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Articles

The Graph of the Truncated Icosahedron and the Last Letter of Galois
Bertram Kostant

The truncated icosahedron has emerged in biology and chemistry as a remarkably stable structure. A new group theoretic approach is discussed here as a possible key to this stability.

Getting Started in Mathematical Biology
Frank Hoppensteadt

Geometrical and structural problems in biology may require application of rather sophisticated mathematical ideas. The breadth and depth of this interaction is surveyed here.

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First-rate people attract first-rate people, second-rate people attract fifth-rate people

—Saying, variously attributed, often quoted, by third-rate mathematicians

Most mathematicians involved in research inhabit a world in which mathematical research is a common activity: we do it ourselves, some of our best friends are research mathematicians, and we belong to extensive professional networks of mathematicians. But reflect on how rare the profession of mathematical research actually is in the United States today.

Here are some numbers: The American Mathematical Society currently has about 30,000 members. The Society classifies its membership by dues category. Using this we find that about 10,500 members are nominees (graduate students nominated by their departments as a privilege of the department's institutional membership); an additional 2,100 members are in dues category S (members from weak-currency countries who pay at a special rate), and 1,500 members are in the emeritus category. That leaves about slightly under 16,000 paying dues at the employed members rate, including those not living in the United States (reciprocity members) and those whose profession is not mathematical educator/scholar/scientist (such as government officials). Let's estimate, therefore, that there are about 15,000 members of the society currently making a living in the mathematics profession.

But how large is the mathematical research community in America? Obviously, the answer depends on what one means by a research mathematician. For estimation purposes, we can use a study performed a few years ago by the National Science Foundation, which found that there were 24,500 full-time U.S. faculty in the mathematical sciences (mathematics, applied mathematics, and statistics) of whom 9,150 were active in research and publication. Of course, some of those researchers would naturally have their primary affiliation with SIAM or IMS rather than AMS, and there are research mathematicians employed other than as full-time faculty. As a rough estimate, let's say that there are 8,000 professional research mathematicians in the United States. Before considering the implications of this number, it's interesting to note that the NSF study found that 23 percent of the mathematical scientists doing research were receiving some federal support and to contrast that with the corresponding percentages for chemists (56 percent) and physicists (75 percent).

What does it mean to belong to a community of 8,000 in a nation of 250 million? An American chosen at random is eight times more likely to be licensed to practice law in the District of Columbia than to be a professional research mathematician; similar figures apply for being licensed to practice medicine in California. The odds against encountering a research mathematician at random are over 30,000 to 1. By any numerical measure, we are a tiny minority.

Or almost any measure: those 23 percent fortunate enough to enjoy federal support for their mathematical research collectively receive about $100 million annually, which is about the same as the (proposed) appropriation for the National Endowment for the Arts, and about twice the amount of federal subsidies for tobacco farmers.

To retain, and hopefully expand, public financial support for mathematics research should be one of our outward facing goals as a mathematical society. But we should also take care to consider the consequences of the smallness of our numbers and the thinness of our ranks, to realize that every research mathematician is a precious resource, and to see that our Society is a supportive, nurturing community for its members. We need to be especially on guard against self-hating, and self-defeating, sentiments such as that in the quotation which begins this letter.

Andy Magid
Weiner, Theory and Activism

In his letter (AMS Notices, June 1955, pp. 653-654), Professor Marcus states that I "apologized" for Wiener's "political acts" in [1]. One such act, taken against the advice of family and friends, was his resignation from the National Academy of Sciences in 1941, accompanied by a long but alas intellectually fuzzy letter. Another was his response of December 1946 to Dr. G. E. Forsyth, printed in the Atlantic Monthly, January 1947 [47b], about which I wrote "the Wiener message is severely blurred by a large dose of Wiener noise" [2, p. 674]. The resignation letter and [47b] are published in [1] and [2], respectively, and readers can judge for themselves. Wiener's charges of anti-Semitism at Harvard in his autobiography are again inadequately substantiated.

Let us lay aside these very few (below par) documents, written mostly in the wake of the Hiroshima tragedy and prior to the Czechoslovakian coup d'état, Berlin blockade, and Korean War (1948, 1950), and think of the remaining 245 or so documents in the Wiener corpus. This corpus, "its enormous range notwithstanding, exhibits a coherence of thought from start to finish reminiscent of a great work of art" [1, p.18]. It is very good of Professor Marcus to remind us that in addition to this, Wiener was "a man of conscience and of great courage." Today we ought to let Wiener's more lasting reflections guide us in deciding what social responsibility entails in the context of current realities.

Wiener's political and economic theory is expounded in his little-known paper [62c] on planning. Briefly, two arms are discernible in the political state (i) a short-time state and a (ii) a long-time state, corresponding roughly to the transient state and the steady state in engineering, or to short-lag linear prediction from good data, and long-lag non-linear prediction from sparse data. The solution of short-time problems involve long-time considerations. Thus, in antiaircraft fire control in World War II, to shoot down the bomber, tracked for 10 seconds, during the next 20, covariances based on long-time records of flight trajectories are needed. Ideally, we need the limit, \( \lim_{t \to \infty} (1/T)^{1/2} \cdots \), on which rests the mathematical theory. Likewise, in the socio-political arena, the damage resulting from shortsighted policy, e.g., the sudden desertion of long-established industries from a city, may call for a long-time re-dress, a policy that looks forward to many decades.

The ideal element (the limit as \( t \to 0 \) or \( x \to \infty \)) was paramount in the mathematical physics ushered in by the Renaissance, but in the political and economic theory that came with it, ideality got muted, perhaps as a result of medieval abuses. So to illustrate his "long-time State", Wiener had to go back to Mencius (300 BC) and cite the "mandate of Heaven". Wiener noted that Mencius' theory is consonant with representative government ("Heaven sees as the people see") and that it recommends revolutions when the Emperor has "lost the mandate of Heaven". Pairings, similar to the Chinese Heaven-Emperor, occur in other classical traditions, e.g. Sacerdotium-Regnum in Christianity.

In practice the classical doctrine suffered from the monopolization of the first arm by the clergy, and from its collusion with the second arm. Wiener's long-time State is more enlightened: its guardians are the durable institutions, i.e. those having life-spans several times that of a human generations, such as cities, churches, universities and academies, as well as associations of manufacturers concerned with long-time engineering such as...
sewage, irrigation, desalination, and nuclear power.

In economics the corresponding pairing is business firm-economy, akin to ontogeny-phylogeny in biology. Just as a bird contributes to the vitality of its species, by species-labor such as nestling, mating, and protecting its young, so a firm's well-being, dependent as it is on the vitality of the economy as a whole, requires it to contribute directly to the economy. Accordingly, there are two standards of success for a firm: a) success as measured by its ledger book, i.e. profitability, b) success as measured by its contribution to the economy, i.e. to the communal well-being.

A free-enterprise system is defined as one that attends to both (a) and (b).

In the industrialized countries, the modes of production and consumption rest on a predominantly inbound traffic of the world's fossil-fuel and protein, and on an illicit but large inbound flow of narcotics. The former traffic retards the industrialization of the remaining regions and the latter traffic has engendered a prosperous criminal class that invests in the cultivation of narcotic plants, and corrupts the governments along its trade conduits. These regions are thus pockmarked with "agro-processing" industries and traffic that fail by the standard (b). The industrialized regions likewise invest heavily in the dubious production, ranging from advertising drivel such as "Pepsi-generation" all the way to pornography, that fails by the standard (b). Thus the prevailing economic system fails short of free enterprise.

An important economic sector is that of noncommodities, such as information, knowledge, design, art, ideology, and especially their communal dissemination in public instruction and entertainment. Wiener strongly believed that all noncommodity commerce should fall under the jurisdiction of the longtime State. However, one of the results of the industrial revolution is that commerce in noncommodities is now short-time and test (b) fails. For example, it was bad policy to lease the channels of communication to networks which measured success by the Nielson rating, i.e. by the standard (a) exclusively.

The misallocation of noncommodity commerce (especially of the channels of communication) in the world economy has resulted in a global demoralization: a large erosion of intellectual, educational, artistic, and ethical standards. There are about 50 million functional illiterates in the U.S.A. alone, many of whom are unable to articulate clearly let alone to reason. There is a loss of civility and an upsurge of criminality. In the destitute regions, there is much hunger among the poor and well-organized economic exploitation of their children.

