed in two area, naturally linked through the combinatorics behind the study of Macdonald polynomials.

Scientific organizers: M. Aguiar (Texas A&M), F. Bergeron (UQAM), N. Bergeron (York), M. Haiman (Berkeley), and S. van Willigenburg (UBC).

Information: email: paradis@crm.umontreal.ca.

*14–16 **Workshop solution methods for Diophantine equations**, Lorentz Center, Leiden, The Netherlands.

Aim: The purpose of the workshop is to discuss recent developments in techniques to solve Diophantine equations. We intend to bring together some experts in the field, who cover all presently existing techniques, coming from Diophantine approximation, p-adic analysis, and Wiles' techniques based on modular forms.

Organizers: Frits Beukers (Utrecht), Jan-Hendrik Evertse (Leiden), and Rob Tijdeman (Leiden).

Information: http://www.lc.leidenuniv.nl/lc/web/2007/230/info.php3?wsid=230.

*14–18 **Stacks in geometry and topology (May-June)**, Fields Institute, Toronto, Canada.

Information: http://www.fields.utoronto.ca/programs/scientific/06-07/homotopy/index.html.

*16–20 **Illinois Number Theory Fest**, University of Illinois at Urbana-Champaign, Illinois.

Main topics include (but not limited to): classical analytic number theory, combinatorial number theory, computational number theory, and Diophantine analysis.

Plenary Speakers (*tentative): George Andrews (Penn. St.), A.O.L. Atkin (UIC), Michael Bennett (UBC), Dan Bernstein (UIC), Ben Brubaker (MIT), Kathrin Bringmann (Wisconsin), Alina Cojocaru (UIC), Brian Conrey (AIM), Jean-Marc Deshouillers (Bordeaux), Peter Elliott (Colorado), Michael Filaseta (South Carolina), Kevin Ford (UIUC), John Friedlander (Toronto), Dan Goldston (San Jose St.), Andrew Granville (U. Montreal), Karl Mahlburg (MIT), Ram Murty (Queen's), Ken Ono (Wisconsin), Carl Pomerance* (Dartmouth), Peter Sarnak* (Princeton), Wolfgang Schmidt* (Colorado), Kannan Soundararajan (Stanford), Robert Vaughan (Penn. St.), Hugh Williams (Calgary), Ae Ja Yee (Penn. St.), Alexandru Zaharescu (UIUC).

Information: http://www.math.uiuc.edu/numbertheoryfest/

*20–26 **Braids and their ramifications**, Cortona, Italy.

Topics: Configuration Spaces, Arrangements, Mapping-Class Groups, 3-Manifolds.

Information: http://www.dm.unipi.it/~gaiffi/braidscortona/.

*21–June 1 **Algebraic Geometry and Algebraic Combinatorics**, Centre de Recherches Mathématiques, Montréal, Québec, Canada.

Description: Workshop: Interactions between Algebraic Combinatorics and Algebraic Geometry.

Organizers: François Bergeron (Université du Québec à Montréal), Sara Faridi (Dalhousie University), Anthony V. Geramita (Queen's University), Allen Knutson (University of California, Berkeley), Ravi Vakil (Stanford University).

Information: email: paradis@crm.umontreal.ca.

* 28-June 2 **Differential Equations, Theory of Functions, and Applications**, Novosibirsk State University, Novosibirsk, Russia.
Conference Topics: Differential Equations, Theory of Functions and Complex Analysis, Theory of Elasticity, Mathematical Modeling.
Information: For additional information visit the site of the Conference `http://math.nsc.ru/conference/invconf/vekua07/eng/`.

June 2007

* 2-9 **Symmetry and Perturbation Theory**, Otranto (Lecce), Italy.
Information: To subscribe to our mailing list just send an empty mail to `spt@sptspt.it` with subject: SUBSCRIBE; `http://www.sptspt.it/`.

* 8-13 **The Ninth International Conference on Geometry, Integrability and Quantization**, Sts. Constantine and Elena resort, Varna, Bulgaria.
Aim: The overall aim is to bring together experts in Classical and Modern Differential Geometry, Complex Analysis, Mathematical Physics and related fields to assess recent developments in these areas and to stimulate research in related topics. `http://www.math.uni-bonn.de/people/fotfs/VI/`.
Scientific Programme: Two Lecture Courses of 4-5 talks each will be delivered by: Andreas Arvanitoyeorgos, Geometrical Aspects of Lie Groups and Homogeneous Spaces; Sebastian Montiel, An Introduction to the Dirac Operator in Riemannian Geometry; plus a few plenary lectures and at least 30-minute talks by the rest of the participants.
Information: `http://www.bio21.bas.bg/conference/`.

* 10-12 **Special Congress on the occasion of the 300th anniversary of Leonhard Euler's birth**, St. Petersburg, Russia.
Description: The Congress will include the Euler Festival and a series of satellite conferences. The main event will comprise a celebration meeting on June 10th and several invited talks related to Euler's tremendous scientific activity. The list of invited speakers will be announced in the near future.
Preliminary List of Conferences: L. Euler and modern combinatorics (A. M. Vershik), Euler Equations and Related Topics (G. A. Seregin), Euler Festival, Arithmetic Geometry (S. V. Vostokov), A conference in Geometry (Yu. D. Burago), The 17th Summer St. Petersburg Conference in Analysis (N. K. Nikolski, S. V. Kislyakov), Modular forms and moduli spaces (V. A. Gritsenko).
Support: The Congress is supported by the Government of Russia and the local authorities of St. Petersburg.
Information: We ask our colleagues who are interested in attending the event to inform us about this. Preliminary registrations should be made at: `http://www.pdmi.ras.ru/EIMI/Euler300/form1.html` or by e-mail: `euler300@imi.ras.ru`.

* 11-22 **Workshop: Real, Tropical, and Complex Enumerative Geometry**, Centre de recherches mathématiques, Montréal, Québec, Canada.
Information: email: `paradis@crm.umontreal.ca`.

* 11-July 6 **Clay Mathematics Institute 2007 Summer School on "Homogeneous flows, moduli spaces, and arithmetic"**, Centro di Ricerca Matematica Ennio De Giorgi, Pisa, Italy.
Description: Designed for graduate students and mathematicians within five years of their Ph.D., the program is an introduction to the theory of flows on homogeneous spaces, moduli spaces and their many applications. The school will consist of three weeks of foundational courses and one week of mini-courses focusing on more advanced topics. The foundational courses will be: "Unipotent flows and applications" (Alex Eskin & Dmitry Kleinbock), "Diagonalizable actions and arithmetic applications" (Manfred Einsiedler & Elon Lindenstrauss) and "Interval exchange maps and translation surfaces" (Jean-Christophe Yoccoz). Shorter courses will be given by Svetlana Katok and Shahar Mozes. Advanced minicourses will be given by Nalini Anantharaman, Artur Avila, Hee Oh, Akshay Venkatesh and others.
Funding: Is available to graduate students and postdoctoral fellows who are within five years of receipt of their Ph.D. Standard support amounts will include funds for local expenses and accommodation plus economy travel.
Deadline: For application: February 28, 2007.
Information: For more information and an application form see `http://www.claymath.org/programs/summer_school/2007/` or contact `summerschool@claymath.org`; tel.: 617-995-2600.

* 15-24 **NEEDS 2007 (Nonlinear Evolution Equations and Dynamical Systems)**, L'Ametlla de Mar, Spain.
Description: An interdisciplinary character with emphasis on the following topics: Integrable and chaotic dynamical systems. Analytic, algebraic and geometric aspects of Integrable Systems. Mathematical methods in Quantum Mechanics: exact solutions, spectral problems.... Nonlinear phenomena and applications: waves, solitons, pattern formation....
Information: `http://www.needs-conferences.net/2007/`.

* 16-17 **NEEDS 2007 School**, L'Ametlla de Mar, Spain.
Description/Topics: This year, the workshop will be preceeded by a school with the following courses: "An introduction to pattern formation", Alastair Rucklidge (Leeds University); "Properties of low dimensional dynamical systems in the large", Carles Simó (Universitat de Barcelona); "The transition from regular to irregular motion as travel on Riemann surfaces", Paolo M. Santini (Università di Roma "La Sapienza"); "Synchronization and networks" Steven H. Strogatz (Cornell University). Participation in the school is open to all participants in the NEEDS 2007 Workshop.
Information:`http://www.needs-conferences.net/2007/school.php`.

* 17-23 **International Conference: Skorokhod Space. 50 Years On**, Institute of Mathematics of the National Academy of Sciences of Ukraine, Kyiv, Ukraine.
Topics: The method of a single probability space; topologies on the Skorokhod space; the Skorokhod refl ection problem; measures in infinite dimensional spaces; the Skorokhod embedding problem; extended stochastic integrals; Markov processes and stochastic differential equations; limit theorems.
Deadlines: Registration deadline: February 1, 2007. Abstract Submission deadline: March 1, 2007.
Information: `http://www.imath.kiev.ua/~skor_space/index.html`; email: `skor_space@imath.kiev.ua`.

* 17-23 **Trends in Harmonic Analysis**, Strobl, Salzburg, Austria.
Topics: Time-frequency analysis, wavelet theory, pseudodifferential operators, sparse representations and probabilistic methods, computational methods, applications in signal and image processing
Plenary talks: Emmanuel Candes (California Institute of Technology; to be confirmed), Pete Casazza (Univ. of Missouri), Albert Cohen (Univ. Paris VI), Vladimir Temlyakov (Univ. of South Carolina), Roman Vershynin (Univ. of California at Davis).
Information: Online registration form: `http://www.univie.ac.at/nuhag-php/strobl07/registration.php`. For questions concerning the online registration please contact `harald.schwab@univie.ac.at`.

* 18-23 **Computability in Europe 2007 (CiE 2007)**, Siena, Italy.
Invited Plenary Speakers: Tutorials: Pieter Adriaans (Amsterdam), Kobi Benenson (Harvard). Plenary lectures: Anne Condon (Vancouver), Stephen Cook (Toronto), Yuri Ershov (Novosibirsk), Wolfgang Maass (Graz), Sophie Laplante (Paris), Anil Nerode (Cornell), Roger Penrose (Oxford), Michael Rathjen (Leeds), Dana Scott (Carnegie Mellon), Robert I. Soare (Chicago), Philip Welch (Bristol).
Deadline for Submission of Papers: January 12, 2007.

Information: http://www.amsta.leeds.ac.uk/~pmt6sbc/cie07.html.

*18–29 **Hamiltonian Dynamical Systems and Applications Systèmes Dynamiques Hamiltoniens et Applications**, Université de Montréal, Montréal, Québec, Canada.
Aim: This summer school is aimed primarily at postdoctoral fellows, doctoral students, and junior faculty.
Speakers: Kam Theory: Eliasson, Hakan, Université de Paris VII, France; Yuan, Xiaoping, Fudan University, People Republic of China; Stolovich, Laurent, Université de Toulouse, France. Hamiltonian PDE and small divisors: Poeschel, Jurgen, Stuttgart, Germany; Bourgain, Jean, Institute for Advanced Study (Princeton), USA. Hamiltonian PDE and Nekhoroshev theory: Bambusi, Dario, Università di Milano, Italy. Variational methods in Hamiltonian dynamics: Rabinowitz, Paul, University of Wisconsin-Madison, USA; Berti, Massimiliano, SISSA/ISAS, Italy. Arnold diffusion: Cheng, C.-Q., Nanjing University, People's Republic of China; De la Llave, Rafael, University of Texas at Austin, USA. Hamiltonian dynamical systems: Treschev, Dimitry, Moscow State University, Russia. Applications to celestial mechanics: Chenciner, Alain, Observatoire de Paris/CNRS, France. Applications to control theory: Agrachev, Andrei, SISSA/ISAS, Italy. Applications to PDE: Wayne, C. Eugene, Boston University, USA. Applications to averaging methods and adiabatic invariants: Neistadt, Anatoly, Space Research Institute, Russia.
Support/Deadline: Financial support available. Application Deadline: February 28, 2007.
Information: http://www.dms.umontreal.ca/sms/index_e.shtml.

*19–22 **Computational Algebraic Geometry**, Oakland University, Rochester, Michigan.
Overview: As computational techniques progress it has become possible to attack many problems of classical algebraic geometry from the computational point of view. The goal of this session is to review such techniques and bring together researchers from this area.
Topics: Algebraic curves and their automorphisms, Hurwitz curves, Jacobians of algebraic curves, curves with split Jacobian, rational torsion points in the Jacobian etc., computational number theory, rational points on curves, field of moduli and field of definition of algebraic curves, covering of the Riemann sphere by a generic curve of genus g, solvable monodromy groups, interaction between computational group theory and algebraic curves, groups acting on surfaces, loci of curves with prescribed automorphism group, Hurwitz spaces, braid action, invariants of binary forms, computational invariant theory, algebraic curves and coding theory, other related topics.
Deadline: For submitting papers to be considered for publication: June 1, 2007.
Information: If you are planning to attend please contact us at shaska@oakland.edu with a title and abstract. We would like to accommodate as many good quality talks as possible.

*20–23 **International Conference "Trends and Challenges in Applied Mathematics" (ICTCAM 2007)**, Technical University of Civil Engineering, Bucharest, Romania.
Topics: Mathematical modelling; Analysis and numerical methods; Optimization, operational researches and statistics.
Deadlines: March 15, 2007. Preliminary Registration; April 15, 2007. Registration and Abstract submission; April 30, 2007. Acceptance of paper presentation.
Information: Emil Popescu, epopescu@utcb.ro; http://civile.utcb.ro/ictcam/.

*26–29 **ALM (Adults learning mathematics) 14th International Conference**, Limerick University, Limerick, Republic of Ireland.
Information: For further details of the 14th annual international conference for researchers and practitioners in the field of adults learning mathematics see the ALM website: http://www.alm-online.org/.

*26–29 **Nonlinear Modeling and Control, An International Seminar**, Nayanova University, Samara, Russia.
Purpose: The seminar's aim is the exchange of information about recent trends in mathematical modeling and control theory and their applications to various problems in physics, chemistry, biology, medicine, economy, and industrial concerns.
Call for Papers: Original papers related to the aim of the Seminar are solicited. Potential speakers should submit an abstract before April 30, 2007. The cover page should contain title, affilation, and e-mail address of each author. Electronic submissions in LATEX are encouraged.
Information and Submission: V. Sobolev, A. Pokrovskii. (Organizers, email: sable@ssu.samara.ru) or E. Shchetinina (Seminar Coordinator), email: schetinina_k@mail.ru, Nayanova University, Molodogvardeiskaya 196, Samara, 443001, Russia.
Languages: English and Russian.
Information and Submission: V. Sobolev, A. Pokrovskii (organizers, email: sable@ssu.samara.ru) or E. Shchetinina (seminar coordinator), email: schetinina_k@mail.ru; Nayanova University, Molodogvardeiskaya 196, Samara, 443001, Russia.

*29–July 1 **SIAM Conference on Control and Its Applications (CT07)**, Hyatt Regency San Francisco Airport, San Francisco, California.
Description: This conference will showcase a wide range of topics in control and systems theory. The topics and applications include real-time optimization and data assimilation, cellular and biological regulation, control techniques for financial mathematics, cooperative control for unmanned autonomous vehicles, biomedical control, risk sensitive control and filtering, control of smart systems, flow control and quantum control.
Deadlines: Minisymposium proposals: November 28, 2006. Abstracts for all contributed and minisymposium presentations: December 28, 2006.
Information: wilden@siam.org.

July 2007

*2–6 **19th International Conference on Formal Power Series and Algebraic Combinatorics**, Nankai University, Tianjin, China.
Topics: All aspects of combinatorics and their relations with other parts of mathematics, physics, computer science, and biology.
Invited Speakers: B. C. Berndt (Univ. of Illinois), P. Biane (Ecole Normale Supérieure, France), A. Buch (Rutgers Univ.), M. Crochemore (Univ. of Marne-la Vallée, France), E.-M. Feichtner (Univ. of Stuttgart, Germany), S. Fomin (Univ. of Michigan), E. Miller (Univ. of Minnesota), S. Okada (Nagoya Univ., Japan), P. Paule (RISC, Austria).
Deadlines: Submission of papers: Authors are invited to submit extended abstracts of at most twelve pages by November 19, 2006. Requests for support: March 1, 2007. Reduced registration fee: April 1, 2007.
Information: See http://www.fpsac.cn/.

*2–13 **Geometry and Lie Theory**, Australian National University, Canberra, and University of Sydney, Australia.
Description: In July, 2007, there will be a conference in Australia to mark the sixtieth birthday of Gus Lehrer. The conference will highlight recent advances in the representation theory of Lie groups and related areas, with a particular emphasis on geometric techniques. Over forty of the world's leading experts have agreed to attend the meeting, including Andersen, Ariki, Broue, Brundan, DeConcini, Gaitsgory, Ginzburg, Hain, Jantzen, Kleshchev, Procesi, Ringel, Rouquier, Segal and Shoji. The conference will take place over two weeks in July, with the first week (July 2-6) held at the ANU in Canberra and the second week (July 9-13) at the University of Sydney.
Information: More details, including registration and accommodation information, can be found on the conference web page: http://www.maths.usyd.edu.au/u/SemConf/lehrerfest.html.