Thus it should be the social responsibility of Wiener activists today to strive for the allocation of the channels of communication (the rivers of the mind) to Wiener's long-time State, and to separate friend from foe accordingly.

References

P. R. Masani
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Erratum
Due to computer error, the key for interpreting the graphed information in Table 1B (1994 Annual AMS-IMS-MAA Survey, p. 865) was not accurately presented. The uppermost graph line represents the Spring Count. The middle line represents Males. The line at the bottom represents Females. The Notices regrets this error.

About the Cover (cont'd)
are represented by wave function clouds. While such C60 crystals are ordinarily insulating, they become superconducting upon introduction of additional small molecules between the buckyballs. The figures were created by Boris Pevzner (pevzn@math.mit.edu) on a silicon graphics Indy Workstation using Ceros' software by Molecular Simulations, Inc.
The Graph of the Truncated Icosahedron and the Last Letter of Galois

Bertram Kostant

The use of group theory by chemists to determine certain properties of suitable molecules is a well-established procedure and there is a vast literature on the subject. For a single molecule the group involved is the molecule's symmetry group which, up to conjugacy, can be considered as a subgroup of $O(3)$ (necessarily finite, assuming the molecule is non-trivial). The most significant part of the symmetry group is its intersection, $G$, with $SO(3)$ and

$$G \subset SO(3)$$

will be referred to as the molecule's proper symmetry group. This use of the word proper in connection with subgroups of $O(3)$ will be maintained throughout the paper.

From the point of view of mathematics the groups $G$ in question— with exactly one exception (up to conjugacy)— are not very interesting since they are easily constructed solvable groups. The one exception is a group which is isomorphic to the alternating group $A_5$. As a subgroup of $SO(3)$ it is the proper symmetry group of the icosahedron (and the dodecahedron). It is the unique finite subgroup of $SO(3)$ which equals its own commutator subgroup—in fact, it is the unique non-abelian simple finite subgroup of $SO(3)$. It can be thought of as the beginning or smallest member of the family of non-abelian finite simple groups. From the point of view of the McKay correspondence it (or more exactly its "double cover") corresponds to the exceptional Lie group $E_8$.

A group isomorphic to $A_5$ will be referred to as an icosahedral group and any structure admitting such a group as a symmetry group is said to have icosahedral symmetry. Given the unique role of the icosahedral group in group theory, any natural structure having icosahedral symmetry surely deserves special attention. In this paper we will be concerned with one such structure—a structure which seems to be appearing with increasing frequency in the scientific literature.

Prior to the discovery of the Fullerenes, around ten years ago, the only known form of pure solid carbon was graphite and diamonds. These two forms are crystalline materials where the bonds between the carbon atoms exhibit hexagonal and tetrahedral structures, respectively. In neither of these two substances, however, are there isolated molecules of pure carbon. On the other hand, in

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Fullerene one finds for the first time a pure carbon crystalline solid with well-defined carbon molecules. See e.g. the top of p. 58 in [6]. Mathematically these molecules can be described as convex polyhedrons where the faces are either hexagons or pentagons and each vertex (carbon atom) is the endpoint of three edges (carbon bonds). The fact that the Euler characteristic of the 2-sphere is 2 easily implies that the number of pentagonal faces is necessarily 12. Hint: Express the number of vertices, edges and faces in terms of the number of pentagons and the number of hexagons. See e.g. [8], p. 16.

Fullerenes exhibit remarkable chemical and physical properties (e.g. superconductivity, ferromagnetism, tremendous stability) and have been the objects of a vast amount of research throughout the world. The shape of the molecules is such that they can behave as cages, encapsulating other atoms or molecules. For an up-to-date account of Fullerene, see [7]. A catalogue of possible Fullerene applications is given in Chapter 20 of [7] and in part III of [11].

Among the many Fullerene molecules the most prominent and the most studied is $C_{60}$. (The term Fullerene is sometimes used to refer specifically to this molecule.) In the case of $C_{60}$ the corresponding polyhedron is the truncated icosahedron (see chapter 8, §4, in [5]). This polyhedron is seen on the surface of a soccer ball. It has thirty-two faces. That is, besides the twelve pentagons there are twenty hexagons. It is of significance that the twelve pentagons are isolated from one another. Chemists believe that the isolation of the pentagons in a Fullerene molecule is a requirement for stability. See e.g. bottom of p. 4 in [8]. $C_{60}$ is the smallest Fullerene molecule in which this isolation occurs.

The truncated icosahedron is also found as the polyhedral coat of a number of viruses. For a survey of the polyhedral structure of viruses, including electron microscope pictures, see [9]. Another important biological occurrence of a truncated icosahedral structure is in a substance—called a clathrin—which is concerned with the release of neurotransmitters into the synapses of neural networks. See p. 365 in [15] (I thank S. Sternberg for this latter reference) and, in more detail, in Chapter 5 of [11].

There are ninety edges in the truncated icosahedron, sixty of which bound the twelve pentagons and separate hexagons from pentagons. We refer to these sixty edges as pentagonal edges. The remaining thirty edges separate hexagons from hexagons and are referred to here as hexagonal edges. According to pp. 46–47 in [8] the pentagonal edges in $C_{60}$ are single carbon bonds and the hexagonal edges are double carbon bonds. Thus each hexagon, reminiscent of a benzine ring, has alternating single and double bonds. However, unlike benzine, single and double bonds in these hexagons of $C_{60}$ remain fixed.

The truncated icosahedron has sixty vertices. Because of the isolation of the pentagonal faces each vertex lies on a unique pentagon. In this way the pentagons define a natural equivalence relation on the set of vertices—partitioning the set of vertices into twelve equivalence classes where each class is the 5-element set of vertices of one of the pentagons. By abuse of terminology we will generally refer to these 5-element sets themselves as pentagons.

One also notes that at each vertex there are three edges, two pentagonal and one hexagonal. The structure of a truncated icosahedron is completely determined by the graph $\Gamma$ of its vertices and edges. The proper symmetry group $G$ of $C_{60}$, or of the truncated icosahedron, is an (60-element) icosahedral group. The group $G$ operates in a simple transitive way on the set $V$ of vertices. Thus, given a pair of ordered vertices there is a unique proper symmetry which carries the first to the second. That is, the action of $G$ on $V$ is equivalent to the action of $G$ on itself by left translations. In particular the action of $G$ on $V$ does not “see” the edge structure in $\Gamma$. This, in our opinion, points to an inadequacy of $G$in dealing with many questions about the nature of $C_{60}$. In the expectation that a group-based harmonic analysis will eventually lead to a deep understanding of the remarkable molecule $C_{60}$, it seems to be highly desirable to be able to express the full structure of $\Gamma$group theoretically. The edge structure in $\Gamma$ determines a $60 \times 60$ adjacency matrix $H$ and consequently $H$ would be expressed group theoretically. In this connection it is useful to point out that the eigenvalues of $H$, via what is called a Hückel approximation, enter into the determination of the molecular energy levels of $C_{60}$. See e.g. [8], p. 44 and §9 in [3].
If \( p \) is a prime number let \( \mathbb{F}_p \) denote the finite field of \( p \) elements. The group \( SL(2, p) \) is the group of all \( 2 \times 2 \) matrices with entries in \( \mathbb{F}_p \) having determinant 1 and \( PSL(2, p) \) is \( SL(2, p) \) modulo its \( (2\)-element if \( p \) is odd) center. The group \( PSL(2, p) \) is simple if \( p \geq 5 \) and \( PSL(2, 5) \) is an icosahedral group. The icosahedral group \( PSL(2, 5) \) admits an embedding into \( PSL(2, 11) \) and the relationship (see section headed "The Embedding of \( PSL(2, 5) \) into \( PSL(2, 11) \)) and Galois' letter to Chevalier", p. 964) between these two groups is quite remarkable. This relationship has much to do with a statement (see p. 964) made by Galois in his famous letter to Chevalier written on the night before his life-ending duel. The set of all elements of order 11 in \( PSL(2, 11) \) decomposes into two conjugacy classes, each of which has sixty elements. The choice of the embedding (there are two such inequivalent embeddings) of \( PSL(2, 5) \) in \( PSL(2, 11) \) favors one of the conjugacy classes, say \( M \). It will be proved that the conjugacy class \( M \) has a natural structure of the graph of a truncated icosahedron. In effect, the model we are proposing for \( C_60 \) is such that each carbon atom can be labeled by an element of order 11 in \( PSL(2, 11) \) in such a fashion that the carbon bonds can be expressed in terms of the group structure of \( PSL(2, 11) \). It will be seen that the twelve pentagons are exactly the intersections of \( M \) with the twelve Borel subgroups of \( PSL(2, 11) \). (A Borel subgroup is any subgroup which is conjugate to the group \( PSL(2, 11) \) defined in (2).) In particular the pentagons are the maximal sets of commuting elements in \( M \). The most subtle point is the natural existence of the hexagonal bonds. This will arise from a group theoretic linkage of any element of order 11 in one Borel subgroup with a uniquely defined element of order 11 in another Borel subgroup.

The Graph of the Icosahedron and a Conjugacy Class in \( A_5 \)

Let \( \tau = \frac{1 + \sqrt{5}}{2} \) be the golden number. A rectangle is referred to as a golden rectangle if the ratio of the larger side to the smaller side is the golden number. In \( \mathbb{R}^2 \) the rectangle with the four vertices \( \{ \pm 1, \pm \tau \} \) is a golden rectangle. Let \( V \) be the set of 12 points in \( \mathbb{R}^3 \) obtained from the vertices of the 3 mutually perpendicular golden rectangles

\[
(1) \quad V = \{ (\pm 1, \pm \tau, 0), (0, \pm 1, \pm \tau), (\pm \tau, 0, \pm 1) \}
\]

Then \( V \) is the set of vertices of an icosahedron \( P \) where \( \langle c, d \rangle \subset V \) define an edge of \( P \) if the scalar product \( c \cdot d = \tau \). See 3 : 75 in [5]. Waxing poetic, one is strongly tempted to describe the icosahedron \( P \) as a symphony in the golden number.

Let \( A \subset SO(3) \) be the group of all rotations which stabilize the 12-element set \( V \). Then \( A \) is an icosahedral group. For any integer \( j > 1 \), let \( A(j) \subset A \) denote the set of all elements in \( A \) of order \( j \). The \( A(j) \neq \emptyset \) only if \( j = 2, 3, \text{ or } 5 \) and where \( | \cdot | \) denotes set cardinality

\[
|A(2)| = 15 \quad |A(3)| = 20 \quad |A(5)| = 24
\]

For any prime \( p \) (or in fact power of a prime) the group \( PSL(2, p) \) naturally operates (transitively) on \( p + 1 \) points. More specifically, it operates on the projective line \( \mathbb{F}_p \cup \{ \infty \} \) over \( \mathbb{F}_p \) as the group of fractional transformations \( x \mapsto \frac{ax + b}{cx + d} \). The isotropy subgroup is the Borel subgroup

\[
B = \{ \begin{pmatrix} a & b \\ 0 & a^{-1} \end{pmatrix} | a \in \mathbb{F}_p^*, b \in \mathbb{F}_p \}
\]

modulo the center

where \( \mathbb{F}_p^* \) is the multiplicative group of invertible elements in \( \mathbb{F}_p \). Thus for the case at hand the projective line is the "flag manifold" for \( PSL(2, p) \)—the set of all conjugates of the Borel subgroup \( B \). Since \( A \cong PSL(2, 5) \) this means that \( A \) naturally operates on six points. Geometrically this is readily seen on the icosahedron \( P \) where the six points may be taken to be six pairs of antipodal vertices. But, of course, \( A \) operates on a set \( F \) of five "objects". Looking at the icosahedron \( P \) this is less obvious. Each edge and its antipodal edge are the edges of a golden rectangle defining in this way fifteen golden rectangles on \( P \). These fifteen golden rectangles break up uniquely into five sets of three mutually orthogonal golden rectangles (one set of which is given by (1)). This is a geometric way of seeing the five objects. Algebraically it is simpler. Define a relation on the 15-element set \( A(2) \) where if \( \sigma, \rho \in A(2) \) then \( \sigma \rho = \rho \sigma \) if \( \sigma \) commutes with \( \rho \). Marvelously in this case the relation is an equivalence relation and there are five equivalence classes each of which has three elements. Thus algebraically we can take

\[
\mathcal{F} = \text{the set of maximal commuting subsets of } A(2)
\]

Of course there is a natural bijective correspondence between \( A(2) \) and the set of fifteen golden rectangles. Each element in \( A(2) \) defines a 180-degree rotation in the plane of the corresponding golden rectangle.
Figure 1

To what extent does $A$ "see" the icosahedron itself? By this we mean: where in $A$ can we find the graph of the vertices and edges of an icosahedron? It was our solution to this question, Theorem 1, given next, which led to the main result of the paper (given in the section entitled "The Graph of the Truncated Icosahedron and the Conjugacy Class Min PS1(2, 11)", p. 965)—the solution of a similar question when the icosahedron is replaced by the truncated icosahedron. The sets $A(2)$ and $A(3)$ are conjugacy classes in $A$. On the other hand, $A(5)$ decomposes into a union of two conjugacy classes, say $C$ and $C'$ each with twelve elements. Being conjugacy classes, they are, of course, $A$-sets with respect to the action of conjugation and both are closed under inversion. The map $C \rightarrow C'$, $\sigma \rightarrow \sigma^2$ is an $A$-bijection.

Consider one of the two, say $C \subset A(5)$, conjugacy classes of elements of order 5 in $A$. We will define a graph $\Delta$ whose set of vertices is $C$. Normally it is not a common practice in group theory to consider whether or not the product of two elements in a conjugacy class is again an element in that conjugacy class. However such a consideration here turns out to be quite productive. For $u, v \in C$ we define

\[ \{u, v\} \text{ to be an edge of } \Delta, \text{ if } uv \in C \]

Note that this is well defined since, being conjugate elements, $uv \in C$ if and only if $vu \in C$. Note also that whatever graph has been defined, it is necessarily invariant under the icosahedral group $A$. But in fact that there are exactly thirty edges and indeed one has the icosahedron. The following theorem is proved in [13].

**Theorem 1.** The graph $\Delta$ is isomorphic to the graph of vertices and edges of an icosahedron. With respect to such an isomorphism for any $u \in C$ the vertex corresponding to $u^{-1}$ is the antipode of the vertex corresponding to $u$.

If $c$ and $d$ are vertices of an icosahedron and $\{c, d\}$ is an edge, we will call $d$ a neighbor of $c$. Each vertex $c$, of course, has five neighbors. The five neighbors of the antipode of $c$ will be referred to as coregions of $c$. Any vertex $d$ not equal to $c$ or its antipode is either a neighbor of $c$ or a coregion of $c$, but not both. Accordingly we refer to the pair $\{c, d\}$ as neighbors or coregions. The same terminology of neighborhood and coregion will be used for the conjugacy class $C$ in $A$.

With an example, we illustrate Theorem 1 for the icosahedral group $A_5$. Let $C$ be the conjugacy class of the permutation cycle $u = (1, 2, 3, 4, 5) \in A_5$. If $w = (1, 5, 2, 4, 3)$ then one readily has $w \in C$. However

\[ (1, 2, 3, 4, 5)(1, 5, 2, 4, 3) = (1, 4, 2) \]

so that necessarily $\{u, w\}$ are coregions. But then $u$ and $v$ must be neighbors where $v = w^{-1}$. Indeed $v = (1, 3, 4, 2, 5)$ and

\[ uv = (1, 2, 3, 4, 5)(1, 3, 4, 2, 5) = (1, 5, 3, 2, 4) \]

and $(1, 5, 3, 2, 4) \in C$.

**Remark 2.** It follows easily from the example above that if $u, w \in C$ are arbitrary then $u$ and $u$ are coregions if and only if $uw$ has order 3.