* 4–7 **APFA 6: Applications of Physics in Financial Analysis Conference**, ISCTE Business School, Lisbon, Portugal.
Aim: The aim of the conference is to bring together scientists, both economists and physicists, interested in problems in economics and finance.
Fees: The registration fee for scientists includes: Admission to all scientific sessions, conference kit, abstract booklet, 1 volume of Proceedings, welcome reception, coffee breaks, lunches, gala dinner and excursion. The registration fees are: Full: $400.00. Individual Ordinary Members of EPS: $300.00. Members of National Physical Societies: $350.00. Ph.D. Student: $300.00. Accompanying Person: $200.00
Deadlines: Abstract Submission: Deadline: March 30, 2007. Abstract Acceptance Notification: April 30, 2007. Early Registration Deadline: June 15, 2007. APFA6 Conference Full-length Paper Submission Deadline: September 30, 2007.
Information: Further information can be obtained very soon from our website at `http://apfa6.dmq.eg.iscte.pt`.

* 6–12 **Sixth Summer School on Potential Theory and Applications**, Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, Sofia, Bulgaria.
Topics: Potential theory with its broad spectrum of related fields and applications.
Deadlines: Registration: March 31, 2007. Abstract submission: April 30, 2007 Hotel registration: May 31, 2007.
Registration: To attend the meeting please fill out Registration Form in the web-page `http://www.math.bas.bg/complan/sspt2007` and send it before March 31 to the Organizing Committee by e-mail `sspt2007@math.bas.bg`.
Application Fees: 120 Euro, if paid before May 31. 150 Euro, if paid after May 31. Accompanying persons: 60 Euro.
Information: Prof. Dr. sci Ralitza Kovacheva, IMI–BAS, Acad. Bonchev str. 8, 1113 Sofia, BG `rkovach@math.bas.bg`, `sspt2007@math.bas.bg`.

* 22–28 **Topological Theory of Fixed and Periodic Points (TTFPP 2007)**, Conference Center of the Mathematical Institute of the Polish Academy of Sciences, Bedlewo near Poznan, Poland.
Program: The aim of the conference is to give the opportunity to present recent achievements and exchange new ideas in the field of fixed and periodic point theory.
Topics: Classical (Lefschetz and Nielsen) theories of fixed points. Lefschetz and Nielsen periodic point theories. Low dimensional discrete dynamical systems and periodic point theory, fixed point index and fixed point indices of iterations. Theory of fixed and periodic points of symplectic maps. Applications of theory of smooth dynamical systems in periodic point theory, connections with topological entropy, Hamiltonian maps.
Contact: `ttfpp@amu.edu.pl`.
Information: `http://www.staff.amu.edu.pl/~ttfpp/conference.html`.

* 23–27 **VII Americas School in Differential Equations**, University of Cartagena, Cartagena, Colombia (South America).
Information: Jorge Cossio, `americasvii@gmail.com`; `http://www.math.hmc.edu/~castro/7asde.html`.

* 24–27 **International workshop "Reliable Methods of Mathamaticall Modelling" (RMMM 2007)**, V. A. Steklov Institute of Mathematics, Saint Petersburg, Russia.
Aims and Scope: Workshop is organized to bring together specialists developing mathematical and computational methods intended to increase the reliability of the results obtained in various mathematical modeling methods.
Topics: Mesh-adaptive numerical methods in various applied problems, a posteriori error control and verification of numerical solutions, validation of mathematical models used in computer simulation.
Important Dates: Deadline for submission of applications: March 1, 2007. Confirmation of acceptance: April 1, 2007. Arrival: July 22 2007. Departure: July 28, 2007.
Information: `http://www.rmmm2007.org.ru`.

August 2007

* 13–17 **Generic Case Complexity**, AIM Research Conference Center, Palo Alto, California.
Description: This workshop, sponsored by AIM and the NSF, will be devoted to exploring the potential contribution of generic-case complexity to cryptography. Generic-case complexity is a new complexity measure which seems to be useful for assessing the algorithmic security of public key cryptosystems. The intended participants include cryptographers, mathematicians, and students.
Deadline: April 1, 2007.
Information: Visit `http://aimath.org/ARCC/workshops/gccomplexity.html`.

* 19–25 **The Eighth International Workshop on Differential Geometry and its Applications**, Cluj-Napoca, Romania.
Program: 50-minute lectures and 25-minute talks. Poster communications are also envisaged. The PROCEEDINGS will be published.
Main Topics: CR-manifolds, Jordan geometry, geometry of immersions and of submanifolds, tube domains, Banach manifolds, geometry over general base fields and rings, geometric topology.
Confirmed Invited Speakers: W. Bertram (Nancy), G. Besson (Grenoble), I. Dimitric (Penn. State, Uniontown), J. Dorfmeister (Muenchen), L. Funar (Grenoble), G. Gentili (Firenze), W. Kaup (Tuebingen), T. Nomura (Kyushu Univ.), D. Otera (Palermo), D. Repovs (Ljubljana), L. Stacho (Szeged), N. Teleman (Ancona), H. Upmeier (Marburg), W. Werner (Muenster).
Organizers: D. Andrica, Babes-Bolyai, Univ. Cluj-Napoca, Faculty of Mathematics and Computer Science, email: `dandrica@math.ubbcluj.ro`, R. Iordanescu, Institute of Mathematics of the Romanian Academy-Bucharest, email: `radu.iordanescu@imar.ro`, S. Moroianu, Institute of Mathematics of the Romanian Academy-Bucharest, email: `sergiu.moroianu@imar.ro`, M. Puta, Univ.of the West, Faculty of Mathematics, Timisoara, email: `puta@math.uvt.ro`.
Information: email: `Radu.Iordanescu@imar.ro`.

* 27–29 **International Conference on Biomathematics 2007**, ITB, Bandung, Indonesia.
Plenary Speakers: Stephan A. van Gills (UTwente, the Netherlands), Zhilan Feng (Purdue University, USA), J.A.P. Heesterbeek (Veterinary Medicine, Utrecht, the Netherlands), Sangkot Marzuki (*, Eijkman Institute, Indonesia), Mick Robert (Institute of Information and Mathematical Sciences, Massey University, New Zealand), Edy Soewono (Institut Teknologi Bandung, Indonesia), Asep Supriatna (Universitas Padjajaran, Indonesia).
Parallel Session: There are parallel sessions for contributed papers on the applications of mathematics in, but not limited to, epidemiology, population dynamics, bio-economics, biological control. Each contributed talk takes 20 minutes presentation.
Deadline: Please submit the abstract for contributed paper before May 1, 2007.
Information: `http://icobm07.math.itb.ac.id/`; email: `icobm07@bdg.centrin.net.id`.

September 2007

* 10–15 **International Conference on Nonlinear Partial Differential Equations dedicated to the memory of Igor V. Skrypnik**, NPDE2007, Yalta, Crimea, Ukraine.
Preliminary List of Main Speakers: V. Barbu, M. Bidaut-Veron, M. Biroli, L. Boccardo, M. Chipot, E. Feireisl, M. Fila, A. G. Kartsatos, R. Kersner, V. A. Kondratiev, A. Kufner, V. Liskevich, H. Matano, N. Mizoguchi, M. Marcus, F. Murat, S. I. Pokhozhaev, V. V. Pukhnachev, E. V. Radkevich, J. Rehberg, V. A. Solonnikov, P. Souganidis, L. Veron, E. Yanagida, V. V. Zhikov.

Information: email: NPDE2007@iamm.ac.donetsk.ua; http://iamm.ac.donetsk.ua/conferences/npde2007.html.

* 11–15 **CSL07: 16th EACSL Annual Conference on Computer Science and Logic**, Lausanne, Switzerland.

Important Dates: Paper Registration Deadline (with short abstracts): April 2, 2007. Paper Submission Deadline: April 9, 2007. Author Notification: May 21, 2007. Final Versions for the Proceedings: June 18, 2007. Conference: September 11-15, 2007.

Information: http://www2.unil.ch/csl07/.

* 17–21 **13th Czech-French-German Conference on Optimization**, University of Heidelberg, Heidelberg, Germany.

Topics: Continuous optimization (smooth and nonsmooth), numerical methods for mathematical programming, optimal control and calculus of variations, robust optimization, mixed integer optimization, optimization with PDE, differential inclusions and set-valued analysis, stochastic optimization, multicriteria optimization, optimization techniques for industrial applications.

Plenary Speakers: Guillaume Carlier (Paris Dauphine), Roger Fletcher (University of Dundee), Roland Griesse (Austrian Academy of Sciences), Pierre Maréchal (UPS Toulouse), Alexander Martin (TU Darmstadt), David Preiss (University College London), Carsten Scherer (TU Delft), Zdenek Strakos (Czech Academy of Sciences), Emmanuel Trélat (Université d'Orléans), Michael Valáúek (Czech Technical University), Luís Nunes Vicente (Universidade de Coimbra), Andreas Wächter (IBM, Yorktown Heights), Andrea Walther (TU Dresden).

Deadlines: Conference: September 17-21, 2007. Talk abstract submission: March 31, 2007.

Information: http://cfg07.uni-hd.de; http://www.iwr.uni-heidelberg.de/groups/agbock/CONFERENCES/2007/CFG/index.php?l=en.

* 23–28 **14th Workshop on Stochastic Geometry, Stereology and Image Analysis**, Friedrich-Schiller-University Jena, Department of Stochastics, Jena, Germany.

Information: http://www.minet.uni-jena.de/stoch_geom_07/.

* 25–28 **The 2nd International Conference on Nonlinear Dynamics: KhPI 2007 in honor of Alexander Lyapunov 150th Anniversary**, National Technical University, Kharkov Polytechnical Institute, Kharkov, Ukraine.

Topics: Analytical and numerical methods in nonlinear dynamics; Resonances, stability analysis and bifurcations in nonlinear systems; Nonlinear normal modes; Transient processes and localization of energy; Chaotic dynamics; Nonlinear dynamics of continuous systems, in particular, plates and shells; Vibro-impact systems and other non-smooth systems; Vibro-creep problems and other problems of nonlinear dynamics

Call for papers: A one-page abstract for presentation at the conference is invited.

Deadlines: The deadline for the pre-registration and abstract submission is February 17th, 2007. Only electronic submission is accepted. Notification of acceptance: April 15, 2007.

Language: English.

Information: Dept. of Applied Mathematics (Prof. Yu.V. Mikhlin, Prof. L.V. Kurpa, Dr. G.V. Rudnyeva), National Technical University "Kharkov Polytechnical University", 21 Frunze str., Kharkov, 61002, Ukraine; Phone: +38-057-7076032; Fax: +38-057-7076601; email: muv@kpi.kharkov.ua, yuri_mikhlin@mail.ru, gayane@kpi.kharkov.ua; http://users.kpi.kharkov.ua/infiz/conf/index.html.

July 2008

* 14–18 **5th European Congress of Mathematics**, Amsterdam, the Netherlands.

Information: http://www.5ecm.nl.

* 22–26 **International Workshop on Operator Theory and its Applications (IWOTA)**, College of William and Mary, Williamsburg, Virginia.

Information: The up-to-date information about the conference is at http://www.math.wm.edu/~vladi/IWOTA/IWOTA2008.htm.

September 2008

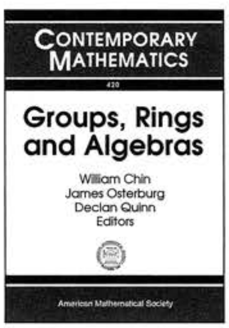
* 24–27 **Vector Measures, Integration and Applications**, Katholische Universitaet Eichstaett-Ingolstadt, Eichstaett, Germany.

Organizers: W. J. Ricker & G. Mockenhaupt.

Information: Will be updated and expanded in due course.

New Publications Offered by the AMS

Algebra and Algebraic Geometry



Groups, Rings and Algebras

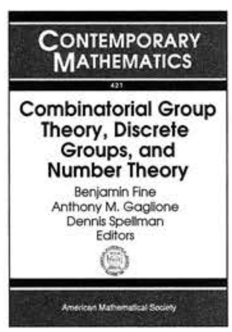
William Chin, *DePaul University, Chicago, IL*, **James Osterburg**, *University of Cincinnati, OH*, and **Declan Quinn**, *Syracuse University, NY*, Editors

This is a companion volume to the conference in honor of Donald S. Passman held in Madison, Wisconsin in June 2005. It contains research papers on Algebras, Group Rings, Hopf Algebras, Invariant Theory, Lie Algebras and their Enveloping Algebras, Noncommutative Algebraic Geometry, Noncommutative Rings, and other topics. The papers represent an important part of the latest research in these areas.

Contents: Y. A. Bahturin and **I. P. Shestakov**, Group gradings on associative superalgebras; **K. I. Beidar**, **S. K. Jain**, and **A. K. Srivastava**, Essential extensions of a direct sum of simple modules; **J. Bergen**, Adjoint actions of cocommutative Hopf algebras; **G. M. Bergman**, Two statements about infinite products that are not quite true; **R. Betz**, **S. Eckel**, **P. Pappas**, and **J. Uyanik**, Cyclic structures with lag-time generators; **O. B. Cristo** and **C. P. Milies**, Central idempotents in group algebras; **D. R. Farkas** and **P. A. Linnell**, Congruence subgroups and the Atiyah conjecture; **E. Formanek**, The adjoint of the Bezoutian; **A. Giambruno** and **S. K. Sehgal**, Group algebras whose Lie algebra of skew-symmetric elements is nilpotent; **J. Z. Gonçalves** and **M. Shirvani**, Free symmetric and unitary pairs in central simple algebras with involution; **R. M. Guralnick** and **M. Lorenz**, Orders of finite groups of matrices; **G. Heide** and **A. E. Zalesskiĭ**, Passman's problem on adjoint representations; **M. Hertweck** and **M. Soriano**, On the modular isomorphism problem: Groups of order 2^6; **W. Kimmerle**, On the prime graph of the unit group of integral group rings of finite groups; **L. Krop** and **D. E. Radford**, Simple modules for the Drinfel'd double of a class of Hopf algebras; **A. I. Lichtman**, The correspondence between groups and restricted Lie algebras for some relatively free groups; **C.-H. Liu**, Semiprime Lie rings of derivations of commutative rings; **I. M. Musson**, Faithful cyclic modules for enveloping algebras and Sklyanin algebras; **D. S. Passman**, Polynomial and inverse forms; **D. Riley** and **H. Usefi**, Restricted Lie algebras with subexponential growth; **M. Ursul**, A few criteria of boundedness of topological rings.

Contemporary Mathematics, Volume 420

December 2006, 301 pages, Softcover, ISBN-10: 0-8218-3904-7, ISBN-13: 978-0-8218-3904-1, LC 2006050359, 2000 *Mathematics Subject Classification:* 08B25, 15A57, 16W25, 17B40, 20C07, 20C15, 20F40; 03C20, 16S34, 16U60, 20B30, 22A05, **All AMS members US$71**, List US$89, Order code CONM/420



Combinatorial Group Theory, Discrete Groups, and Number Theory

Benjamin Fine, *Fairfield University, CT*, **Anthony M. Gaglione**, *U.S. Naval Academy, Annapolis, MD*, and **Dennis Spellman**, *Temple University, Philadelphia, PA*, Editors

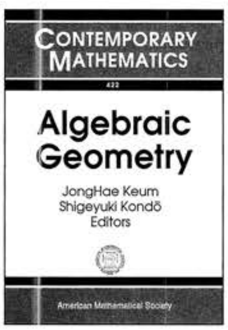
This volume consists of contributions by participants and speakers at two conferences. The first was entitled Combinatorial Group Theory, Discrete Groups and Number Theory and was held at Fairfield University, December 8–9, 2004. It was in honor of Professor Gerhard Rosenberger's sixtieth birthday. The second was the AMS Special Session on Infinite Group Theory held at Bard College, October 8–9, 2005. The papers in this volume provide a very interesting mix of combinatorial group theory, discrete group theory and ring theory as well as contributions to noncommutative algebraic cryptography.