Being a polyhedron, any edge of the icosahedron is the boundary of two faces. For the icosahedron the faces are triangles. Hence if $\{u, v\} \subset C$ are neighbors, there are exactly two other elements $w \in C$ which are neighbors of both $u$ and $v$. Since $(uv)^{-1} = u^{-1}v^{-1}$ and $(uv)^{-1} = v^{-1}u^{-1}$ satisfy these conditions they must be two other elements as indicated in Figure 1.

Starting with the edge defined by $u$ and $v$, and choosing the orientation of the icosahedron so that the edge $\{u, v^{-1}u^{-1}\}$ is obtained from $\{u, v\}$ by counterclockwise rotation, the five neighbors of $u$ can be expressed in terms of $u$ and $v$, as indi-
cated in Figure 2, exhibiting the five faces of the icosahedron which have \( u \) as a vertex.

Of course the five coneighbors of \( u \) are the inverses of the five neighbors.

**Remark 3.** Note that a comparison of Figure 1 and Figure 2 yields the equation

\[
(5) \quad u^2vu^{-2} = u^{-1}v^{-1}
\]

Since \( u \) has order 5 the equation (5) is equivalent to the condition that \( x = u^{-2}v \) has order 2. By Remark 2 the element \( ux = u^{-1}v \) has order 3. These three relations involving \( u \) and \( x \) are a presentation (referred to in (12) as a standard presentation) of the icosahedral group and such a presentation will later be seen (Theorem 7) to define, as a Cayley graph, the graph of the truncated icosahedron.

For non-solvable groups it is difficult to keep track of commutators of pairs of elements. The icosahedral group is the group of smallest order which equals its own commutator subgroup so that it is not without interest to see how commutators in \( A \) distribute themselves. For the conjugacy class \( C \), we will now see that this distribution is neatly expressed in terms of the three orthogonal golden rectangles. Assume \( u, v \in C \) are neighbors. Then \( \{u, v, u^{-1}, v^{-1}\} \) are the vertices of one of the fifteen golden rectangles. On the other hand, given two elements in any group, there are eight ways of forming a commutator and these eight expressions decompose naturally into two sets with four expressions in each. For \( u \) and \( v \) these are set forth in the second and third columns of the array

\[
\begin{align*}
\text{Table 1} & \\
u & uvu^{-1}v^{-1} & uv^{-1}u^{-1}v \\
v^{-1} & v^{-1}u^{-1}vu & vu^{-1}v^{-1}u \\
u^{-1} & vuv^{-1}u^{-1} & v^{-1}uv^{-1} \\
v & u^{-1}v^{-1}uv & u^{-1}uvu^{-1}
\end{align*}
\]

**Theorem 2.** The elements in \( A \) defined by the twelve expressions in (6) are distinct and lie in \( C \) and hence in fact exhaust \( C \). Furthermore the elements in any one of the 3-columns are the vertices of a golden rectangle and the three golden rectangles are orthogonal (i.e. correspond to orthogonal golden rectangles in the icosahedron \( P \subset \mathbb{R}^3 \)). In particular the second and third golden rectangles are the unique (among the fifteen golden rectangles) golden rectangles which are orthogonal to the first.

This theorem is proved as Theorem 1.18 in [13].

The following diagram (Figure 3) illustrates Theorem 2 and gives additional expressions (see §1 in [13]) for some of the vertices of the icosahedron in the terms of a pair \( \{u, v\} \subset C \) of neighbors.
The Embedding of \( \text{PSL}(2,5) \) into \( \text{PSL}(2,11) \) and Galois’ Letter to Chevalier

A major theme in what follows is the relationship between the 60-element icosahedral group \( \text{PSL}(2,5) \) and the 660-element group \( \text{PSL}(2,11) \). Up to conjugacy the group \( \text{PSL}(2,5) \) embeds into \( \text{PSL}(2,11) \) as a subgroup in two different ways (which, however, are interchanged by an outer automorphism of \( \text{PSL}(2,11) \)). That the relationship between the group \( \text{PSL}(2,11) \) and its subgroup \( \text{PSL}(2,5) \) is distinguished and extraordinary goes back to Galois. It will be discussed shortly. That the relationship has to do with the icosahedron is discussed in [3] and is further developed in [13].

As we noted before the 6-element projective line \( \text{Pro} \) over the field \( \mathbb{F}_5 \), as a \( \text{PSL}(2,5) \)-set, may be identified with the six pairs of antipodal vertices on the icosahedron. The point is that the 12-element projective line \( \text{Pro} \) over the field \( \mathbb{F}_{11} \), as a \( \text{PSL}(2,11) \)-set, may be identified with the full set of vertices \( V \) of the icosahedron in such a fashion that there exists a partition of \( \text{Pro} \) into six pairs of elements whose stabilizing subgroup of \( \text{PSL}(2,11) \) is \( \text{PSL}(2,5) \), recovering the action of \( \text{PSL}(2,5) \) on \( \text{Pro} \). Actually there exists two inequivalent such partitions corresponding to the two embeddings of \( \text{PSL}(2,5) \) in \( \text{PSL}(2,11) \). As evidence that the bijective correspondence between \( \text{Pro} \) and \( V \) is more than a coincidence it was shown in [3] that the graph of vertices and edges of the icosahedron may be neatly expressed in terms of the cross-ratio in \( \text{Pro} \). See Theorem 1 in [3].

We are concerned here not with the graph of the icosahedron but with the more sophisticated graph associated with the truncated icosahedron. A step in this direction will be a consequence of an idea inherent in Galois’ result. The three groups \( A_4, S_4 \), and \( A_5 \) are, up to conjugacy, the only finite subgroups of \( \text{SO}(3) \) which operate irreducibly on \( \mathbb{R}^3 \). They are, of course, the proper symmetry groups of the five Platonic solids. For the tetrahedron there is \( A_4 \). For the octahedron and the cube, there is \( S_4 \), and for the icosahedron and dodecahedron there is \( A_5 \). From the point of view of the McKay correspondence the groups \( A_4, S_4 \), and \( A_5 \) correspond, respectively, to the simple Lie groups \( E_6, E_7 \), and \( E_8 \).

Now if \( p \) is a prime number then the group \( \text{PSL}(2,p) \) is simple whenever \( p \geq 5 \) and it of course operates on the \( p+1 \)-element projective line over the field \( \mathbb{F}_p \). Galois’ result, reported in his letter to Chevalier (see p. 268 in [4] and p. 214 in [10]) is that if \( p > 11 \) then \( \text{PSL}(2,p) \) cannot operate, non-trivially, on a set with fewer than \( p+1 \)-elements. In particular it cannot operate non-trivially on a set with \( p \) elements when \( p > 11 \). This may be expressed as follows. The cyclic group \( \mathbb{Z}_p \) of order \( p \) embeds uniquely in \( \text{PSL}(2,p) \), up to conjugacy, as the Sylow \( p \)-subgroup. It is the unipotent radical of a Borel subgroup and pulled up to \( S L(2,p) \) may be taken to be

\[
\mathbb{Z}_p = \left\{ \begin{array}{cccc}
1 & x \\
0 & 1 \\
\end{array} \right| x \in \mathbb{F}_p \right\}
\]

The result of Galois is that if \( p > 11 \),

There exists no subgroup of \( \text{PSL}(2,p) \) which is complementary to \( \mathbb{Z}_p \).

By this we mean that there exists no subgroup \( F \) such that set theoretically \( \text{PSL}(2,p) = F \times \mathbb{Z}_p \). The notation here, of course, does not mean direct product of groups. It means that every element \( g \) can be uniquely written \( g = fz \) where \( f \in F \) and \( z \in \mathbb{Z}_p \). Implicit in Galois’ statement is certainly the knowledge that his statement is not true for the three cases of a simple \( \text{PSL}(2,p) \) where \( p \leq 11 \)—namely \( p = 5, 7, 11 \). It is surely a marvelous fact, that for the three exceptional cases, the groups \( F \) which run counter to Galois’ statement are precisely the symmetry groups of the Platonic solids. Namely one has

\[
\text{PSL}(2,5) = A_4 \times Z_5
\]

\[
\text{PSL}(2,7) = S_4 \times Z_7
\]

\[
\text{PSL}(2,11) = A_5 \times Z_{11}
\]

These exceptional cases merit elaboration. The fact that \( \text{PSL}(2,5) \) operates on five points...
was discussed on page 961 (see (3)) in connection with the commutativity equivalence relation on the set of elements of order 2 in $PSL(2,5)$. This action sets up the isomorphism of $PSL(2,5)$ with $A_5$. The group $PSL(2,7)$ is isomorphic to $PSL(3,2)$. The 3 here implies that $PSL(3,2)$ operates on a projective plane and the 2 implies that the plane is over the field of two elements. This plane has $1+2+2^2=7$ lines and 7 points, exhibiting seven objects on which $PSL(2,7)$ operates. The plane is classically represented by the diagram in Figure 4.