Contents: P. Ackermann, A description of the arithmetic Fuchsian groups with signature (2;—); **R. B. J. T. Allenby**, **G. Kim**, and **C. Y. Tang**, Outer automorphism groups of certain orientable Seifert 3-manifold groups; **M. Anshel** and **A. M. Gaglione**, The search for origins of the commutator calculus; **G. Baumslag**, **B. Fine**, **A. M. Gaglione**, and **D. Spellman**, A note on nondiscrimination of nilpotent groups and Mal'cev completions; **G. Baumslag**, **B. Fine**, and **X. Xu**, A proposed public key cryptosystem using the modular group; **H. Bluhm** and **M. Kreuzer**, Gröbner basis techniques in the computation of two-sided syzygies; **M. Conder**

and **P. Dobcsányi**, Normal subgroups of the modular group and other Hecke groups; **O. B. Cristo** and **C. P. Milies**, Commutativity of units in group rings; **M. J. Evans**, Presentations of groups involving more generators than are necessary. II.; **B. Fine**, **A. M. Gaglione**, and **D. Spellman**, Unions of varieties and quasivarieties; **B. Fine**, **A. M. Gaglione**, and **D. Spellman**, Finitely presented infinite torsion groups and a question of V. H. Dyson; **A. Fonseca** and **R. M. Thomas**, Context-free irreducible word problems in groups; **D. Garrison**, **L.-C. Kappe**, and **D. Yull**, Autocommutators and the autocommutator subgroup; **J. Gilman**, Informative words and discreteness; **R. Goldstein**, An algorithm for potentially positive words in F_2; **G. Kern-Isberner**, Using group theory for knowledge representation and discovery; **M. Kreuzer**, **A. Myasnikov**, **G. Rosenberger**, and **A. Ushakov**, Quotient tests and Gröbner bases; **L. A. Kurdachenko** and **I. Y. Subbotin**, Transitivity of normality and pronormal subgroups; **C. Maclachlan**, Torsion in maximal arithmetic Fuchsian groups; **S. Majewicz**, Nilpotent $\mathbb{Q}[x]$-powered groups; **R. F. Morse**, On the Rosenberger monster; **C. F. Rocca, Jr.**, Density of test elements in finite abelian groups; **R. Weidmann**, Adjoining a root does not decrease the rank.

Contemporary Mathematics, Volume 421

February 2007, 273 pages, Softcover, ISBN-10: 0-8218-3985-3, ISBN-13: 978-0-8218-3985-0, LC 2006043026, 2000 *Mathematics Subject Classification:* 01A60, 03C05, 20E05, 20E06, 20E26, 20F05, 20F12, 20F18, 20H10, **All AMS members US$63**, List US$79, Order code CONM/421



Algebraic Geometry

JongHae Keum, *Korea Institute for Advanced Study, Seoul, Korea*, and **Shigeyuki Kondō**, *Nagoya University, Japan*, Editors

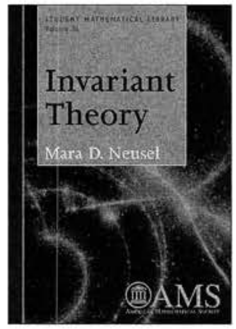
This volume contains the proceedings of the Korea-Japan Conference on Algebraic Geometry in honor of Igor Dolgachev on his sixtieth birthday. The articles in this volume explore a wide variety of problems that illustrate interactions between algebraic geometry and other branches of mathematics. Among the topics covered by this volume are algebraic curve theory, algebraic surface theory, moduli space, automorphic forms, Mordell–Weil lattices, and automorphisms of hyperkähler manifolds. This book is an excellent and rich reference source for researchers.

Contents: L. A. Borisov, Holomorphic Eisenstein series with Jacobian twists; **E. Dardanelli** and **B. van Geemen**, Hessians and the moduli space of cubic surfaces; **M. Gizatullin**, On covariants of plane quartic associated to its even theta characteristic; **J. Keum**, A rationality criterion for projective surfaces–Partial solution to Kollár's conjecture; **S. Kondō**, The moduli space of 8 points on $\mathbb{P}^1$ and automorphic forms; **E. Looijenga**, Invariants of quartic plane curves as automorphic forms; **V. V. Nikulin**, On correspondences of a K3 surface with itself. II; **K. Oguiso**, Automorphisms of hyperkähler manifolds in the view of topological entropy; **I. Shimada** and **D.-Q. Zhang**, $K3$ surfaces with ten cusps; **T. Shioda**, Classical Kummer surfaces and Mordell-Weil lattices; **D.-Q. Zhang**, Niemeier lattices and K3 groups.

Contemporary Mathematics, Volume 422

March 2007, approximately 234 pages, Softcover, ISBN-10: 0-8218-4201-3, ISBN-13: 978-0-8218-4201-0, LC 2006049918, 2000 *Mathematics Subject Classification:* 11D25, 11F11, 14H10, 14J15, 14J26, 14J28, 14J50, 14J60, 14L24, 32N15, **All AMS members US$55**, List US$69, Order code CONM/422

COURSE ADOPTION



Invariant Theory

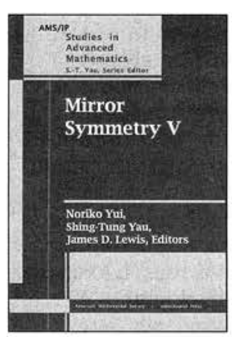
Mara D. Neusel, *Texas Tech University, Lubbock, TX*

This book presents the characteristic zero invariant theory of finite groups acting linearly on polynomial algebras. The author assumes basic knowledge of groups and rings, and introduces more advanced methods from commutative algebra along the way. The theory is illustrated by numerous examples and applications to physics, engineering, numerical analysis, combinatorics, coding theory, and graph theory. A wide selection of exercises and suggestions for further reading makes the book appropriate for an advanced undergraduate or first-year graduate level course.

Contents: Introduction; *Recollections:* Linear representations of finite groups; Rings and algebras; *Introduction and Göbel's bound:* Rings of polynomial invariants; Permutation representations; Application: Decay of a spinless particle; Application: Counting weighted graphs; *The first fundamental theorem of invariant theory and Noether's bound:* Construction of invariants; Noether's bound; Some families of invariants; Application: Production of fibre composites; Application: Gaussian quadrature; *Noether's theorems:* Modules; Integral dependence and the Krull relations; Noether's theorems; Application: Self-dual codes; *Advanced counting methods and the Shephard-Todd-Chevalley theorem:* Poincaré series; Systems of parameters; Pseudoreflection representations; Application: Counting partitions; Appendix A: Rational invariants; Suggestions for further reading; Index.

Student Mathematical Library, Volume 36

January 2007, 314 pages, Softcover, ISBN-10: 0-8218-4132-7, ISBN-13: 978-0-8218-4132-7, LC 2006049944, 2000 *Mathematics Subject Classification:* 13A50; 13-XX, 20-XX, **All AMS members US$39**, List US$49, Order code STML/36



Mirror Symmetry V

Noriko Yui, *Queen's University, Kingston, ON, Canada*, **Shing-Tung Yau**, *Harvard University, Cambridge, MA*, and **James D. Lewis**, *University of Alberta, Edmonton, AB, Canada*, Editors

Since its discovery in the early 1990s, mirror symmetry, or more generally, string theory, has exploded onto the mathematical landscape. This topic touches upon many branches of mathematics and mathematical physics, and has revealed deep connections between subjects previously considered unrelated. The papers in this volume treat mirror symmetry from the perspectives of both mathematics and physics. The articles can be roughly grouped into four sub-categories within the topic of mirror symmetry: arithmetic aspects, geometric aspects, differential geometric and mathematical physics aspects, and geometric analytic aspects. In these works, the reader will find mathematics addressing, and in some cases solving, problems inspired and influenced by string theory.

This item will also be of interest to those working in mathematical physics.

Titles in this series are co-published with International Press, Cambridge, MA.

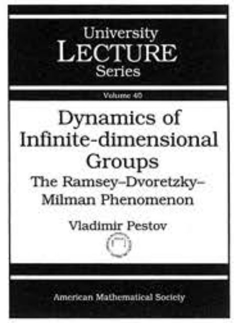
Contents: *Arithmetic aspects:* **M. J. Bertin**, Mahler's measure and L-series of $K3$ hypersurfaces; **K. Hulek**, **H. Verrill**, and **L. V. Dieulefait**, On the modularity of Calabi-Yau threefolds containing elliptic ruled surfaces Appendix A. A Modularity Criterion for Integral Galois Representations and Calabi-Yau Threefolds; **S. Kadir**, Arithmetic mirror symmetry for a two-parameter family of Calabi-Yau manifolds; **K. Kimura**, A rational map between two threefolds; **E. Lee**, A modular non-rigid Calabi-Yau threefold; **M. Lynker** and **R. Schimmrigk**, Arithmetic of algebraic curves and the affine algebra $A_1^{(1)}$; **J. Stienstra**, Mahler measure variations, Eisenstein series and instanton expansions; **J. Stienstra**, Mahler measure, Eisenstein series and dimers; **D. Wan** and **C. D. Haessig**, Mirror symmetry for zeta functions with appendix; **N. Yui** and **Y. Goto**, The L-series of Calabi-Yau orbifolds of CM type Appendix B. The L-series of Cubic Hypersurface Fourfolds; *Geometric aspects:* **V. Batyrev** and **M. Kreuzer**, Integral cohomology and mirror symmetry for Calabi-Yau 3-folds; **X. Chen** and **J. D. Lewis**, The real regulator for a product of $K3$ surfaces; **Y. Kawamata**, Derived equivalence for stratified Mukai flop on $G(2,4)$; **M. Kerr**, A survey of transcendental methods in the study of Chow groups of zero-cycles; **E. Viehweg** and **K. Zuo**, Geometry and arithmetic of non-rigid families of Calabi-Yau 3-folds; Questions and examples; **Y. Zhang**, Some results on families of Calabi-Yau varieties; *Differential geometric and mathematical physical aspects:* **K. Hori**, Boundary RG flows of $\mathcal{N} = 2$ minimal models; **S. Hosono**, Central charges, symplectic forms, and hypergeometric series in local mirror symmetry; **C.-H. Liu** and **S.-T. Yau**, Extracting Gromov-Witten invariants of a conifold from semi-stable reduction and relative GW-invariants of pairs; **W.-D. Ruan**, Generalized special Lagrangian torus fibrations for Calabi-Yau hypersurfaces in toric varieties II; *Geometric analytic aspects: Picard-Fuchs equations:* **G. Almkvist** and **W. Zudilin**, Differential equations, mirror maps and zeta values; **C. F. Doran** and **J. W. Morgan**, Mirror symmetry and integral variations of Hodge structure underlying one-parameter families of Calabi-Yau threefolds; **C. van Enckevort** and **D. van Straten**, Monodromy calculations of fourth order equations of Calabi-Yau type; **B. Forbes**, Open string mirror maps from Picard-Fuchs equations; **N. Yui**, **S.-T. Yau**, and **J. D. Lewis**, Problems.

AMS/IP Studies in Advanced Mathematics, Volume 38

January 2007, 576 pages, Softcover, ISBN-10: 0-8218-4251-X, ISBN-13: 978-0-8218-4251-5, LC 2006047914, 2000 *Mathematics Subject Classification:* 14-XX, 11-XX, 32-XX, 81-XX, **All AMS members US$87**, List US$109, Order code AMSIP/38

Analysis

COURSE ADOPTION



Dynamics of Infinite-dimensional Groups

The Ramsey–Dvoretzky–Milman Phenomenon

Vladimir Pestov, *University of Ottawa, Ontario, Canada*

The "infinite-dimensional groups" in the title refer to unitary groups of Hilbert spaces, the infinite symmetric group, groups of homeomorphisms of manifolds, groups of transformations of measure spaces, etc. The book presents an approach to the study of such groups based on ideas from geometric functional analysis and from exploring the interplay between dynamical properties of those groups, combinatorial Ramsey-type theorems, and the phenomenon of concentration of measure.

The dynamics of infinite-dimensional groups is very much unlike that of locally compact groups. For instance, every locally compact group acts freely on a suitable compact space (Veech). By contrast, a 1983 result by Gromov and Milman states that whenever the unitary group of a separable Hilbert space continuously acts on a compact space, it has a common fixed point.

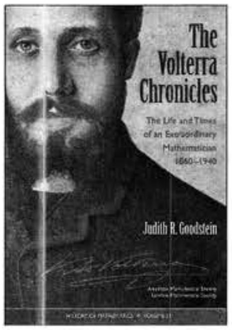
In the book, this new fast-growing theory is built strictly from well-understood examples up. The book has no close counterpart and is based on recent research articles. At the same time, it is organized so as to be reasonably self-contained. The topic is essentially interdisciplinary and will be of interest to mathematicians working in geometric functional analysis, topological and ergodic dynamics, Ramsey theory, logic and descriptive set theory, representation theory, topological groups, and operator algebras.

Contents: Introduction; The Ramsey–Dvoretzky–Milman phenomenon; The fixed point on compacta property; The concentration property; Lévy groups; Urysohn metric space and its group of isometries; Minimal flows; Further aspects of concentration; Oscillation stability and distortion; Bibliography; Index.

University Lecture Series, Volume 40

January 2007, 192 pages, Softcover, ISBN-10: 0-8218-4137-8, ISBN-13: 978-0-8218-4137-2, LC 2006048749, 2000 *Mathematics Subject Classification:* 05D10, 22F05, 43A05, 46B09; 05C55, 20B30, 22A05, 22F10, 22F50, 28D15, 37A15, 37A20, 37A40, 43A07, 46L05, 46L10, 51F25, 54E70, 54H15, 54H25, 60B05, **All AMS members US$31**, List US$39, Order code ULECT/40

General and Interdisciplinary



The Volterra Chronicles

The Life and Times of an Extraordinary Mathematician 1860–1940

Judith R. Goodstein, *California Institute of Technology, Pasadena, CA*

The life of Vito Volterra, one of the finest scientists and mathematicians Italy ever produced, spans the period from the unification of the Italian peninsula in 1860 to the onset of the Second World War—an era of unparalleled progress and unprecedented turmoil in the history of Europe. Born into an Italian Jewish family in the year of the liberation of Italy's Jewish ghettos, Volterra was barely in his twenties when he made his name as a mathematician and took his place as a leading light in Italy's modern scientific renaissance. By his early forties, he was a world-renowned mathematician, a sought-after figure in European intellectual and social circles, the undisputed head of Italy's mathematics and physics school—and still living with his mother, who decided the time was ripe to arrange his marriage. When Italy entered World War I in 1915, the fifty-five-year-old Volterra served with distinction and verve as a lieutenant and did not put on civilian clothes again until the Armistice of 1918. By 1925, he was president of the world's oldest scientific society, the Accademia dei Lincei, the founder and president of Italy's National Research Council, a mentor to the brilliant and restless Enrico Fermi, and "Mr. Italian Science" to the rest of the world. But none of this was enough to keep the government of Benito Mussolini from stripping him of all his honors and affiliations in 1931, when he was one of only twelve professors in the entire country to refuse to sign an oath of loyalty to the Fascist regime.

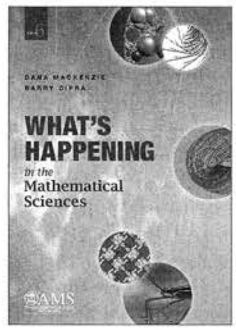
This book, based in part on unpublished personal letters and interviews, traces the extraordinary life and times of one of Europe's foremost scientists and mathematicians, from his teenage struggles to avoid the stifling life of a "respectable" bank clerk in Florence, to his seminal mathematical work—which today influences fields as diverse as economics, physics, and ecology—and from his spirited support of Italy's scientific and democratic institutions during his years as an Italian Senator, to his steadfast defiance of the Fascists and Mussolini. In recounting the life of this outstanding scientist, European Jewish intellectual, committed Italian patriot, and devoted if frequently distracted family man, *The Volterra Chronicles* depicts a remarkable individual in a prodigious age and takes the reader on a vivid and splendidly detailed historical journey.

Co-published with the London Mathematical Society beginning with Volume 4. Members of the LMS may order directly from the AMS at the AMS member price. The LMS is registered with the Charity Commissioners.

Contents: "The Jewish mathematician"; "A new era is dawning," 1860; "This, above all, I promise," 1863-1870; "That damned passion," 1874-1877; "Long live the republic," 1878-1882; "Professor by deed," 1880-1883; "Our professor of small intervals," 1883-1893; "The life I live," 1887-1895; "Demonstrations of their resentment," 1893-1900; "God liberate us from his symbols"; "It is the greatest desire of my life," 1900; "Most important for our fatherland"; "Will they create a new world?"; "A political man"; "A professor in America"; "Empires die"; Epilogue; Illustrations; Sir Edmund Whittaker, "Vito Volterra, 1860-1940"; On the attempts to apply mathematics to the biological and social sciences; Science at the present moment and the new Italian society for the progress of science; Acknowledgments; Selected bibliography; Notes; Index.

History of Mathematics, Volume 31

March 2007, approximately 315 pages, Hardcover, ISBN-10: 0-8218-3969-1, ISBN-13: 978-0-8218-3969-0, LC 2006051752, 2000 *Mathematics Subject Classification:* 01A60, 01A70, **All AMS members US$47**, List US$59, Order code HMATH/31



What's Happening in the Mathematical Sciences

Dana Mackenzie and **Barry Cipra**

The AMS series *What's Happening in the Mathematical Sciences* distills the amazingly rich brew of current research in mathematics down to a few choice samples. This volume leads off with an update on the Poincaré Conjecture, a hundred-year-old problem that has apparently been solved by Grigory Perelman of St. Petersburg, Russia. So what did topologists do when the oldest and most famous problem about closed manifolds was vanquished? As the second chapter describes, they confronted a suite of problems concerning the "ends" of open manifolds... and solved those, too.

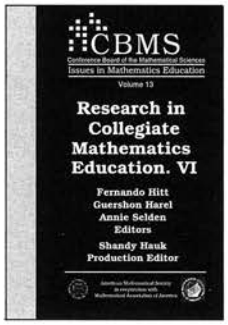
Not to be outdone, number theorists accomplished several unexpected feats in the first five years of the new century, from computing a trillion digits of pi to finding arbitrarily long equally-spaced sequences of prime numbers. Undergraduates made key discoveries, as explained in the chapters on Venn diagrams and primality testing. In applied mathematics, the Navier-Stokes equations of fluid mechanics continued to stir up interest. One team proved new theorems about the long-term evolution of vortices, while others explored the surprising ways that insects use vortices to move around. The random jittering of Brownian motion became a little less mysterious. Finally, an old and trusted algorithm of computer science had its trustworthiness explained in a novel way.

Barry Cipra explains these new developments in his wry and witty style, familiar to readers of Volumes 1–5, and is joined in this volume by Dana Mackenzie. Volume 6 of *What's Happening* will convey to all readers—from mathematical novices to experts—the beauty and wonder that is mathematics.

Contents: D. Mackenzie and **B. Cipra**, Introduction; **B. Cipra**, First of seven millennium problems nears completion; **D. Mackenzie**, Classifying hyperbolic manifolds—All's well that ends well; **B. Cipra**, Digits of pi; **B. Cipra**, Combinatoricists solve a Venn-erable problem; **B. Cipra**, New insights into prime numbers; **D. Mackenzie**, From Rubik's Cube to quadratic number fields...and beyond; **B. Cipra**, Vortices and the Navier-Stokes equations; **D. Mackenzie**, Fluid dynamics explains mysteries of insect motion; **D. Mackenzie**, Brownian motion, phase transitions, and conformal maps; **B. Cipra**, Smoothed analysis speeds up the simplex method.

What's Happening in the Mathematical Sciences, Volume 6

January 2007, 122 pages, Softcover, ISBN-10: 0-8218-3585-8, ISBN-13: 978-0-8218-3585-2, 2000 *Mathematics Subject Classification:* 00A06, **All AMS members US$18**, List US$23, Order code HAPPENING/6



Research in Collegiate Mathematics Education. VI

Fernando Hitt, *Université du Québec à Montréal, QC, Canada*, **Guershon Harel**, *University of California, San Diego, CA*, and **Shandy Hauk**, *University of Northern Colorado, Greeley, CO*, Editors

The sixth volume of *Research in Collegiate Mathematics Education* presents state-of-the-art research on understanding, teaching, and learning mathematics at the postsecondary level. The articles advance our understanding of collegiate mathematics education while being readable by a wide audience of mathematicians interested in issues affecting their own students. This is a collection of useful and informative research regarding the ways our students think about and learn mathematics.

The volume opens with studies on students' experiences with calculus reform and on the effects of concept-based calculus instruction. The next study uses technology and the van Hiele framework to help students construct concept images of sequential convergence. The volume continues with studies on developing and assessing specific competencies in real analysis, on introductory complex analysis, and on using geometry in teaching and learning linear algebra. It closes with a study on the processes used in proof construction and another on the transition to graduate studies in mathematics.

Whether they are specialists in education or mathematicians interested in finding out about the field, readers will obtain new insights about teaching and learning and will take away ideas that they can use.

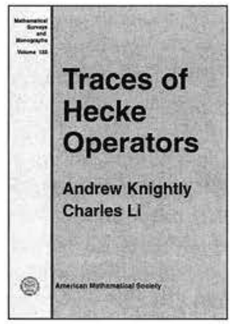
This series is published in cooperation with the Mathematical Association of America.

Contents: J. R. Star and **J. P. Smith III**, An image of calculus reform: Students' experiences of Harvard calculus; **K. K. Chappell**, Effects of concept-based instruction on calculus students' acquisition of conceptual understanding and procedural skill; **M. A. Navarro** and **P. P. Carreras**, Constructing a concept image of convergence of sequences in the van Hiele framework; **N. Grønbæk** and **C. Winslow**, Developing and assessing specific competencies in a first course on real analysis; **P. Danenhower**, Introductory complex analysis at two British Columbia universities: The first week–complex numbers; **G. Gueudet-Chartier**, Using geometry to teach and learn linear algebra; **K. Weber**, Investigating and teaching the processes used to construct proofs; **J. Duffin** and **A. Simpson**, The transition to independent graduate studies in mathematics.

CBMS Issues in Mathematics Education, Volume 13

December 2006, 248 pages, Softcover, ISBN-10: 0-8218-4243-9, ISBN-13: 978-0-8218-4243-0, 2000 *Mathematics Subject Classification:* 00-XX, 97-XX, **All AMS members US$39**, List US$49, Order code CBMATH/13

Number Theory



Traces of Hecke Operators

Andrew Knightly, *University of Maine, Orono, ME*, and **Charles Li**, *Academia Sinica, Taipei, Taiwan*

The Fourier coefficients of modular forms are of widespread interest as an important source of arithmetic information. In many cases, these coefficients can be recovered from explicit knowledge of the traces of Hecke operators. The original trace formula for Hecke operators was given by Selberg in 1956. Many improvements were made in subsequent years, notably by Eichler and Hijikata.

This book provides a comprehensive modern treatment of the Eichler–Selberg/Hijikata trace formula for the traces of Hecke operators on spaces of holomorphic cusp forms of weight $k > 2$ for congruence subgroups of $SL_2(\mathbf{Z})$. The first half of the text brings together the background from number theory and representation theory required for the computation. This includes detailed discussions of modular forms, Hecke operators, adeles and ideles, structure theory for $GL_2(\mathbf{A})$, strong approximation, integration on locally compact groups, the Poisson summation formula, adelic zeta functions, basic representation theory for locally compact groups, the unitary representations of $GL_2(\mathbf{R})$, and the connection between classical cusp forms and their adelic counterparts on $GL_2(\mathbf{A})$.

The second half begins with a full development of the geometric side of the Arthur–Selberg trace formula for the group $GL_2(\mathbf{A})$. This leads to an expression for the trace of a Hecke operator, which is then computed explicitly. The exposition is virtually self-contained, with complete references for the occasional use of auxiliary results. The book concludes with several applications of the final formula.

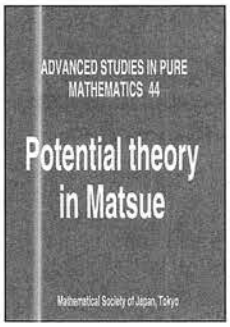
Contents: Traces of Hecke operators; Odds and ends; Groundwork; The trace formula; Computation of the trace; Applications; Bibliography; Tables of notation; Statement of the final result; Index.

Mathematical Surveys and Monographs, Volume 133

January 2007, 378 pages, Hardcover, ISBN-10: 0-8218-3739-7, ISBN-13: 978-0-8218-3739-9, LC 2006047814, 2000 *Mathematics Subject Classification:* 11-XX, **All AMS members US$76**, List US$95, Order code SURV/133

New AMS-Distributed Publications

Analysis



Potential Theory in Matsue

Hiroaki Aikawa, *Hokkaido University, Sapporo, Japan*, **Takashi Kumagai**, *Kyoto University, Japan*, **Yoshihiro Mizuta**, *Hiroshima University, Japan*, and **Noriaki Suzuki**, *Nagoya University, Japan*, Editors

This volume collects, in written form, eight plenary lectures and twenty-five selected contributions from invited and contributed lectures delivered at the International Workshop on Potential Theory 2004. The workshop was held at Shimane University, Matsue, Japan, from August 23 to 28, 2004. The topic of the workshop was potential theory and its related fields. There were stimulus talks from classical potential theory to pluripotential theory and probabilistic potential theory.

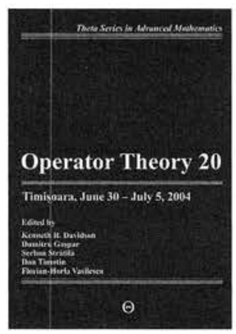
This item will also be of interest to those working in differential equations.

Published for the Mathematical Society of Japan by Kinokuniya, Tokyo, and distributed worldwide, except in Japan, by the AMS.

Contents: Z. Błocki, The Bergman kernel and pluripotential theory; **K. Burdzy**, Neumann eigenfunctions and Brownian couplings; **T. Carroll**, Brownian motion and harmonic measure in conic sections; **S. J. Gardiner**, Radial limits of harmonic functions; **Y. Guivarc'h**, Renewal theorems, products oif random matrices, and toral endomorphisms; **J. Ortega-Cerdà**, Densities and harmonic measure; **N. Shanmugalingam**, Sobolev type spaces on metric measure spaces; **J.-M. Wu**, Quasisymmetric extension, smoothing and applications; **J. Björn**, Wiener criterion for Cheeger p-harmonic functions on metric spaces; **F. Di Biase**, On the sharpness of certain approach regions; **T. Futamura** and **Y. Mizuta**, Continuity of weakly monotone Sobolev functions of variable exponent; **K. Hirata**, Martin kernels of general domains; **K. Ishizaki** and **N. Yanagihara**, Singular directions of meromorphic solutions of some non-autonomous Schröder equations; **K. Janssen**, Integral representation for space-time excessive functions; **T. Kurokawa**, A decomposition of the Schwartz class by a derivative space and its complementary space; **K. Kuwae** and **M. Takahashi**, Kato class functions of Markov processes under ultracontractivity; **E. G. Kwon**, A subharmonic Hardy class and Bloch pullback operator norms; **H. Masaoka**, Quasiconformal mappings and minimal Martin boundary of p-sheeted unlimited covering surfaces of the once punctered Riemann sphere $\hat{\mathbb{C}} \setminus \{0\}$ of Heins type; **H. Masaoka** and **S. Segawa**, Hyperbolic Riemann surfaces without unbounded positive harmonic functions; **I. Miyamoto** and **H. Yosida**, On a covering property of rarefied sets at infinity in a cone; **Y. Miyazaki**, The L^p resolvents for elliptic systems of divergence form; **Y. Mizuta** and **T. Shimomura**, Maximal functions, Riesz potentials and Sobolev's inequality in generalized Lebesgue spaces; **M. Murata**, Representations of nonnegative solutions for parabolic equations; **M. Nakai**, Types of pasting arcs in two sheeted spheres; **M. Nishio**, **K. Shimomura**, and **N. Suzuki**, L^p-boundedness of Bergman projections for α-parabolic operators; **Y. Okuyama**, Vanishing theorem on the pointwise defect of a rational iteration sequence for moving targets; **T. Ono**, Hölder continuity of solutions to quasilinear elliptic equations with measure data; **Y. Pinchover**, On Davies' conjecture and strong ratio limit properties for the heat kernel; **Premaltha** and **A. K. Kalyani**, Some potential theoretic results of an infinite network; **M. Stoll**, The Littlewood-Paley inequalities for Hardy-Orlicz spaces of harmonic functions on domains in $\mathbb{R}^n$; **H. Watanabe**, Estimates of maximal functions by Hausdorff contents in a metric space; **M. Yamada**, Harmonic conjugates of parabolic Bergman functions; **M. Yanagishita**, On the behavior at infinity for non-negative superharmonic functions in a cone.

Advanced Studies in Pure Mathematics, Volume 44

August 2006, 413 pages, Hardcover, ISBN-10: 4-931469-33-7, ISBN-13: 978-4-931469-33-4, 2000 *Mathematics Subject Classification:* 31-XX; 31Bxx, 31Cxx, 32Axx, 32Uxx, 35Bxx, 35Cxx, 35Gxx, 35Jxx, 35Kxx, 35Pxx, 37Fxx, 39Bxx, 42Bxx, 46Exx, 58Jxx, 60Gxx, 60Hxx, 60Jxx, **All AMS members US$83**, List US$104, Order code ASPM/44



Operator Theory 20

Timisoara, June 30–July 5, 2004

Kenneth R. Davidson, *University of Waterloo, ON, Canada*, **Dumitru Gaspar**, *West University of Timisoara, Romania*, **Serban Stratila**, *Institute of Mathematics, Bucharest, Romania*, **Dan Timotin**, *Romanian Academy, Bucharest, Romania*, and **Florian-Horia Vasilescu**, *University of Lille I, Villeneuve d'Ascq, France*, Editors

The volume represents the proceedings of the 20th International Conference on Operator Theory, held in Timisoara (Romania), between June 30 and July 5, 2004. Besides a presentation of the life and works of G. K. Pedersen, it contains twenty-one refereed research papers written by leading experts in the field and by young researchers. These cover a large variety of topics of interest, including: single operator algebras, C* algebras, von Neumann algebras, Hilbert and Banach modules, differential and integral operators, noncommutative probability, and spectral theory.

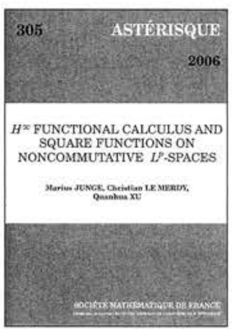
A publication of the Theta Foundation. Distributed worldwide, except in Romania, by the AMS.

Contents: D. Olesen and **E. Størmer**, The life and works of Gert Kjærgaard Pedersen; **H. Bercovici**, On Boolean convolutions; **A. M. Bikchentaev**, Representation of elements of von Neumann algebras in the form of finite sums of products of projections. II;

E. Boasso, On Cartan joint spectra; **J. Bračič**, Reflexivity of the space of module homomorphisms; **M. R. Buneci**, C^*-algebras associated to groupoids with proper orbit space; **G. Cassier** and **N. Suciu**, Analytic functions of a uniformly stable p-contraction; **R. Dumitru**, **C. Peligrad**, and **B. Viinescu**, Automorphisms inner in the local multiplier algebra and Connes spectrum; **D. E. Dutkay** and **G. Picioroaga**, The von Neumann algebra of the canonical equivalence relation of the generalized Thompson group; **S. H. Ferguson** and **R. Rochberg**, Description of certain quotient Hilbert modules; **A. Gomilko**, **I. Wróbel**, and **J. Zemánek**, Numerical ranges in a strip; **A. Khosravi** and **B. Khosravi**, Frames in tensor products of Hilbert C^*-modules; **A. S. Kostenko**, Spectral analysis of some indefinite Sturm-Liouville operators; **V. G. Kravchenko**, **A. B. Lebre**, and **J. S. Rodríguez**, The kernel of singular integral operators with a finite group of linear-fractional shifts; **R. Nicoara**, On the finiteness of the number of N-dimensional Hopf C^*-algebras; **M. Popa**, A non-commutative analogue of Gaussian Hilbert spaces; **D. Popovici**, Dilatable solutions for some operator moment problems; **F. Rădulescu**, Combinatorial aspects of Connes's embedding conjecture and asymptotic distribution of traces of products of unitaries; **A. Sandovici**, Canonical extensions of symmetric linear relations; **L. Suciu**, Ergodic properties and saturation for A-contractions; **N. Suciu**, On the generalized Harnack domination for contractions; **L. Zielinski**, Semiclassical distributions of eigenvalues for elliptic operators with Hölder continuous coefficients, part II: critical case.

International Book Series of Mathematical Texts

August 2006, 274 pages, Hardcover, ISBN-10: 973-85432-9-0, ISBN-13: 978-973-85432-9-4, 2000 *Mathematics Subject Classification:* 46-06, 47-06, **All AMS members US$38**, List US$48, Order code THETA/9



H^∞ Functional Calculus and Square Functions on Noncommutative L^p-Spaces

Marius Junge, *University of Illinois, Urbana, IL*, and **Christian Le Merdy** and **Quanhua Xu**, *Université de Franche-Comté, Besançon, France*

The authors investigate sectorial operators and semigroups acting on noncommutative L^p-spaces. They introduce new square functions in this context and study their connection with H^∞ functional calculus, extending some famous work by Cowling, Doust, McIntoch and Yagi concerning *commutative* L^p-spaces. This requires natural variants of Rademacher sectoriality and the use of the matricial structure of noncommutative L^p-spaces. They mainly focus on noncommutative diffusion semigroups, that is, semigroups $(T_t)_{t\geq 0}$ of normal selfadjoint operators on a semifinite von Neumann algebra $(\mathcal{M},\tau)$ such that $T_t\colon L^p(\mathcal{M}) \to L^p(\mathcal{M})$ is a contraction for any $p \geq 1$ and any $t \geq 0$. They discuss several examples of such semigroups for which they establish bounded H^∞ functional calculus and square function estimates. This includes semigroups generated by certain Hamiltonians or Schur multipliers, q-Ornstein-Uhlenbeck semigroups acting on the q-deformed von Neumann algebras of Bozejko-Speicher, and the noncommutative Poisson semigroup acting on the group von Neumann algebra of a free group.