Of course our main interest is in the final and most sophisticated case, $PSL(2,11)$. Its action on eleven points arises from its symmetry of a special and remarkable geometry. The eleven points will be the field $F_{11}$ itself—as represented by the integers from 1 to 11 where of course $11=0$. The set of non-zero squares in $F_{11}$ is the set $\{1,3,4,5,9\}$. Now using the additive structure in $F_{11}$ translate this five-element set by each of the elements in $F_{11}$. One then obtains the following eleven five-element sets

\begin{align}
1,3,4,5,9 \\
2,4,5,6,10 \\
3,5,6,7,11 \\
1,4,6,7,8 \\
2,5,7,8,9 \\
3,6,8,9,10 \\
4,7,9,10,11 \\
1,5,8,10,11 \\
1,2,6,9,11 \\
1,2,3,7,10 \\
2,3,4,8,11
\end{align}

If we regard these sets as lines then it may be noted that any two distinct lines intersect in exactly two points and any two distinct points lie in exactly two lines. That is, intersection sets up a bijection between the 55-element set of all pairs of distinct points and the 55-element set of all pairs of distinct lines. This is referred to as a biplane geometry on p. 7 in [1]. If we identify the symmetric group $S_11$ with the permutation group of the set $F_{11}$ then the subgroup of $S_{11}$ which stabilizes the set of these eleven lines is isomorphic to $PSL(2,11)$. This then yields an embedding of $PSL(2,11)$ into $S_{11}$ or an action of $PSL(2,11)$ on eleven objects. The isotropy subgroup of $PSL(2,11)$ at a point in $F_{11}$ is isomorphic to $PSL(2,5)$. The second embedding of $PSL(2,5)$ in $PSL(2,11)$ is obtained by taking the isotropy subgroup of a line instead of a point.

The biplane geometry on eleven elements is directly related to the existence of $12 \times 12$ Hadamard matrices. A Hadamard matrix is a square matrix all of whose elements are either 1 or $-1$ and which has orthogonal columns (and hence has orthogonal rows). The set $H_n$ of all $n \times n$ Hadamard matrices is clearly stable under the action of the group $G_n$ of all row and column permutations and sign changes. If $R \in H_{12}$ then, first of all using sign changes, we may make the last row and the last column have only $1$'s. If $R'$ is the complementary $11 \times 11$ principal minor of $R$ then, since the first 11 columns of $R$ are orthogonal to the last column, each column of $R'$ must have exactly five $1$'s. Taking the row indices of these five $1$'s defines a 5-element subset of $\{1,\ldots,11\}$. The eleven 5-element subsets obtained in this way must make a biplane geometry in order that the columns of $R$ be orthogonal—and conversely. In particular (9) yields the following $12 \times 12$ Hadamard matrix.

\[
R = \begin{pmatrix}
1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 \\
-1 & 1 & -1 & -1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 & 1 \\
-1 & -1 & 1 & -1 & 1 & 1 & 1 & -1 & 1 & 1 & 1 & 1 \\
1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 \\
1 & 1 & -1 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 \\
-1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 \\
-1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
-1 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{pmatrix}
\]

Remark 5. Andrew Gleason informed me that it is easy to show that $H_{12}$ is a single $G_{12}$ orbit. This, of course, implies that one can obtain all elements in $H_{12}$ by applying $G_{12}$ to (10). He also conjectures that $n=12$ is maximum such that $H_n$ is a single $G_n$ orbit, assuming of course that $n$ is such that $H_n$ is not empty.

The Graph of the Truncated Icosahedron and the Conjugacy Class $M$ in $PSL(2,11)$

Now returning to (8), instead of considering, as above, the 11-element $PSL(2,11)$-set $PSL(2,11)/H$ where $H$ is the subgroup $A_5$, consider the 60-element $PSL(2,11)$-set $PSL(2,11)/H$ where the subgroup $H$ is chosen to be $Z_{11}$. We now raise the question of the possibility that $X = PSL(2,11)/Z_{11}$ has a natural structure of the graph of the truncated icosahedron. Evidence for this is that one immediately sees a canonical $PSL(2,11)$ invariant decomposition of $X$ into a union of twelve “pentagons”. Namely if $B$ is the normalizer of $Z_{11}$ in $PSL(2,11)$ then from general principles the group of $B/Z_{11}$ op-
erates (on the right) faithfully on \( X \) and the action not only commutes with the action of \( \text{PSL}(2, 11) \) but is its full centralizer in the full group of permutations of \( X \). But \( B \) is just that Borel subgroup of \( \text{PSL}(2, 11) \) whose unipotent radical is \( \mathbb{Z}_{11} \). Thus

\[
B / \mathbb{Z}_{11} = \mathbb{Z}_5
\]

The orbits of \( B / \mathbb{Z}_{11} \) are the twelve pentagons. In addition, from (8), \( X \) is a principal homogeneous space for \( A_5 \) which is exactly how \( A_5 \) operates on the vertices of a truncated icosahedron. What is missing, of course, is the most sophisticated part of the graph of the truncated icosahedron—namely the hexagonal edges—the edges which tie together the various pentagons (the double carbon bonds in \( C_{60} \)).

A graph, namely a Cayley graph, is defined on a group by choosing generators. In the case of an icosahedral group there is a classical choice of a pair of generators. Actually, there are three such (which are easily related to one another) depending on whether one wants the generators to have orders 2 and 5, or 2 and 3, or 3 and 5. We make the first choice. A presentation of the icosahedral group—which we refer to as a standard presentation—is given by a pair of non-trivial group elements \( \phi, \tau \) satisfying the relations

\[
\phi^5 = 1, \quad \tau^2 = 1, \quad (\phi \tau)^3 = 1
\]

See e.g. Lemma 13.6, p. 120 in [14]. Non-trivial elements \( \phi, \tau \) in an icosahedral group \( A' \) define a Cayley graph on \( A' \). The following theorem says that this Cayley graph is the graph of a truncated icosahedron. Actually it is more convenient for us to express the result in terms of a principal homogeneous space (i.e. trivial isotropy groups) rather than the group itself.

Theorem 7 is just a more detailed version of Theorem 1 in [3]. It is proved in [3] and as Theorem 2.10 in [13].

**Theorem 7.** Let \( M \) be any 60-element set and let \( S_{60} \) be the full group of permutations of \( M \). Assume that \( \phi, \tau \in S_{60} \) satisfy the relations (12) and that \( \phi, \tau \) and \( \phi \tau \) have no fixed points in \( M \). Then the subgroup \( A' \subset S_{60} \) generated by \( \phi \) and \( \tau \) is an icosahedral group and \( M \) is a principal homogeneous space for \( A' \). Let \( A \) be the centralizer of \( A' \) in \( S_{60} \) so that \( A \) is also an icosahedral group (\( A \) and \( A' \) are each other’s centralizer) and \( M \) is also a principal homogeneous space for \( A \).

Let \( \Gamma \) be the graph on \( M \) so that for any \( x \in M \) the edges (three of them) containing \( x \) are \( \{ x, \phi x \} \), \( \{ x, \phi^{-1} x \} \), and \( \{ x, \tau x \} \). Then \( \Gamma \) is isomorphic to the graph of a truncated icosahedron where the two pentagonal edges containing \( x \) are \( \{ x, \phi x \} \) and \( \{ x, \phi^{-1} x \} \) and the unique hexagonal edge containing \( x \) is \( \{ x, \tau x \} \).

Finally, \( A \) is the proper symmetry group of \( \Gamma \).

If we apply Theorem 7 to the coset space \( X = \text{PSL}(2, 11) / \mathbb{Z}_{11} \) we note that the element \( \phi \) has been essentially given to us. It is a generator of the “torus” \( B / \mathbb{Z}_{11} \) operating from the right on \( X \). Explicitly what is missing is the permutation \( \tau \) which with \( \phi \) defines a standard presentation of the centralizer of \( A_5 \) in the permutation group of \( X \). To find \( \tau \) we seek a more natural setting for \( X \), where there is more underlying structure, and we will find it as a conjugacy class \( M \) of elements of order 11 in \( \text{PSL}(2, 11) \).

Let \( A \) be a fixed choice of an icosahedral subgroup of \( \text{PSL}(2, 11) \). (Recall there are two such subgroups, up to conjugacy.) Then if \( \mathbb{Z}_{11} \) is the unipotent radical of any Borel subgroup one has, using multiplication, the set (non-group) direct product

\[
\text{PSL}(2, 11) = A \times \mathbb{Z}_{11}
\]

If \( \mathbb{Z}_{11}^* \) is the set of elements of order 11 in \( \mathbb{Z}_{11} \) then, of course, \( |\mathbb{Z}_{11}^*| = 10 \). Since there are twelve Borel subgroups it follows that there are 120 elements of order 11 in \( \text{PSL}(2, 11) \). Since \( B \) has two 5-element orbits on \( \mathbb{Z}_{11}^* \) it then follows that there are 2 conjugacy classes \( M, M' \) of elements of order 11 and each has sixty elements. Let \( M \) be either one of these two classes.

**Remark 9.** Actually, as stated in Theorem 11 below, the choice of \( A \) will be seen to favor one of these classes over the other. Any non-trivial outer automorphism of \( \text{PSL}(2, 11) \) interchanges the two choices of \( A \) and also interchanges the two choices of \( M \).

Since the centralizer of any element in \( M \) is the unipotent radical of the unique Borel subgroup \( B \) which contains it, one has an isomorphism

\[
\text{PSL}(2, 11) \cong X = \text{PSL}(2, 11) / \mathbb{Z}_{11}
\]

of \( \text{PSL}(2, 11) \) sets. The twelve “pentagons” \( P \subset M \) then turn out to be the subsets of the form

\[
P = B' \cap M
\]

where \( B' \) is a Borel subgroup of \( \text{PSL}(2, 11) \).
note that Galois' result can be interpreted as saying that $M_p$ cannot be a principal homogeneous space for the conjugation action of a subgroup of $PSL(2, p)$, in case $p > 11$. In particular then, the Cayley graph structure on $M$ which will be now be constructed can have no analogous generalization for $M_p$ when $p > 11$.

The use of the term pentagon implies that there is an implicit graph structure on the orbits of the torus $B/Z_{11}$. Up to now this has not been made clear. But in fact there are two polygonal Cayley graphs on the cyclic group $B/Z_{11} = Z_5$—each defining a pentagonal structure on this group and consequently on its orbits. These are illustrated as the single and double edge structure in Figure 5. Note that $n = 5$ is the minimal value of $n$ for which $Z_n$ has more than one polygonal Cayley graph.

The action of this $Z_5$ can be expressed in terms of group multiplication in $PSL(2, 11)$. For one pentagonal structure the two pentagonal edges containing any $x \in M$ are $\{x, x^3\}$ and $\{x, x^4\}$. For the other structure the edges are $\{x, x^9\}$ and $\{x, x^5\}$—noting that $x^4 = x^{-3}$ and $x^5 = x^{-9}$. A choice of one these two determines $\phi$ (see Theorem 11) up to inversion.

Finding the graph of the truncated icosahedron in the conjugacy class $M$, group theoretically, is clearly analogous, and was motivated by, finding, as in Theorem 1, the graph of the icosahedron in a conjugacy class $C$ of elements of order 5 in the icosahedral group $A$. There is another heuristic reason for taking $M$ to be the vertices of the truncated icosahedron. It goes something like this: The twelve vertices of the icosahedron have been identified here, and previously in [3], with the points of the "flag manifold" of $PSL(2, 11)$—the twelve Borel subgroups of $PSL(2, 11)$. Truncating a polyhedron can be viewed as a finite analogue of blowing up points in algebraic varieties. In the operation of blowing up points one replaces the point by objects in the tangent space at the point. Changing tangent space to cotangent space, it is a well known and standard fact that an orbit of the principal unipotent elements of a semisimple Lie group embeds naturally in the cotangent bundle of its flag manifold. Thus regarding truncation of an icosahedron as the operation of replacing a Borel subgroup $B'$, regarded as an element (of the "flag manifold"), by the elements of the pentagon $B' \cap M$ is not entirely without motivation.

The subtle point in the construction of the graph of the truncated icosahedron in the conjugacy class $M$ is the determination of the permutation $\tau$ of $M$ of order 2 which with $\phi$ defines a standard presentation of the centralizer of the conjugation action of $A$ on $M$. Given any $x \in M$ the pair $\{x, \tau x\}$ would define the hexagonal edge containing $x$. In effect, then what $\tau$ is to do is to assign to any $x \in M$, which, of course, is a unipotent element lying in a unique Borel subgroup, not only another Borel subgroup...
$B'$ but a distinguished unipotent element $\tau x$ in that subgroup. I know of no operation for general groups which does that sort of thing. Geometrically this linking together of the pentagons is represented locally as dotted lines in the diagram (Figure 6).

(Of course, to represent bonds in $C_{60}$ the single and double lines in Figure 6 should be reversed).

In the notation of the following theorem the map $\tau$ is given by putting $\tau x = \rho_x x$. Theorem 11 is proved as the main theorem, Theorem 3.30, in [13]. Although its proof makes no use of com­versed) .

Theorem 11. Let $A$ be any icosahedral subgroup of $PSL(2, 11)$. Let $A(2)$ be the set of all elements of order 2 in $A$. Then for any $x \in PSL(2, 11)$ of order 11 there exists a unique choice $\sigma_x \in A(2)$ such that the commutator $\rho_x = x^{-1} \sigma_x x \sigma_x$ is again in $A(2)$. Moreover, there exists a unique choice $C_{A}$ of a (12-element) conjugacy class of elements of order 5 in $A$ and a unique choice of a (60-element) conjugacy class, $M$, of elements of order 11 in $PSL(2, 11)$ such that if $x \in M$ there exists $u \in C_{A}$ which normalizes the cyclic groups generated by $x$ and $\sigma_x x \sigma_x$ and is such that the pair $u, \rho_x$ defines a standard presentation of $A$. (That is, $u \rho_x$ has order 3). Furthermore if $x \in M$ then $\rho_x x \in M$ and a truncated icosahedral structure $\Gamma$ is defined on $M$ where the two pentagonal edges containing $x$ are $\{x, x^5\}$ and $\{x, x^{-3}\}$ and the unique hexagonal edge containing $x$ is $\{x, \rho_x x\}$.

Next given $x \in M$ the element $u \in C_{A}$ satisfying the condition above, is unique up to inversion and may be fixed by the condition that $ux^{-1} = x^5$. As such write $u = u(x)$. The space $P$ of twelve pentagons is then parameterized by $C_{A}$ so that, for $u \in C_{A}$, one has $P_u \in P$ where $P_u = \{x \in M | u = u(x)\}$. In addition the icosahedral graph structure $\Delta$ induced on $P$ by $\Gamma$ is such that $\{P_u, P_v\}$ is an edge if and only if $uv \in C_{A}$.

Tables, which among other things, label the vertices of the truncated icosahedron and their neighbors by elements in $M$ are given in [12] as well as in [13].

References

[13] B. KOSTANT, Structure of the truncated icosahedron (e.g. Fullerene or $C_{60}$, viral coatings) and a 60-element conjugacy class in $PSL(2, 11)$, Selecta Mathematica, New Series, 1 (1995), Birkhäuser, 163–195.
Mathematicians are sometimes known in high school biology classes for their tendency to faint during dissections and their ability to cook experiments to fit straight lines. In spite of these impressions, mathematicians and biologists, including medical scientists, have a long history of working successfully together.