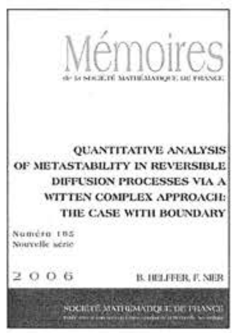
A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Noncommutative Hilbert space valued L^p-spaces; Bounded and completely bounded H^∞ functional calculus; Rademacher boundedness and related notions; Noncommutative diffusion semigroups; Square functions on noncommutative L^p-spaces; H^∞ functional calculus and square function estimates; Various examples of multipliers; Semigroups on q-deformed von Neumann algebras; A noncommutative Poisson semigroup; The non tracial case; Comparing row and column square functions; Measurable functions in $L^p(L^2)$; Bibliography.

Astérisque, Number 305

September 2006, 138 pages, Softcover, ISBN-10: 2-85629-189-9, ISBN-13: 978-2-85629-189-4, 2000 *Mathematics Subject Classification:* 47A60, 46L53, 46L55, 46L89, 47L25, **Individual member US$34**, List US$38, Order code AST/305

Differential Equations



Quantitative Analysis of Metastability in Reversible Diffusion Processes via a Witten Complex Approach

The Case with Boundary

Bernard Helffer, *Université Paris-Sud, Orsay, France*, and **Francis Nier**, *Université de Rennes 1, France*

This article is a continuation of previous works by Bovier-Eckhoff-Gayrard-Klein, Bovier-Gayrard-Klein and Helffer-Klein-Nier. The main object is the analysis of the small eigenvalues (as $h \to 0$) of the Laplacian attached to the quadratic form

$$C_0^\infty(\Omega) \ni v \to h^2 \int_\Omega |\nabla v(x)|^2\, e^{-2f(x)/h} dx,$$

where Ω is a bounded connected open set with C^∞-boundary and f is a Morse function on $M = \overline{\Omega}$. The previous works were devoted to the case of a manifold M which is compact but without boundary or $\mathbb{R}^n$. The authors' aim here is to analyze the case with boundary. After the introduction of a Witten cohomology complex adapted to the case with boundary, they give a very accurate asymptotics for the exponentially small eigenvalues. In particular, they analyze the effect of the boundary in the asymptotics.

This item will also be of interest to those working in geometry and topology and probability.

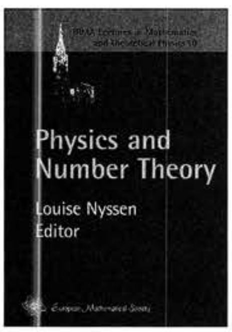
A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: Introduction; An appropriate self-adjoint realization of Witten Laplacians with boundary; First localization of the spectrum; Accurate WKB analysis near the boundary for $\Delta^{(1)}_{f,h}$; Saddle sets and main assumptions; Quasimodes; Result and final proof; An example in dimension 1; Biblliography.

Mémoires de la Société Mathématique de France, Number 105

October 2006, 89 pages, Softcover, ISBN-10: 2-85629-218-6, ISBN-13: 978-2-85629-218-1, 2000 *Mathematics Subject Classification:* 58J10, 58J32, 58J65, 60J60, 81Q10, 81Q20, **Individual member US$34**, List US$38, Order code SMFMEM/105

Number Theory



Physics and Number Theory

Louise Nyssen, *Université Montpellier II, France*, Editor

There is a rich and historical relationship between theoretical physics and number theory. This volume presents a selection of problems which are currently in full development and inspire a lot of research. Each of the seven contributions starts with an introductory survey which makes it possible even for non-specialists to understand the results and to gain an idea of the great variety of subjects and techniques used.

Topics covered are: phase locking in oscillating systems, crystallography, Hopf algebras and renormalisation theory, Zeta-function and random matrices, Kloosterman sums and the local Langlands correspondence.

Intended for research mathematicians and theoretical physicists as well as graduate students, this volume gives an overview of recent developments in an exciting subject crossing several disciplines.

This item will also be of interest to those working in mathematical physics.

A publication of the European Mathematical Society. Distributed within the Americas by the American Mathematical Society.

Contents: M. Planat, The phase of oscillations and prime numbers: classical and quantum; **J.-L. Verger-Gaugry**, On self-similar finitely generated uniformly discrete (SFU-)sets and sphere packings; **J.-P. Gazeau**, **Z. Masáková**, and **E. Pelantová**, Nested quasicrystalline discretisations of the line; **C. Bergbauer** and **D. Kreimer**, Hopf algebras in renormalization theory: locality and Dyson–Schwinger equations from Hochschild cohomology; **E. Royer**, Fonction ζ et matrices aléatoires; **P. Michel**, Some recent applications of Kloostermania; **A. Mézard**, Introduction à la correspondance de Langlands locale.

IRMA Lectures in Mathematics and Theoretical Physics, Volume 10

October 2006, 275 pages, Softcover, ISBN-10: 3-03719-028-0, ISBN-13: 978-3-03719-028-9, 2000 *Mathematics Subject Classification:* 11Fxx, 11Lxx, 11Mxx, 81Txx, 52Cxx, 68R15, **All AMS members US$38**, List US$48, Order code EMSILMTP/10

Classified Advertisements

Positions available, items for sale, services available, and more

ARIZONA

**ARIZONA STATE UNIVERSITY
Department of Mathematics and Statistics
Assistant Professor**

The Department of Mathematics and Statistics at Arizona State University invites applications for a tenure-track position at the assistant professor level beginning in the fall semester of 2006. Applicants are required to have a Ph.D. in the mathematical sciences with a research emphasis in probability and/or stochastic processes by August 14, 2007. Candidates must also have demonstrated potential for excellence in teaching at all levels. The successful candidate will be expected to conduct research and publish in the area of probability and/or its applications, provide quality teaching of undergraduate and graduate courses in probability and participate in on-campus interdisciplinary activities and appropriate professional service.

The Tempe campus of Arizona State University has approximately 49,000 students. It is located in the rapidly growing metropolitan Phoenix area, which provides a wide variety of recreational and cultural opportunities. The Department of Mathematics and Statistics currently has 51 full time faculty members and over 80 supported graduate students. Excellent computing resources are available in the department that include individual faculty workstations as well as access to the university's central computing facilities and the Fulton High Performance Computing Initiative.

The Department of Mathematics and Statistics has a strongly interdisciplinary oriented research profile that includes numerous collaborations and joint projects inside and outside the university. Current research strengths include large-scale dynamical systems with applications to weather prediction, mathematical biology and neurophysiology, medical imaging and manufacturing. The department is particularly interested in candidates who are able to collaborate in interdisciplinary research with current faculty in applications to the biological and medical sciences and to other applied sciences.

Demand for probabilistic research and instruction at ASU is continuing to increase. There are numerous opportunities for interdisciplinary collaboration, for example with TGen, the Biodesign Institute (which includes centers involving nanobiosciences, nanotechnology, bioengineering, genomics, and vaccinology), the Center for Environmental Studies, and many other projects spanning the social sciences, education, physical sciences, and medicine. The successful candidate will have a unique opportunity to help shape the future direction of the mathematical sciences at ASU.

Applications must be submitted online through `http://www.mathjobs.org`. All applications must include the following: i) a curriculum vita; ii) a personal statement addressing their research agenda; iii) a statement of teaching philosophy and iv) a completed AMS Standard Cover Sheet form. At least three letters of recommendation are also to be submitted at this site.

A background check is required for employment.

Review of the applications will begin on February 9, 2007; if not filled, weekly thereafter until the search is closed. Pending budgetary approval. AA/EOE.

000024

DISTRICT OF COLUMBIA

GEORGE WASHINGTON UNIVERSITY

In an effort to increase its research stature and expand its undergraduate and doctoral programs, the Mathematics Department of The George Washington University is recruiting a tenure-track associate professor in either applied mathematics or probability. The successful applicant is expected to teach at all undergraduate and graduate levels, excel in research, interact with researchers in mathematics or other disciplines, and become actively involved in the life of the department and the university. Basic Qualifications: Applicants must possess a Ph.D.; excellent teaching credentials as demonstrated by your teaching approach and either teaching evaluations or letters

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 2007 rate is \$100 per inch or fraction thereof on a single column (one-inch minimum), calculated from top of headline. Any fractional text of 1/2 inch or more will be charged at the next inch rate. 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: March 2007 issue–December 29, 2006; April 2007 issue–January 29, 2007; May 2007 issue–February 28, 2007; June/July 2007 issue–April 27, 2007; August 2007 issue–May 29, 2007; September 2007–June 28, 2007.

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.

from peers or supervisors; a record of excellent research as demonstrated by publications in research journals; the potential for leadership as demonstrated in your letters of recommendation. Preferred Qualifications: Preference will be given those applicants with prior research funding. For those applicants in applied mathematics, preference will be shown those applicants with experience in computing. To Apply: Send a brief cover letter, CV, synopsis of your research plans (not to exceed three pages), and evidence of good teaching (which should include an overview of your teaching approach) to: Professor John B. Conway, Associate Professor Search, Mathematics, Old Main, 1922 F Street NW, Washington DC 20052. Also arrange to have at least three letters of recommendation sent to the same address or to mathsrch@gwu.edu. Only complete applications will be considered. Review of applications began January 1, 2007, and continue until the position is filled. The George Washington University is an Equal Opportunity/Affirmative Action Employer and seeks to attract culturally diverse faculty of the highest caliber.

000013

GEORGE WASHINGTON UNIVERSITY

In an effort to increase its research stature and expand its undergraduate and doctoral programs, the Mathematics Department of The George Washington University is recruiting a tenure-track assistant professor in an area where the department has strength: applied mathematics, combinatorics, dynamical systems, logic, and topology. The successful applicant is expected to teach at all undergraduate and graduate levels, excel in research, interact with researchers in mathematics or other disciplines, and become actively involved in the life of the department and the university. Basic Qualifications: Applicants must possess a Ph.D. and good teaching credentials as demonstrated by your teaching approach and either teaching evaluations or letters from peers or supervisors. To Apply: Send a brief cover letter, CV, synopsis of your research plans (not to exceed three pages), and evidence of good teaching (which should include an overview of your teaching approach) to: Professor John B. Conway, Assistant Professor Search T, Mathematics, Old Main, 1922 F Street NW, Washington DC 20052. Also arrange to have at least three letters of recommendation sent to the same address or to mathsrch@gwu.edu. Only complete applications will be considered. Applicants with postdoctoral experience will be given preference. Review of applications began January 1, 2007, and willcontinue until the position is filled. The George Washington University is an Equal Opportunity/Affirmative Action Employer and seeks to attract culturally diverse faculty of the highest caliber.

000014

GEORGE WASHINGTON UNIVERSITY

In an effort to increase its research stature and expand its undergraduate and doctoral programs, the Mathematics Department of The George Washington University is recruiting for a three-year (renewable) contract position at the level of assistant professor in either applied mathematics or probability. The successful candidate is expected to teach at all undergraduate and graduate levels, do research, and become actively involved in the life of the department and the university. Basic Qualifications: Applicants must possess a Ph.D., have good research potential as evidenced by strong publications and letters of recommendation, and excellent teaching credentials as demonstrated by your approach to teaching and either teaching evaluations or letters from peers or supervisors. Preferred Qualifications: For those applicants in applied mathematics, preference will be shown those applicants with experience in computing. To Apply: Send a brief cover letter, CV, synopsis of your research plans (not to exceed three pages), and evidence of good teaching (which should include an overview of your teaching approach) to: Professor John B. Conway, Assistant Professor Search C, Mathematics, Old Main, 1922 F Street NW, Washington DC 20052. Also arrange to have at least three letters of recommendation (which should include an assessment of research potential) sent to the same address or to mathsrch@gwu.edu. Only complete applications will be considered. Review of applications began January 1, 2007, and will continue until the position is filled. The George Washington University is an Equal Opportunity/Affirmative Action Employer and seeks to attract culturally diverse faculty of the highest caliber.

000015

FLORIDA

FLORIDA ATLANTIC UNIVERSITY
Department of Mathematical Sciences

The Department of Mathematical Sciences at Florida Atlantic University invites applications fora tenure-track position at the assistant professor level, starting in August 2007. Preference will be given to applicants in the areas of control theory and dynamical systems, including computational methods and applications.

Responsibilities for this position will include research, professional service, teaching, and advising in our undergraduate, masters, and doctoral programs. Applicants must possess a Ph.D. in the mathematical sciences and must demonstrate strong evidence of research ability and experience in teaching. For information about the position, please contact us by email at search@math.fau.edu. The position will remain open until filled. Consideration is guaranteed for applications received by February 7, 2007.

Applicants should send an AMS cover sheet, a curriculum vitae, a statement describing their current and planned research, a dissertation summary and/or up to three preprints or reprints, and three letters of recommendation to: Search Committee, Florida Atlantic University, Department of Mathematical Sciences, 777 Glades Road, Boca Raton, FL 33431. Beginning December 11, 2006, the materials may be submitted electronically by logging onto: https://jobs.fau.edu/. Florida Atlantic University is an Equal Opportunity/Equal Access Institution.

000022

FLORIDA ATLANTIC UNIVERSITY
Department of Mathematical Sciences

The Department of Mathematical Sciences at Florida Atlantic University invites applicants for a tenure-track position as associate professor or assistant professor in bioinformatics. Florida Atlantic University is at the center of a large, exciting and rapidly growing research community in the biomedical sciences. Scripps Florida, a branch of the La Jolla-based world leader in biomedical research, is located on an FAU campus, and has already developed strong research ties with the university. Other research organizations, both for-profit and non-profit, will be joining them in our area.

Responsibilities for this position will be teaching, scholarly research, and professional service. The successful candidate will be expected to collaborate with researchers in related disciplines and with the local research community outside the university. Applicants must possess a Ph.D. in mathematics or a related field, teaching experience, and a record of scholarly publications; demonstrated ability to obtain federal research funding is desirable. For more information about the position, please email: search@math.fau.edu. The position will remain open until filled. Consideration is guaranteed for applications received by February 7, 2007.

Applicants should send an AMS cover sheet, a curriculum vitae, and 3 letters of recommendation to: Search Committee, Florida Atlantic University, Department of Mathematical Sciences, 777 Glades Road, Boca Raton, FL 33431. Beginning December 11, 2006, the materials may be submitted electronically by logging onto: https://jobs.fau.edu/. Florida Atlantic University is an Equal Opportunity/Equal Access Institution.

000023

MISSISSIPPI

UNIVERSITY OF MISSISSIPPI
Department of Mathematics

The department of mathematics seeks to fill a tenure-track Assistant Professor position, beginning August 2007. All candidates should have a Ph.D. (or equivalent) by August 2007 in mathematics or statistics, and outstanding potential in both research and teaching. Candidates whose research interests are in the areas of statistics, algebra, and differential equations are sought. The successful applicant will teach 6 hours per semester and is also expected to conduct a vigorous research program. Applicants should complete the application form, cover letter, and curriculum vitae online at: http://jobs.olemiss.edu. At least one page of a statement on the applicant's research interest, three letters of recommendation about the applicant's research, and at least one letter of recommendation about the applicant's teaching must be sent to:

University of Mississippi
Department of Mathematics
Chairman of Tenure Track Search Committee
305 Hume Hall
University, MS 38677 USA

The letters of recommendation must be submitted directly by the referees. Inquiries about this position may be sent to mdepart@pop.olemiss.edu.

Screening of applications will begin immediately and will continue until the position is filled. For information about the department please visit http://www.olemiss.edu/depts/mathematics and for information about the University of Mississippi see http://www.olemiss.edu/.

The University of Mississippi is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA employer.

000016

UNIVERSITY OF MISSISSIPPI
Department of Mathematics

The department of mathematics seeks to fill a tenure-track assistant professor position in functional analysis, beginning August 2007. All candidates should have a Ph.D. in mathematics by August 2007. We seek candidates with outstanding potential in both research and teaching. Candidates whose research interests coincide with those of existing faculty will be given preference. The successful applicant will teach 6 hours per semester and is also expected to conduct a vigorous research program.