Sophisticated mathematical results have been used in and have emerged from the life sciences. Examples are given by the development of stochastic processes and statistical methods to solve problems in genetics and epidemics [1, 2] and in recent articles in these Notices on DNA topology and the genome project [3, 4]. Aristotle, Pythagoras, Fibonacci, Cardano, Fourier, Gauss, von Helmholtz, Riemann, Einstein, d'Arcy Thompson, Turing, Wiener, von Neumann, and Keller are other names associated with both significant applications of mathematics to life science problems and significant developments in mathematics motivated by the life sciences.

Mathematical biology, like mathematical chemistry and physics, is a highly interdisciplinary area that defies classification into the usual categories of mathematical research. The area lies at the intersection of significant mathematical problems and interesting biology. Work in the intersection is referred to here as being mathematical biology, but labels and the taxonomy of who works on what in this interdisciplinary field are unimportant. We have moved beyond the early question "Is it mathematics?" The value of mathematics comes partly from routine applications of statistics and calculus to solving life science problems, but more importantly from the sophisticated point of view it can bring to complicated real life problems.

Mathematical scientists and many more from physics, chemistry, engineering, and medicine have developed and used mathematical methods in biology problems, and so it is difficult to give an accurate sense of the scope of influence mathematics has had in biology. However, we try here to give a rough description of important areas for interaction, to illustrate some interesting research problems, to point out some known pitfalls, and to report some experiences of those getting into mathematical biology.

Activity in mathematical biology is at an all time high! Interest ranges from entry level undergraduate courses to advanced research by some of our best workers and from elementary and secondary education to the popular press [5, 6]. Some mathematics departments have significant strength in this area, and most major departments now have faculty working in collab-
omination with life scientists. There are significant
problems involving interesting mathematics in
almost all areas of life and medical sciences that
need the attention of mathematicians.

What are important areas of biology? The Na-
tional Research Council [7] identified eleven
major themes in biological research:
1. Cell organization
2. Ecology and ecosystems
3. Evolution and diversity
4. Genome organization and expression
5. Growth and development
6. Immune system, pathogens and host de-
fenses
7. Integrative approaches to organism func-
tion and disease
8. Molecular structure and function
9. Neurobiology and behavior
10. New technology and industrial biotechnol-
ygy
11. Plant biology and agriculture

Mathematics has influenced almost all of
these areas.

The longstanding interaction between math-
ematical methods and biology is illustrated by
one of the major problems facing neurobiology
and behavior: How does a brain work? Math-
ematics has long played a role in studies of the
brain, ranging from early work of von Helmholtz
[8] who sought an energy-like function to de-
scribe physical and chemical bases of brain dy-
namics, through work of Norbert Wiener on Cy-
bernetics (the study of biological control mech-
nanisms [9]), to mathematical studies of the
nervous system [10], and finally to quite recent
work using mathematics to study consciousness

Neurons, or nerve cells, are the basic building
blocks of the nervous sys-
tem and the brain. They
are complicated, having
electrical, mechanical, and chemical aspects.

Their electrical activity is dominated by ionic cur-
rents passing through their membranes, and
mechanical deformations of neurons and their
interconnections are caused by contractile pro-
teins in them. Neurons communicate primarily
by passing powerful chemicals, called neuro-
transmitters, from one to another. There are
many kinds of neurons, and what they do and
how they work is still mostly unknown although
significant progress is being made on these ques-
tions across many disciplines.

There is a basic fill-and-flush dynamics in the
ionic currents in neurons that has been cap-
tured by mathematical models. Hodgkin's and
Huxley's Nobel Prize-winning work on nerve
membranes proposed a model, though one not
central to their work, of the form

\[ \dot{V} + V = f(W, V) \]
\[ T(V)\dot{W} + W = g(W, V) \]

where \( V \) denotes the voltage across a patch of
nerve membrane and \( W \) is a vector of (phenom-
enological) recovery variables. When stimu-
lated, \( V \) increases and causes the opening of
ionic channels in the membrane that are de-
scribed by the variables in \( W \). Opening and clos-
ing of channels is triggered by \( V \) as it passes
through various threshold values and the vari-
ables in \( W \) describe depolarization and recov-
er of the membrane. This is accounted for in
the model by the form of the functions \( T, f \) and
\( g. \) Models of this sort have been extensively
studied by mathematicians. Notably, Lapicque
(1907), van der Pol (1926), Littlewood and
Cartwright (1940s), Levinson (1950), Smale
(1960), and many others as reported, e.g. in [12].

Networks of neurons have been successfully
studied as well. An important feature of neurons
acting together is the timing of their activity. So,
models have been devised that make accessible
phase information and ensemble behavior.

These can be viewed in the following way.

Consider the region of a neuron where voltage
spikes are formed, and denote its voltage at time
t by \( V(\phi(t)) \) where \( V \) is a voltage wave form
\((\cos \phi \) is a reasonable choice) and \( \phi \) is the volt-
age phase at time \( t \). This typically has the (as-

-7ymptotic) form \( \phi(t) \approx \omega t + \phi_0 \) where \( \omega \) is the
firing frequency and \( \phi_0 \) is a phase lag or lead.

The equations

\[ \dot{\phi} = \alpha \]
\[ \tau \dot{\alpha} + \alpha = \omega + \beta \cos \phi \]

describe the dynamics of such a neuron model.

The variable \( \alpha \) describes the cell's activity (here
its firing rate) and \( \phi \) the cell's action potential
phase. The data \( \tau, \beta, \) and \( \omega \) describe a time
delay, tuning and driving frequency, respec-
tively. This model is in the spirit of the nonlin-
er pendulum (anharmonic oscillators), and it
has been extensively studied in many contexts
including mechanics, power systems, super con-
ductivity, phase-locked loop integrated circuits,
and quantum mechanics.

Networks of neurons can process information
by passing appropriate signals on to other brain
or body systems and they can store and retrieve
information. Information may be in terms of
chemical concentrations or in terms of electric-
ical pulses.
A network of $N$ such models is described by the system of differential equations
\[
\phi_j = a_j \\
\tau \frac{d}{dt} a_j + a_j = \omega_j + \beta_j \cos \phi_j \\
+ \sum_{k=1}^{N} (C_{k,j} f(a_k) + E_{k,j} V(\phi_k))
\]
for $j = 1, \ldots, N$ where $f(a)$ is an S-shaped function (e.g., $f(a) = 1 - e^{-a^2}$ for $a > 0$), or an \(\cap\)-shaped function, and the matrices $C$ and $E$ describe the network's chemical and electrical connections, respectively.

When $\beta = 0$ and $E = 0$, this network can be a gradient system with respect to the activities $a$, and the underlying potential function describes the remembered states of the system, and so it represents a kind of energy for the system. Work on spin-glass models and adaptive filters is in this direction [13].

Under other conditions, the system may have an invariant torus, say $a = A(\phi)$ of dimension $N$, and the flow on it can be a combination of stable torus knots (phase-locked quasi-periodic motions) and unstable ergodic behavior. Work on phase models is in this direction [12, 14].

The mathematical problems revolving around such systems touch on bifurcation, perturbation, and stability theories for dynamical systems [15], differential geometry, variational theory, and the geometry of knots. There is an abundant store of good mathematical problems residing in such systems.

Another rich direction mathematicians have taken toward brain dynamics began with work of Turing, McCulloch and Pitts [17], and Kleene. In these, a neuron is modeled as being a 0-1 device, so the state of a network at any instant is described by an array whose elements are zeros and ones. Turing machines [16, 18] and recursive function theory [19] are fundamental mathematical results related to this work. On the other hand, McCulloch's and Pitts's approach blended nicely with later developments of spin-glass models in physics and ultimately with recent developments of such models [20].

Finally, recent work on neurons has led to speculation that quantum mechanical aspects of them are related to consciousness, attention, and understanding. Thus, Schroedinger's equation and the paradoxes of quantum mechanics have come into discussions of brain dynamics as well. These exciting developments will blossom over the next decade and beyond, with possible connections to algebra, algebraic geometry, complex analysis, and topology through new mathematical theories that fill the gap between quantum mechanics and relativity [11, 21].