Applicants should complete the application form, cover letter, and curriculum vitae online at http://jobs.olemiss.edu. A statement of at least one page on the applicant's research interests, three letters of recommendation about the applicant's research, and at least one letter of recommendation about the applicant's teaching must be sent to:

University of Mississippi
Department of Mathematics
Chairman of Tenure Track Search Committee
305 Hume Hall
University, MS 38677 USA

The letters of recommendation must be submitted directly by the referees. Inquiries about this position may be sent to mdepart@pop.olemiss.edu. Screening of applications will begin immediately and will continue until the position is filled. For information about the department please visit http://www.olemiss.edu/depts/mathematics and for information about the University of Mississippi see http://www.olemiss.edu.

The University of Mississippi is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA employer.

000017

NEW JERSEY

RUTGERS UNIVERSITY-NEW BRUNSWICK
Mathematics Department

The Mathematics Department of Rutgers University-New Brunswick invites applications for the following position/s which may be available September 2007 subject to availability of funding.

TENURE-TRACK ASSISTANT PROFESSORSHIP: Subject to availability of funding, the department may be able to make one or more appointments at this level. Candidates with interests in numerical analysis/scientific computation, mathematics of materials science, algebra, differential geometry, or mathematical biology are especially encouraged to apply, although strong candidates in all fields will be considered. Candidates should have received the Ph.D., show outstanding research accomplishments in pure or applied mathematics, and demonstrate concern for teaching. The normal annual teaching load for research-active faculty is two courses for one semester, plus one course for the other semester. Review of applications begins December 15, 2006.

Applicants should send a printed resumé with AMS Application Cover Sheet attached and have four letters of recommendation (one of which evaluates teaching) sent to: Search Committee-TTAF, Dept. of Math-Hill Center, Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. In addition, an electronic version of the AMS Application Cover Sheet should also be submitted at the website http://www.mathjobs.org/jobs. It is essential that applicants fill out this cover sheet completely, including specific position(s) applied for and the AMS Subject Classification number(s) of area(s) of specialization.

The department will begin reviewing applications on the dates listed above, and will continue its review until the positions are filled. Updated details of 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.

000019

OHIO

THE OHIO STATE UNIVERSITY
Assistant Professors in Mathematical Biology/ Evolution and Ecology
Department of Evolution, Ecology, & Organismal Biology (EEOB)
Department of Mathematics

The Department of Evolution, Ecology, and Organismal Biology (EEOB) and the Department of Mathematics invite applications for two tenure-track positions as Assistant Professor in Mathematical Biology. While these positions will be joint hires between the two departments, one position will be tenure-eligible in EEOB and the other in mathematics. Preference will be given to individuals with interests in areas related to strengths within the Department of EEOB, which include ecology, population biology, population genetics, systematics and evolution, fisheries and aquatic ecology, biodiversity conservation, and behavioral biology. The successful applicants will develop strong, externally funded interdisciplinary research programs, train graduate students, and contribute to undergraduate and graduate teaching. The appointees will be part of a growing faculty in the area of mathematical biology at OSU, with opportunities to participate in the activities of the Mathematical Biosciences Institute, an NSF-funded National Institute located at The Ohio State University. Through research and teaching, the appointees will contribute to bridging biology and mathematics at OSU. Exceptional candidates at the rank of Associate or Full Professor also may be considered. Flexible work options are available.

Applicants should submit their curriculum vitae, statement of research and teaching interests, and contact information for three references online to: http://www.math.ohio-state.edu/applications/eeob/ or by mail to:

The Ohio State University
Department of Evolution, Ecology and Organismal Biology
Chair, Mathematical Biology Search

318 W. 12th Avenue
Columbus, OH 43210

Review of applications begins December 15, 2006, and will continue until suitable candidates are hired. To build a diverse workforce Ohio State encourages applications from individuals with disabilities, minorities, veterans, and women. EEO/AA employer.

000020

COLOMBIA

UNIVERSIDAD DE LOS ANDES
Department of Mathematics
Regular and visiting positions

The Department of Mathematics invites applications for positions at the tenure-track assistant professor level and visiting professor to begin in August 2007. All areas of pure and applied mathematics will be considered but preference will be given to analysis, algebra, differential and algebraic geometry, probability and statistics. Applicants are required to have a Ph.D. in the mathematical sciences and be able to develop a significant research program. A strong commitment with undergraduate and graduate teaching is also required. Duties include courses for undergraduate students in natural sciences, engineering, and economics; graduate courses in mathematics; and the eventual supervising of undergraduate, master or Ph.D. theses. The department offers internationally competitive salaries with start-up grants for research. Proficiency in Spanish is desirable. Please send an AMS Standard Cover Sheet, curriculum vitae, research plan, teaching statement, and three letters of recommendation to:

Faculty Hiring
Department of Mathematics
Universidad de los Andes
A.A. 4976
Bogotá, Colombia

Electronic submission can also be sent to: `matema@uniandes.edu.co`. Applicants interested in any further information regarding the Mathematics Department at Los Andes please visit the website: `http://matematicas.uniandes.edu.co/`. Preference will be given to applicants whose applications are submitted by March 8, 2007. Review of applications will continue until positions are filled.

000018

TAIWAN

NATIONAL TAIWAN UNIVERSITY
Department of Mathematics

The Department of Mathematics at the National Taiwan University invites applications for several openings at the levels of tenure-track assistant, associate and full professors in the research areas of pure mathematics, computational and applied mathematics, probability and financial mathematics, statistical sciences and other related areas beginning August 1, 2007. The department also invites applications for several post-doctoral positions in all research areas beginning August 1, 2007. Applicants for all positions should send a letter of application, an up-to-date curriculum vitae, recent publications, and three letters of recommendation to:

Office
Department of Mathematics
National Taiwan University
No. 1, Sec. 4, Roosevelt Rd.
Taipei City 10617, Taiwan (R.O.C.)
Tel: (+886) 2-33662815
Fax: (+886) 2-23914439
email: `mailbox@math.ntu.edu.tw`

Applicants should specify clearly on the letter of application the position(s) they are applying for. Complete applications received before February 15, 2007, will receive full consideration. For more information about the department please consult the Web at `http://www.math.ntu.edu.tw`.

000021

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.

Davidson, North Carolina

Davidson College

March 3–4, 2007

Saturday – Sunday

Meeting #1024

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: January 2007
Program first available on AMS website: January 18, 2007
Program issue of electronic *Notices*: March 2007
Issue of *Abstracts*: Volume 28, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses

Nigel Boston, University of South Carolina and University of Wisconsin, Madison, *Novel applications of algebra to engineering.*

Chaim Goodman-Strauss, University of Arkansas at Fayetteville, *Growth, aperiodicity, and undecidability.*

Andrew J. Granville, University of Montreal, *Erdős's dream and pretentious characters* (Erdős Memorial Lecture).

Alex Iosevich, University of Missouri-Columbia, *Analysis, combinatorics, and arithmetic of incidence theory.*

Shrawan Kumar, University of North Carolina, *Eigenvalue problem for Hermitian matrices and its generalization to arbitrary reductive groups.*

Special Sessions

Algebraic and Extremal Combinatorics, **Gábor Hetyei**, University of North Carolina-Charlotte, and **László A. Székely**, University of South Carolina.

Applicable Algebra, **Nigel Boston**, University of South Carolina, and **Hiren Maharaj**, Clemson University.

Between Harmonic Analysis, Number Theory, and Combinatorics, **Alex Iosevich**, University of Missouri-Columbia, **Michael T. Lacey**, Georgia Institute of Technology, and **Konstantin Oskolkov**, University of South Carolina.

Commutative Algebra and Algebraic Geometry, **Florian Enescu**, Georgia State University, and **Andrew R. Kustin** and **Adela N. Vraciu**, University of South Carolina.

Commutative Rings and Monoids, **Evan G. Houston** and **Thomas G. Lucas**, University of North Carolina, Charlotte.

Computational Group Theory, **Arturo Magidin**, University of Louisiana at Lafayette, **Luise Charlotte Kappe**, Binghamton University, and **Robert F. Morse**, University of Evansville.

Computational and Combinatorial Aspects of Tiling and Substitutions, **Chaim Goodman-Strauss**, University of Arkansas, **Casey Mann**, University of Texas at Tyler, and **Edmund O. Harriss**, Queen Mary University of London.

Dynamical Systems, **Emily B. Gamber**, Santa Fe Institute, **Donna K. Molinek**, Davidson College, and **James S. Wiseman**, Agnes Scott College.

Geometric and Combinatorial Methods in Representation Theory, **Brian Boe** and **William A. Graham**, University of Georgia, and **Kailash C. Misra**, North Carolina State University.

Microlocal Analysis and Partial Differential Equations (in Honor of Michael E. Taylor's 60th Birthday), **Anna L. Mazzucato**, Pennsylvania State University, and **Martin Dindos**, University of Edinburgh.

Noncommutative Algebra, **Ellen E. Kirkman** and **James J. Kuzmanovich**, Wake Forest University, and **James Zhang**, University of Washington.

Recent Applications of Numerical Linear Algebra, **Timothy P. Chartier**, Davidson College, and **Amy Langville**, College of Charleston.

Representation Theory and Galois Cohomology in Number Theory, **Ján Mináč**, University of Western Ontario, and **John R. Swallow**, Davidson College.

Stochastic Analysis and Applications, **Armando Arciniéga**, University of Texas at San Antonio.

Oxford, Ohio

Miami University

March 16–17, 2007

Friday – Saturday

Meeting #1025

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: January 2007
Program first available on AMS website: February 1, 2007
Program issue of electronic *Notices*: March 2007
Issue of *Abstracts*: Volume 28, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: January 23, 2007

Invited Addresses

Sergey Fomin, University of Michigan, *Title to be announced.*

Naichung Conan Leung, University of Minnesota, *Title to be announced.*

Emil J. Straube, Texas A&M University, *Title to be announced.*

Shouhong Wang, Indiana University, *Title to be announced.*

Special Sessions

Combinatorial and Geometric Group Theory (Code: SS 5A), **John Donnelly**, Mount Union College, and **Daniel Farley**, Mathematisches Institut Einsteinstrasse and Miami University.

Complex Dynamics and Complex Function Theory (Code: SS 9A), **Stephanie Edwards**, University of Dayton, and **Rich Lawrence Stankewitz**, Ball State University.

Finite Geometry and Combinatorics (Code: SS 3A), **Mark A. Miller**, Marietta College.

Geometric Topology (Code: SS 2A), **Jean-Francois LaFont**, Ohio State University, and **Ivonne J. Ortiz**, Miami University.

Graph Theory (Code: SS 4A), **Tao Jiang**, **Zevi Miller**, and **Dan Pritikin**, Miami University.

Large Cardinals in Set Theory (Code: SS 1A), **Paul B. Larson**, Miami University, **Justin Tatch Moore**, Boise State University, and **Ernest Schimmerling**, Carnegie Mellon University.

Noncommutative Algebraic Geometry (Code: SS 7A), **Dennis S. Keeler**, Miami University, **Rajesh Shrikrishna Kulkarni**, Michigan State University, and **Daniel S. Rogalski**, University of California San Diego.

Optimization Theory and Applications (Code: SS 11A), **Olga Brezhneva** and **Doug E. Ward**, Miami University.

PDE Methods in Several Complex Variables (Code: SS 6A), **Jeffery D. McNeal**, Ohio State University, and **Emil J. Straube**, Texas A&M University.

Quantum Topology (Code: SS 13A), **Sergei Chmutov** and **Thomas Kerler**, Ohio State University.

Random Matrices and Non-commutative Probability (Code: SS 12A), **Wlodzimierz Bryc**, University of Cincinnati, and **Narcisse J. Randrianantoanina**, Miami University.

Spectral Theory, Orbifolds, Symplectic Reduction and Quantization. (Code: SS 15A), **William Kirwin**, University of Notre Dame, and **Christopher Seaton**, Rhodes College.

Theoretical and Numerical Issues in Fluid Dynamics (Code: SS 14A), **Jie Shen**, Purdue University, and **Shouhong Wang**, Indiana University.

Time Scales: Theory and Applications (Code: SS 10A), **Ferhan M. Atici**, Western Kentucky University, and **Paul W. Eloe**, University of Dayton.

Vector Measures, Banach Spaces and Applications (Code: SS 8A), **Patrick N. Dowling**, Miami University, and **Christopher J. Lennard**, University of Pittsburgh.

Hoboken, New Jersey

Stevens Institute of Technology

April 14–15, 2007

Saturday – Sunday

Meeting #1026

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: February 2007
Program first available on AMS website: March 8, 2007
Program issue of electronic *Notices*: April 2007
Issue of *Abstracts*: Volume 28, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: February 27, 2007

Invited Addresses

Neal Koblitz, University of Washington, *Stormy marriage—A periodizaton of the history of the relationship between mathematics and cryptography.*

Florian Luca, Universidad Nacional Autónoma de México, *Values of arithmetic functions.*

Natasa Pavlovic, Princeton University, *The enigma of the equations of fluid motion: A survey of existence and regularity results.*

Elisabeth Werner, Case Western Reserve University, *Convex bodies: Best and random approximation.*

Special Sessions

Affine Invariants, Randomness, and Approximation in Convex Geometry (Code: SS 2A), **Elisabeth Werner**, Case Western Reserve University, and **Artem Zvavitch**, Kent State University.

Automorphic Forms and Arithmetic Geometry (Code: SS 5A), **Gautam Chinta**, City College of New York, and **Paul E. Gunnells**, University of Massachusetts, Amherst.

Combinatorial Algebraic Geometry (Code: SS 9A), **Angela C. Gibney**, University of Pennsylvania, and **Diane Maclagan**, Rutgers University.

Convex Sets (Code: SS 1A), **David Larman**, University College London, and **Valeriu Soltan**, George Mason University.

Differential Algebra (Code: SS 4A), **Phyllis J. Cassidy**, Smith College and The City College of CUNY, **Richard C. Churchill**, Hunter College and The Graduate Center of CUNY, **Li Guo** and **William F. Keigher**, Rutgers University at Newark, and **Jerald J. Kovacic** and **William Sit**, The City College of CUNY.

Fourier Analysis and Convexity (Code: SS 3A), **Alexander Koldobsky**, University of Missouri Columbia, and **Dmitry Ryabogin**, Kansas State University.

Graph Theory and Combinatorics (Code: SS 11A), **Daniel J. Gross**, **Nathan W. Kahl**, and **John T. Saccoman**, Seton Hall University, and **Charles L. Suffel**, Stevens Institute of Technology.

History of Mathematics on Leonhard Euler's Tercentenary (Code: SS 8A), **Patricia R. Allaire**, Queensborough Community College, CUNY, and **Robert E. Bradley** and **Lee J. Stemkoski**, Adelphi University.

Languages and Groups (Code: SS 6A), **Sean Cleary**, The City College of New York and CUNY Graduate Center, **Murray J. Elder**, Stevens Institute of Technology, and **Gretchen Ostheimer**, Hofstra University.

Mathematical Aspects of Cryptography (Code: SS 7A), **Robert H. Gilman**, Stevens Institute of Technology, **Neal I. Koblitz**, University of Washington, and **Susanne Wetzel**, Stevens Institute of Technology.

Nonlinear Waves in Dissipative/Dispersive Media (Code: SS 12A), **Keith S. Promislow**, Michigan State University, and **Yi Li**, Stevens Institute of Technology.

Number Theory (Code: SS 10A), **Florian Luca**, Universidad Nacional Autónoma de México, and **Allison M. Pacelli**, Williams College.

Accommodations

Participants should make their own arrangements directly with a hotel of their choice. Special rates have been negotiated at the hotels listed below. Rates quoted do not include sales tax of 14%. The AMS is not responsible for rate changes or for the quality of the accommodations. When making a reservation, participants should state that they are with the **American Mathematical Society (AMS) Meeting at Stevens Institute**. Cancellation and early checkout penalties vary with each hotel; be sure to check the policy when you make your reservations.

N.B. The number of rooms available at these prices in these hotels is limited! Call early to ensure your reservation.

Participants may choose to take the PATH transit system (the station is about one to two blocks from these hotels) to the Stevens campus. The ride takes a few minutes and will drop you off six streets from the campus (see Travel below). The PATH system will also take you into the heart of New York City in about ten minutes: `www.panynj.gov/CommutingTravel/path/html/index.html`.

DoubleTree Club Suites, 455 Washington Blvd., Jersey City, NJ 07310, 201-499-2400, fax: 201-499-2406. US$169/single or double; comfortable all-suites facility with many amenities (in-room microwave, refrigerator, high-speed Internet access) including a bar and restaurant serving New American cuisine; fitness center; Newport Center Mall within walking distance; parking is US$10/daily; about three miles from campus. **The deadline for reservations is March 1, 2007.** Be sure to check the policy for cancellation and early checkout penalties when you make your reservations: `www.doubletree.com/jerseycityclubsuites.doubletree.com`.

Jersey City-Newport Courtyard by Marriott, 540 Washington Blvd., Jersey City, NJ 07310, 201-626-6600, fax: 201-626-6601. US$129/single, double, triple, quad; rooms have one king-sized bed and one sleeper sofa, and complimentary high-speed Internet access; on-site fitness center; café open for breakfast and dinner; parking is US$14/daily. **The deadline for reservations is March 1, 2007.** Be sure to check the policy for cancellation and early checkout penalties when you make your reservations: `http://marriott.com/property/propertypage/EWRNW`.

Food Service, Local Information, and Campus Map

Campus dining facilities in the Howe Center will be open for breakfast, lunch, and dinner during the meeting. More information on local restaurants will be included in the program. The Stevens website is at `www.stevens.edu`. The Department of Mathematical Sciences site is at `www.math.stevens.edu/`. A full campus map is at `www.stevens.edu/main/maps/campus_map.shtml`.

Other Activities

AMS Book Sale: Examine the newest titles from the AMS. Most books will be available at a special 50% discount offered only at meetings. Complimentary coffee will be served courtesy of AMS membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Reception

On Saturday all participants are invited to a reception hosted by the Department of Mathematical Sciences. The Society thanks the department for its gracious hospitality.

Registration and Meeting Information

The meeting is on the campus of Stevens Institute of Technology, Hoboken, New Jersey. Registration and exhibits will be in the Burchard Building, on Saturday from 7:30 a.m. to 4:30 p.m. and Sunday from 8:00 a.m. to noon. All sessions will take place in Burchard and the Edward A. Stevens Building.

Registration fees (payable on site only) are US$40/AMS or CMS members; US$60/nonmembers; US$5/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Parking

Do not park on the side of the streets requiring permits! Violators will be ticketed and "booted" (illegal parking fine is US$126; if your car is booted and towed, towing charges will also apply). Participants may find the metered parking side of the street to be inconvenient because they require frequent (every two to four hours) insertion of coins. Watch the AMS website at `www.ams.org/amsmtgs/sectional.html` for update on available parking options.

Travel

The closest airport is Newark Liberty International Airport, located about ten miles from the Stevens campus: `www.newarkliberty.com/CommutingTravel/airports/html/newarkliberty.html`.

Taxi fare to campus is approximately US$35 and the trip takes about 20-30 minutes. You may also take New Jersey Transit's bus service (800-772-3606) to Penn Station, Newark. Take the PATH train for US$1.50 to Exchange Place and switch to the train for Hoboken (HOB). From the Hoboken station, Stevens is a 10-minute walk up River St. or about a US$5 ride by taxi.

Taxi fare from the airport to the hotels cited above is about US$40.

Driving directions: From the north: 1-95 south to the New Jersey Turnpike south, Exit 17-Lincoln Tunnel. Or, the Garden State Parkway south, Exit 153-Route 3 east will turn into Route 495 east going toward the Lincoln Tunnel. Exit at "Weehawken/Hoboken–Last Exit in NJ". Get in the right lane, go to the bottom of the hill and turn right. Proceed straight to 14th Street following the signs for Hoboken.

From all points south and west: Take the Garden State Parkway or the New Jersey Turnpike north, Exit 16E (if coming from the south) or Exit 17 (if coming from the west) to Route 3 east to Route 495-Lincoln Tunnel and follow as above.

From Long Island and New York City: Take the Midtown Tunnel to the Lincoln Tunnel. Bear to extreme right at the end of the tunnel. Exit immediately at "Hoboken-Local Streets" and proceed straight to 14th Street in Hoboken.

Once at 14th Street in Hoboken, turn left at the traffic light onto 14th St. Proceed to the end and turn right onto Hudson St. Go through several traffic lights, staying right at the fork. Turn left onto 9th St., then two blocks to Castle Point Terrace. When in doubt, just follow the red "Stevens" signs located at entrances to and throughout Hoboken. Watch the meeting website for updates on available parking lots.

By train: New Jersey Transit trains stop at the Hoboken station. All other trains stop at Penn Station, Newark, or Penn Station, New York City. From Newark take a cab to campus for about US$30 or the Path train for US$1.50 to Exchange Place and switch trains to Hoboken (HOB). From New York City walk one block to 33rd St. and take the PATH train for US$1.50 to Hoboken. From the Hoboken station, Stevens is a 10-minute walk up River St. Taxi fare is about US$5.

Car Rental

Avis is the official car rental company for the sectional meeting in Hoboken, NJ.

All rates include unlimited free mileage. Weekend daily rates are available from noon Thursday–Monday at 11:59 p.m. Rates for this meeting are effective April 7–22, 2007 and begin at US$56/day (weekend rate). Should a lower qualifying rate become available at the time of booking, Avis is pleased to offer a 5% discount off the lower qualifying rate or the meeting rate, whichever is lowest. Rates do not include any state or local surcharges, tax, optional coverages, or gas refueling charges. Renters must meet Avis' age, driver, and credit requirements. Reservations can be made by calling 800-331-1600 or online at `www.avis.Acom`. Meeting Avis Discount Number **B159266**.

Weather

Typical spring weather in the New York City area is about 60ºF with cooler evenings.

Information for International Participants

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the U.S. found at `http://www7.nationalacademies.org/visas/Traveling_to_US.html` and `http://travel.state.gov/visa/index.html`. If you need a preliminary conference invitation in order to secure a visa, please send your request to `dls@ams.org`.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of "binding" or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:

- family ties in home country or country of legal permanent residence

- property ownership

- bank accounts

- employment contract or statement from employer stating that the position will continue when the employee returns;

* Visa applications are more likely to be successful if done in a visitor's home country than in a third country;

* Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;

* Include a letter of invitation from the meeting organizer or the U.S. host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;

* If travel plans will depend on early approval of the visa application, specify this at the time of the application;

* Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the websites above for the most up-to-date information.

Tucson, Arizona

University of Arizona

April 21-22, 2007
Saturday - Sunday

Meeting #1027

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: February 2007
Program first available on AMS website: March 8, 2007
Program issue of electronic *Notices*: April 2007
Issue of *Abstracts*: Volume 28, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: February 27, 2007

Invited Addresses

Liliana Borcea, Rice University, *Title to be announced.*

James Cushing, University of Arizona, Tucson, *Title to be announced.*

Hans Lindblad, University of California, San Diego, *The weak null condition and global existence for Einstein's equations.*

Vinayak Vatsal, University of British Columbia, Vancouver, *Title to be announced.*

Special Sessions

Advances in Spectral Theory of Operators (Code: SS 12A), **Roger Roybal**, California State University, Channel Islands, and **Michael D. Wills**, Weber State University.

Algebraic Combinatorics (Code: SS 14A), **Helene Barcelo** and **Susanna Fishel**, Arizona State University.

Automorphisms of Curves (Code: SS 4A), **Aaron D. Wootton**, University of Portland, **Anthony Weaver**, Bronx Community College, and **S. Allen Broughton**, Rose-Hulman Institute of Technology.

Graph Theory and Combinatorics (Code: SS 9A), **Sebastian M. Cioaba**, University of California at San Diego, and **Joshua Cooper**, University of South Carolina.

Inverse Problems for Wave Propagation (Code: SS 2A), **Liliana Borcea**, Rice University.

Mathematical Modeling in Biology and Medicine (Code: SS 3A), **Carlos Castillo-Chavez, Yang Kuang, Hal L. Smith**, and **Horst R. Thieme**, Arizona State University.

Moduli Spaces and Invariant Theory (Code: SS 7A), **Philip Foth** and **Yi Hu**, University of Arizona.

New Developments and Directions in Random Matrix Theory (Code: SS 13A), **Peter David Miller**, University of Michigan, and **Estelle Basor**, California Polytechnic State University.

Number Theory in the Southwest (Code: SS 10A), **Dinesh S. Thakur** and **Douglas L. Ulmer**, University of Arizona.

Operator Algebras (Code: SS 6A), **Steven P. Kaliszewski**, **Jack Spielberg**, and **John C. Quigg**, Arizona State University.

Partial Differential Equations and Geometric Analysis (Code: SS 11A), **Sunhi Choi**, **Lennie Friedlander**, and **David Alan Glickenstein**, University of Arizona.

Representations of Algebras (Code: SS 1A), **Frauke Maria Bleher**, University of Iowa, **Birge K. Huisgen-Zimmermann**, University of California Santa Barbara, and **Dan Zacharia**, Syracuse University.

Special Functions and Orthogonal Polynomials (Code: SS 15A), **Diego Dominici**, State University of New York at New Paltz, and **Robert S. Maier**, University of Arizona.

Spectral Analysis on Singular and Noncompact Manifolds (Code: SS 8A), **Juan Bautista Gil** and **Thomas Krainer**, Pennsylvania State University.

Subjects in and Around Fluid Dynamics (Code: SS 5A), **Robert Owczarek**, Los Alamos National Laboratory, and **Mikhail Stepanov**, University of Arizona.

Accommodations:

Participants should make their own arrangements directly with the hotel of their choice and state that they will be attending the American Mathematical Society (AMS) meeting at the University of Arizona and ask for the **University rate**. The AMS is not responsible for rate changes or for the quality of the accommodations. Rates quoted do not include taxes. Hotels have varying cancellation or early checkout penalties; be sure to ask for details when making your reservation.

Embassy Suites Hotel, 5335 E. Broadway, Tucson, AZ 85711-3703 ; 520-745-2700 or 800-362-2779; US$139/single or double, US$149/triples, US$159/quads. **The deadline for reservations is March 23, 2007.** For further information please visit: http://www.embassysuites.com/en/es/hotels/index.jhtml?ctyhocn=TUSBWES.

Marriott University Park, 880 E. Second St., Tucson, AZ 85719; 520-792-4100 or 800-228-9290; US$150/single or double (2 ppl/1bed), doubles with 2 beds are US$165/triples, and US$175/quads; walking distance to meeting. **The deadline for reservations is March 23, 2007.** For further information please visit: http://www.marriotttucson.com/?source=adwords.

Four Points Sheraton, 1900 E. Speedway, Tucson, AZ 85719; 520-327-7341 or 800-843-8052; US$109/single or double; walking distance to meeting. **The deadline for reservations is March 23, 2007.** For further information please visit: http://www.starwoodhotels.com/fourpoints/property/overview/index.html?propertyID=97506.

Food Service

There are a number of restaurants adjacent to the campus. A list of restaurants will be available at the registration desk. The Student Union hours for Saturday and Sunday are on an average 11:00 a.m. to 8:00 p.m.

Local Information

Please visit the website maintained by the Department of Mathematics at www.math.arizona.edu/ and the University of Arizona website at www.arizona.edu.

Other Activities

AMS Book Sale: Examine the newest titles from AMS! Complimentary coffee will be served, courtesy of AMS Membership Services. The AMS Book Sale will operate during the same hours as registration. The book sale is in the Manuel Pacheco Integrated Learning Center.

AMS Editorial Activity: An acquisitions editor from the AMS Book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS please stop by the book exhibit.

Parking

Please refer to the web address http://parking.arizona.edu/pdf/maps/visitor.pdf for parking information. The nearest parking lot/structure is at the 2nd Street garage.

Registration and Meeting Information

The registration desk will be located in the Manuel Pacheco Integrated Learning Center and will be open 7:30 a.m. to 4:00 p.m. on Saturday and 8:00 a.m. to noon on Sunday. Talks will take place in the Manuel Pacheco Integrated Learning Center and the Modern Languages Building.

Registration fees: (payable on-site only) US$40/AMS members; US$60/nonmembers; US$5/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, Mastercard, Discover, or American Express.

Travel

By Air: The Tucson International Airport is served by most major airlines. Service to the University of Arizona campus is provided by Stagecoach Shuttle at a cost of approximately US$32 per person. Taxi fare is approximately US$25.

Driving: Take the Speedway exit from the I-10 freeway and proceed east approximately 2.5 miles to Euclid Avenue. Turn right (south) and continue to 6th Street; take a left (east to Santa Rita (approximately 4 blocks)); make a left (north) on Santa Rita and the Math Building will be directly ahead.

Car Rental

Avis is the official car rental company for the sectional meeting in Tucson, AZ.

All rates include unlimited free mileage. Weekend daily rates are available from noon Thursday–Monday at 11:59 p.m. and start at US$30 per day. Rates for this meeting are effective April 14, 2007–April 9, 2007. Should a lower qualifying rate become available at the time of booking, Avis is pleased to offer a 5% discount off the lower qualifying rate or the meeting rate, whichever is lowest. Rates do not include any state or local surcharges, tax, optional coverages or gas refueling charges. Renters must meet Avis' age, driver, and credit requirements. Reservations can be made by calling 800-331-1600 or online at www.avis.com. Meeting Avis Discount Number **B159266**.

Weather

Temperatures vary from 50ºF at the beginning of April to 75ºF towards the end of the month. For up-to-date weather information visit: http://nimbo.wrh.noss.gov/Tucson/twc.html.

Information for International Participants

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the U.S. found at `http://www7.nationalacademies.org/visas/Traveling_to_US.html` and `http://travel.state.gov/visa/index.html`. If you need a preliminary conference invitation in order to secure a visa, please send your request to `dls@ams.org`.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of "binding" or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:

- family ties in home country or country of legal permanent residence

- property ownership

- bank accounts

- employment contract or statement from employer stating that the position will continue when the employee returns;

* Visa applications are more likely to be successful if done in a visitor's home country than in a third country;

* Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;

* Include a letter of invitation from the meeting organizer or the U.S. host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;

* If travel plans will depend on early approval of the visa application, specify this at the time of the application;

* Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the websites above for the most up-to-date information.

Zacatecas, Mexico

Universidad Autónoma de Zacatecas

May 23–26, 2007

Wednesday – Saturday

Meeting #1028

Seventh Joint International Meeting of the AMS and the Sociedad Matematica Mexicana.
Associate secretary: Matthew Miller
Announcement issue of *Notices*: March 2007
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

Warsaw, Poland

University of Warsaw

July 31 – August 3, 2007

Tuesday – Friday

Meeting #1029

First Joint International Meeting between the AMS and the Polish Mathematical Society
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Henryk Iwaniec, Rutgers University, *Title to be announced.*

Tomasz J. Luczak, Adam Mickiewicz University, *Title to be announced.*

Tomasz Mrowka, Massachusetts Institute of Technology, *Title to be announced.*

Ludomir Newelski, University of Wroclaw, *Title to be announced.*

Madhu Sudan, Massachusetts Institute of Technology, *Title to be announced.*

Anna Zdunik, Warsaw University, *Title to be announced.*

Special Sessions

Complex Analysis and Operator Theory, **Zeljko Cuckovic**, University of Toledo, **Zbigniew Blocki**, Jagiellonian University, **Marek Ptak**, University of Agriculture.

Complex Dynamics, **Robert Devaney**, Boston University, **Jane N. Hawkins**, University of North Carolina, and **Janina Kotus**, Warsaw University of Technology.

Complexity of Multivariate Problems, **Joseph F. Traub**, Columbia University, **Grzegoorz W. Wasilkowski**, University of Kentucky, **Henryk Wozniakowski**, Columbia University.

Control and Optimization of Non-linear PDE Systems, **Irena Lasiecka**, University of Virginia, **Jan Sokolowski**, Systems Research Institute.

Dynamical Systems, **Steven Hurder**, University of Illinois at Chicago, **Michal Misiurewicz**, Indiana University-Purdue Univ Indianapolis, and **Pawel Walczak**, University of Lodz.

Ergodic Theory and Topological Dynamics, **Dan Rudolph**, Colorado State University, **Mariusz Lemanczyk**, Nicholas Copernicus University.

Extremal and Probabilistic Combinatorics, **Joel Spencer**, New York University-Courant Institute, **Michal Karonski**, Adam Mickiewicz University, **Andrzej Rucinski**, Adam Mickiewicz University.

Geometric Applications of Homotopy Theory, **Yuli B. Rudyak**, University of Florida, **Boguslaw Hajduk**, Warsaw University, **Jaroslaw Kedra**, University of Aberdeen, and **Aleksy Tralle**, The College of Economics & Comp Science.

Geometric Function Theory, **Michael Dorff**, Brigham Young University, **Piotr Liczberski**, University of Lodz, **Maria Nowak**, Biblioteka Instytutu Matematyki, **Ted Suffridge**, University of Kentucky.

Geometric Group Theory, **Mladen Bestvina**, University of Utah, **Tadeusz Januszkiewicz**, Ohio State University, and **Jacek Swiatkowski**, University of Wroclaw.

Invariants of Links and 3-Manifolds, **Mieczyslaw Dabkowski**, University of Texas at Dallas, **Jozef H. Przytycki**, George Washington University, **Adam S. Sikora**, State University of New York at Buffalo, **Pawel Traczyk**, Warsaw University.

Mathematics of Large Quantum Systems, **Michael Loss**, Georgia Institute of Technology, **Jan Philip Solovej**, University of Copenhagen, **Jan Derezinski**, University of Warsaw.

Partial Differential Equations of Evolution Type, **Susan J. Friedlander**, University of Illinois at Chicago, and **Grzegorz A. Karch**, University of Wroclaw.

Quantum Information Theory, **Robert Alicki**, University of Gdansk, **Mary Beth Ruskai**, Tufts University.

Chicago, Illinois

DePaul University

October 5–6, 2007

Friday – Saturday

Meeting #1030

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: August 2007
Program first available on AMS website: August 16, 2007
Program issue of electronic *Notices*: October 2007
Issue of *Abstracts*: Volume 28, Issue 3

Deadlines

For organizers: March 6, 2007
For consideration of contributed papers in Special Sessions: June 19, 2007
For abstracts: August 7, 2007

Invited Addresses

Martin Golubitsky, University of Houston, *Title to be announced.*

Matthew J. Gursky, University of Notre Dame, *Title to be announced.*

Alex Iosevich, University of Missouri, *Title to be announced.*

David E. Radford, University of Illinois at Chicago, *Title to be announced.*

Special Sessions

Algebraic Combinatorics: Association Schemes and Related Topics (Code: SS 1A), **Sung Y. Song**, Iowa State University, and **Paul Terwilliger**, University of Wisconsin.

New Brunswick, New Jersey

Rutgers University-New Brunswick, Busch Campus

October 6–7, 2007

Saturday – Sunday

Meeting #1031

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 2007
Program first available on AMS website: August 16, 2007
Program issue of electronic *Notices*: October 2007
Issue of *Abstracts*: Volume 28, Issue 3

Deadlines

For organizers: March 6, 2007
For consideration of contributed papers in Special Sessions: June 19, 2007
For abstracts: August 7, 2007

Invited Addresses

Satyan L. Devadoss, Williams College, *Title to be announced.*

Tara S. Holm, University of Connecticut, *Title to be announced.*

Sir Roger Penrose, University of Oxford, *Title to be announced* (Einstein Public Lecture in Mathematics).

Scott Sheffield, Courant Institute and Institute for Advanced Science, *Title to be announced.*

Mu-Tao Wang, Columbia University, *Title to be announced.*

Special Sessions

Commutative Algebra (Code: SS 4A), **Jooyoun Hong**, University of California Riverside, and **Wolmer V. Vasconcelos**, Rutgers University.

Mathematical and Physical Problems in the Foundations of Quantum Mechanics (in Honor of Shelly Goldstein's 60th Birthday) (Code: SS 3A), **Roderich Tumulka** and **Detlef Dürr**, München University, and **Nino Zanghi**, University of Genova.

Partial Differential Equations in Mathematical Physics (in Honor of Shelly Goldstein's 60th Birthday) (Code: SS 2A), **Sagun Chanillo**, **Michael K.-H. Kiessling**, and **Avy Soffer**, Rutgers University.

Probability and Combinatorics (Code: SS 1A), **Jeffry N. Kahn** and **Van Ha Vu**, Rutgers University.

Set Theory of the Continuum (Code: SS 5A), **Simon R. Thomas**, Rutgers University.

Toric Varieties (Code: SS 6A), **Milena S. Hering**, Institute for Mathematics and Its Applications, and **Diane Maclagan**, Rutgers University.

Albuquerque, New Mexico

University of New Mexico

October 13–14, 2007

Saturday – Sunday

Meeting #1032

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2007
Program first available on AMS website: August 30, 2007
Program issue of electronic *Notices*: October 2007
Issue of *Abstracts*: Volume 28, Issue 4

Deadlines

For organizers: March 13, 2007
For consideration of contributed papers in Special Sessions: June 26, 2007
For abstracts: August 21, 2007

Invited Addresses

Emmanuel Candes, California Institute of Technology, *Title to be announced.*

Alexander Polischuk, Univerity of Oregon, *Title to be announced.*

Eric Raines, University of California Davis, *Title to be announced.*

William E. Stein, University of California San Diego, *SAGE: Software for Algebra and Geometry Experimentation.*

Special Sessions

Computational Methods in Harmonic Analysis and Signal Processing (Code: SS 1A), **Emmanuel Candes**, California Institute of Technology, and **Joseph D. Lakey**, New Mexico State University.

Murfreesboro, Tennessee

Middle Tennessee State University

November 3–4, 2007

Saturday – Sunday

Meeting #1033

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: September 2007
Program first available on AMS website: September 20, 2007
Program issue of electronic *Notices*: November 2007
Issue of *Abstracts*: Volume 28, Issue 4

Deadlines

For organizers: April 3, 2007
For consideration of contributed papers in Special Sessions: July 17, 2007
For abstracts: September 11, 2007

Invited Addresses

Sergey Gavrilets, University of Tennessee, *Title to be announced.*

Daniel K. Nakano, University of Georgia, *Title to be announced.*

Carla D. Savage, North Carolina State University, *Title to be announced.*

Sergei Tabachnikov, Pennsylvania State University, *Title to be announced.*

Special Sessions

Advances in Algorithmic Methods for Algebraic Structures (Code: SS 3A), **James B. Hart**, Middle Tennessee State University.

Applied Partial Differential Equations (Code: SS 4A), **Yuri A. Melnikov**, Middle Tennessee State University, and **Alain J. Kassab**, University of Central Florida.

Differential Equations and Dynamical Systems (Code: SS 1A), **Wenzhang Huang** and **Jia Li**, University of Alabama, Huntsville, and **Zachariah Sinkala**, Middle Tennessee State University.

Graph Theory (Code: SS 2A), **Rong Luo**, **Don Nelson**, **Chris Stephens**, and **Xiaoya Zha**, Middle Tennessee State University.

Wellington, New Zealand

To be announced

December 12–15, 2007

Wednesday – Saturday

Meeting #1034

First Joint International Meeting between the AMS and the New Zealand Mathematical Society (NZMS).
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: March 31, 2007
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

AMS Invited Addresses

Marston Condor, University of Auckland, *Title to be announced.*

Rodney G. Downey, Victoria University of Wellington, *Title to be announced.*

Michael H. Freedman, Microsoft Research/University of California Santa Barbara, *Title to be announced.*

Gavin J. Martin, Massey University, *Title to be announced.*

Assaf Naor, Microsoft Research/Courant Institute, *Title to be announced.*

Theodore A. Slaman, University of California Berkeley, *Title to be announced.*

Matthew J. Visser, Victoria University of Wellington, *Title to be announced.*

AMS Special Sessions

Computability Theory, **Rodney G. Downey** and **Noam Greenberg**, Victoria University of Wellington.

Dynamical Systems: Probabilistic and Semigroup Methods, **Arno Berger**, University of Canterbury, **Rua Murray**, University of Waikato, and **Matthew J. Nicol**, University of Houston.

Hopf Algebras and Quantum Groups, **M. Susan Montgomery**, University of Southern California, and **Yinhuo Zhang**, Victoria University of Wellington.

Infinite-dimensional Groups and Their Actions, **Christopher Atkin**, Victoria University of Wellington, **Greg Hjorth**, University of California Los Angeles/University of Melbourne, **Alica Miller**, University of Louisville, and **Vladimir Pestov**, University of Ottawa.

Matroids, Graphs, and Complexity, **Dillon Mayhew**, Victoria University of Wellington, and **James G. Oxley**, Louisiana State University.

New Trends in Spectral Analysis and Partial Differential Equations, **Boris P. Belinskiy**, University of Tennessee, Chattanooga, **Anjan Biswas**, Delaware State University, and **Boris Pavlov**, University of Auckland.

Special Functions and Orthogonal Polynomials, **Shaun Cooper**, Massey University, **Diego Dominici**, SUNY New Paltz, and **Sven Ole Warnaar**, University of Melbourne.

San Diego, California

San Diego Convention Center

January 6–9, 2008

Sunday – Wednesday
Joint Mathematics Meetings, including the 114th Annual Meeting of the AMS, 91st 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: Michel L. Lapidus
Announcement issue of *Notices*: October 2007
Program first available on AMS website: November 1, 2007
Program issue of electronic *Notices*: January 2008
Issue of *Abstracts*: Volume 29, Issue 1

Deadlines

For organizers: April 1, 2007
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New York, New York

Courant Institute of New York University

March 22–23, 2008

Saturday – Sunday
Eastern Section
Associate secretary: Lesley M. Sibner
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 22, 2007
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

L-Functions and Automorphic Forms (Code: SS 1A), **Alina Bucur**, Institute for Advanced Study, **Ashay Venkatesh**, Courant Institute of Mathematical Sciences, **Stephen D. Miller**, Rutgers University, and **Steven J. Miller**, Brown University.

Baton Rouge, Louisiana

Louisiana State University, Baton Rouge

March 28-30, 2008

Friday - Sunday
Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 28, 2007
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Bloomington, Indiana

Indiana University

April 4-6, 2008

Friday - Sunday
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 4, 2007
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Claremont, California

Claremont McKenna College

May 3-4, 2008

Saturday - Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: October 4, 2007
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Rio de Janeiro, Brazil

Instituto Nacional de Matemática Pura e Aplicada (IMPA)

June 4-7, 2008

Wednesday - Saturday
First Joint International Meeting between the AMS and the Sociedade Brasileira de Matemática.
Associate secretary: Lesley M. Sibner
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

Vancouver, Canada

University of British Columbia and the Pacific Institute of Mathematical Sciences (PIMS)

October 4-5, 2008

Saturday - Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 9, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Middletown, Connecticut

Wesleyan University

October 11–12, 2008

Saturday – Sunday
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 11, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Kalamazoo, Michigan

Western Michigan University

October 17–19, 2008

Friday – Sunday
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 17, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Huntsville, Alabama

University of Alabama, Huntsville

October 24–26, 2008

Friday – Sunday
Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 24, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Shanghai, People's Republic of China

Fudan University

December 17–21, 2008

Wednesday – Sunday
First Joint Interntional Meeting Between the AMS and the Shanghai Mathematical Society
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Washington, District of Columbia

Marriott Wardman Park Hotel and Omni Shoreham Hotel

January 7–10, 2009

Wednesday – Saturday
Joint Mathematics Meetings, including the 115th Annual Meeting of the AMS, 92nd 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: Lesley M. Sibner
Announcement issue of *Notices*: October 2008
Program first available on AMS website: November 1, 2008
Program issue of electronic *Notices*: January 2009
Issue of *Abstracts*: Volume 30, Issue 1

Deadlines

For organizers: April 1, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Urbana, Illinois

University of Illinois at Urbana-Champaign

March 27–29, 2009

Friday – Sunday
Southeastern Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 29, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Raleigh, North Carolina

North Carolina State University

April 4–5, 2009

Saturday – Sunday
Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 4, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Francisco, California

San Francisco State University

April 25–26, 2009

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 25, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Francisco, California

Moscone Center West and the San Francisco Marriott

January 6–9, 2010

Wednesday – Saturday
Joint Mathematics Meetings, including the 116th Annual Meeting of the AMS, 93rd Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society of Industrial and Applied Mathematics (SIAM).
Associate secretary: Matthew Miller
Announcement issue of *Notices*: October 2009
Program first available on AMS website: November 1, 2009
Program issue of electronic *Notices*: January 2010
Issue of *Abstracts*: Volume 31, Issue 1

Deadlines

For organizers: April 1, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New Orleans, Louisiana

New Orleans Marriott and Sheraton New Orleans Hotel

January 5–8, 2011

Wednesday – Saturday
Joint Mathematics Meetings, including the 117th Annual Meeting of the AMS, 94th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 2010
Program first available on AMS website: November 1, 2010
Program issue of electronic *Notices*: January 2011
Issue of *Abstracts*: Volume 32, Issue 1

Deadlines

For organizers: April 1, 2010
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Boston, Massachusetts

John B. Hynes Veterans Memorial Convention Center, Boston Marriott Hotel, and Boston Sheraton Hotel

January 4–7, 2012

Wednesday – Saturday
Joint Mathematics Meetings, including the 118th Annual Meeting of the AMS, 95th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2011
Program first available on AMS website: November 1, 2011
Program issue of electronic *Notices*: January 2012
Issue of *Abstracts*: Volume 33, Issue 1

Deadlines

For organizers: April 1, 2011
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 9–12, 2013

Wednesday – Saturday
Joint Mathematics Meetings, including the 119th Annual Meeting of the AMS, 96th Annual meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2012
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: Michel L. Lapidus, Department of Mathematics, University of California, Sproul Hall, Riverside, CA 92521-0135; e-mail: `lapidus@math.ucr.edu`; telephone: 951-827-5910.

Central Section: Susan-J. Friedlander, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: `susan@math.nwu.edu`; telephone: 312-996-3041.

Eastern Section: Lesley-M. Sibner, Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: `lsibner@duke.poly.edu`; telephone: 718-260-3505.

Southeastern Section: Matthew Miller, Department of Mathematics, University of South Carolina, Columbia, SC 29208-0001, e-mail: `miller@math.sc.edu`; telephone: 803-777-3690.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information can be found at** `www.ams.org/meetings/`.

Meetings:

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 78 in the the January 2007 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset in LaTeX. Visit `http://www.ams.org/cgi-bin/abstracts/abstract.pl`. Questions about abstracts may be sent to `abs-info@ams.org`. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (see `http://www.ams.org/meetings/` for the most up-to-date information on these conferences.)

June 16–July 6, 2007: Joint Summer Research Conferences, Snowbird, Utah.

July 8–July 12, 2007: von Neumann Symposium on Sparse Representation and High-Dimensional Geometry, Snowbird, Utah.

American Mathematical Society

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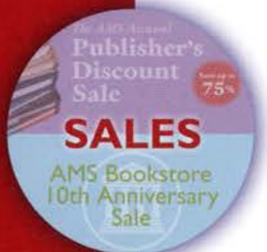

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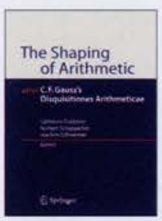
New and Noteworthy

Yesterday and Long Ago

Vladimir I. Arnold, Steklov Mathematical Institute, Moscow, Russia

This charming book by one of the leading mathematicians of our day, Vladimir Igorevich Arnold, is a collection of his memories from early childhood up to recent days. Some marvelous historical and geographical stories occupy a large part of the book, and their characteristic lively style draws the reader into the past as though it were happening today.
The book will be of value to historians of twentieth-century mathematics as source material, and mathematicians will read it for the pure pleasure of learning more about one of their most eminent colleagues. Written with both humor and pathos, even a non-mathematical reader will find it very difficult to set down.

2007. 229 pp. 43 illus., Hardcover
ISBN 978-3-540-28734-6 ▶ **$39.95**

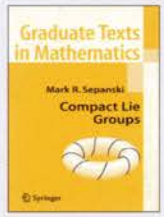


The Shaping of Arithmetic after C.F. Gauss's Disquisitiones Arithmeticae

Catherine Goldstein, Paris, France; **Norbert Schappacher**, Université Louis Pasteur, Strasbourg, France; and **Joachim Schwermer**, University of Vienna, Austria (eds.)

Since its publication, C.F. Gauss's Disquisitiones Arithmeticae (1801) has acquired an almost mythical reputation, standing as an ideal of exposition in notation, problems and methods; as a model of organization and theory building; and as a source of mathematical inspiration. Eighteen authors - mathematicians, historians, philosophers - have collaborated in this volume to assess the impact of the Disquisitiones, in the two centuries since its publication.

2007. 578 pp. 36 illus., Hardcover
ISBN 978-3-540-20441-1 ▶ **$89.95**



Compact Lie Groups

Mark R. Sepanski, Baylor University, Texas

Blending algebra, analysis, and topology, the study of compact Lie groups is one of the most beautiful areas of mathematics and a key stepping stone to the theory of general Lie groups. Assuming no prior knowledge of Lie groups, this book covers the structure and representation theory of compact Lie groups. Coverage includes the construction of the Spin groups, Schur Orthogonality, the Peter-Weyl Theorem, the Plancherel Theorem, the Maximal Torus Theorem, the Commutator Theorem, the Weyl Integration and Character Formulas, the Highest Weight Classification, and the Borel-Weil Theorem. The book develops the necessary Lie algebra theory with a streamlined approach focusing on linear Lie groups.

2007. 216 pp., (Graduate Texts in Mathematics, Vol. 235) Hardcover
ISBN 978-0-387-30263-8 ▶ **$49.95**

Random Fields and Geometry

R.J. Adler, Israel Institute of Technology, Haifa, Israel and **Jonathan Taylor**, Stanford University, California

This monograph focuses on recent important developments in the study of random fields, stochastic processes defined over high dimensional parameter spaces. It recasts topics in random fields by following a completely new way of handling both geometry and probability.
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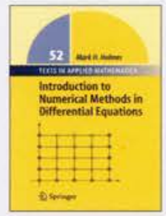

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