The impact of mathematical work on understanding the brain has been copious and significant, but not always obvious. For example, there is a direct bridge from von Helmholtz to Freud (oddly enough through a professor named Bruecke), who used the idea of psychic energy as a basis for his work on catharsis [22], and to Jung who investigated synchronicity [23]. Work by these psychoanalysts has fed back in many ways to influence scientific thought about the brain.

Can mathematicians and biologists collaborate? There are some basic problems to be overcome. R. Thom [24] identifies a possible philosophical obstacle to collaborations between life scientists and mathematicians. He points out that two principal approaches are taken toward modeling: ordinary language models, that are precise where data are known and suitably vague otherwise, and mathematical models that are reduced to minimal parts but still produce results consistent with experimental observations. In some senses, the issue is one between analysis and synthesis: one can synthesize a mathematical model and analyze its solutions, or one can analyze a phenomenon and synthesize a word model for it. Hopefully, iteration between these two approaches leads to useful descriptions of biological phenomena and new insights to mathematics. At various stages during this iterative process, the ordinary language model that is being analyzed and the mathematical model that is being synthesized are reviewed and updated. Resynthesis of the word model and analysis of the solutions of the mathematical model are included in this review.

This is not quite as simple as it might sound. Following is a fanciful interaction between imaginary word and math modelers. While modeling in this illustration uses differential equations, the illustration could as well have been done with orientation reversing fission in some bacteria leading to a discussion of the dunce's cap in point set topology and back to discovery of three dimensional dynamics of cell division, or comparing two strands of DNA leading to a discussion of correlation matrices and Fourier analysis of them. This example is chosen because it involves widely known and straightforward mathematics. An interesting thing about joint work is the discovery of new mathematical problems, which this fictional dialog does not really capture. Still, the example does indicate the economy of word models and the convergence of theory and experiments, and it serves to identify some obstacles to collaboration.

Word: After a population of bacteria is exposed to an alternating starvation-nutrition regimen for a while, we observe that the cells syn-
chronize their division times many generations into the future.

**Math:** Let \( B(t) \) be the number of bacteria at time \( t \). Then under steady conditions we have

\[
\frac{dB}{dt} = AB
\]

where \( \log 2/A \) is the cell doubling time. If we use \( A \) as a control variable by alternately setting it to 0 and \( A_{\text{max}} \) reflecting starvation and nutrition, respectively, and then eventually setting it equal to \( A_{\text{max}} \) we see no mechanism for creating or sustaining oscillations. Are there time delays in the system?

**Word:** The life cycle of a bacterium is in four parts:

- \( G_1 \), the first gap interval when we believe materials are taken up for metabolism and to prepare for DNA synthesis,
- \( S \), an interval during which DNA is synthesized in the cell,
- \( G_2 \), the second gap interval in which the cells prepare for division,
- Mitosis during which cell fission occurs. This interval is quite short compared to the others.

**Math:** Let \( p \) denote the cell cycle phase, and let \( p_1 \) and \( p_2 \) denote the boundaries between intervals, so \( G_1 \) corresponds to \( 0 \leq p < p_1 \), \( S \) corresponds to \( p_1 \leq p < p_2 \), \( G_2 \) corresponds to \( p_2 \leq p < 1 \), and cell division corresponds to \( p = 1 \). Let \( u(p, t) \) denote the number of cells at cell cycle phase \( p \) at time \( t \). Then conservation of bacteria implies

\[
\frac{\partial u}{\partial t} + A \frac{\partial u}{\partial p} = 0
\]

\( A \) denotes the ageing rate of bacteria, i.e., the rate at which they progress through the cell cycle. Cell fission is described by the boundary conditions

\[
u(0, t) = 2u(1, t)
\]

We can solve this model using the method of characteristics by solving the characteristic equations

\[
\frac{dt}{ds} = 1
\]  
\[
\frac{dp}{ds} = A
\]

on the cylinder \( \{(t, p \mod 1)\} \). Again, we can use \( A \) as being a control variable, but when we analyze the model, we see no mechanism for bringing cells to similar phases or for sustained oscillations in cell division when \( A \) is eventually set to a constant \( A = A_{\text{max}} \).

Is there something in the cell cycle that could lead to convergence of the characteristics, and so bring several cell lines to division at nearly the same time?

**Word:** After some experimentation, we see that during starvation the cells seem to progress through the synthesis stage even though there are no external nutrients.

We deduce that cells do not start synthesis until they have enough material to complete it.

**Math:** Keen observation! So \( A \) can change with \( p \), too: We write \( A = A(p, t) \). Then

\[
\frac{\partial u}{\partial t} + \frac{\partial}{\partial p}(A(p, t)u) = 0
\]

For \( p \in \{p_1, p_2\} \) we set \( A = c \), a constant corresponding to the observed rate at which a cell passes through synthesis, and in \( G_1 \) and \( G_2 \), we set \( A = \alpha \), which we will use as a control variable. During starvation, we set \( \alpha = 0 \) and during nutrition \( \alpha = \alpha_{\text{max}} \).

Now, we see that during starvation the characteristics will accumulate at the end of the \( S \) phase. This is a mechanism for converging cell lines. Since there is no mechanism for changing synchrony under steady nutrition, synchrony will be sustained into the future.

The project is wrapped up by experimental determination of relevant rates, calculation of optimal starvation-nutrition cycling to synchronize all cell reproduction in the shortest time using the model, experimental corroboration of suggested optimal schedules, generation of model control charts to use as diagnostic tools to test the differences between bacterial species and genetic types, computation of the rate at which synchrony might be lost if noise is introduced, and production of a written record of the work, perhaps for publication.

This is not to say that collaboration will stop at this point since there are numerous new experiments and mathematical problems suggested by the project.

It is clear that there are a number of points in this interaction where philosophical differences, unsuccessful mathematical modeling or analysis, or incomplete experiments could block success. Among the impediments to joint projects are the following:

First, there is legitimate reluctance by life scientists to invest effort in understanding preliminary mathematical characterizations of a phenomenon when they could be "just going ahead and doing the experiments".

Second, there are linguistic barriers. For example, the precision of word models depends on interpretation of the words. One sees scientists disagreeing over the interpretation of data (How can you interpret my data correctly? You never did a rotation in my lab!). In addition to inter-
preparations, there are other communication barriers: Often mathematical modelers do not appreciate the subtlety and complexity of word models; on the other hand, biologists often do not "speak mathematics". Various languages enable one to create new words of increased precision that is not so easy in other languages. Finally, there are cultural differences to be aware of. For example, modes for funding graduate students and postdocs in the two disciplines are quite different. Mathematics often supports students through the use of teaching assistantships while for the most part biologists support their graduate students through grants. The pressures on both sides shape attitudes of researchers as to how "blue sky" an approach one can take.

Third, there are some deep-seated conflicts between rationalists and irrationalists dating back at least to the Enlightenment [25] that manifest themselves when one threatens to mathematize some biological phenomena. For example, work on consciousness is sometimes dismissed as being too close to God.

Finally, even when the iterative process between word and math models converges, it can be difficult to communicate the results effectively to both audiences.

Meetings of combinations of mathematicians, biologists, and engineers are now frequent, and they attract excellent minds (e.g., [35, 36]). These are important for helping to develop common languages for communication between biologists and mathematical scientists, and so for breaking down some of these barriers. We need more such meetings—especially seminars in university and industry settings.

Is one approach better than the other? There are compelling reasons for pursuing both word and math models. Obviously, new biological facts are needed to be uncovered through experiments, and the results must be communicated in accurate and accessible ways. Word models are entirely appropriate.

On the other hand, mathematics has proven to be useful in many important ways.

First, there are many developments in both biology and in mathematics that have benefited by iteration, not always in phase, between biologists and mathematicians. Irregular solutions of nonlinear difference equations arising in ecology models [26] eventually were explained by mathematicians in subsequent work on chaos [5]. Early developments in probability theory motivated by studies of Mendel's and Darwin's theories of genetics and evolution [1] led to development of statistical methods that now form a major part of descriptions of most experiments. They also (should) play a major role in the design of experiments [27]. These developments over the past seventy-five years have established mathematics as being important in suggesting, designing, and interpreting experiments.

Second, the power of mathematics to synthesize models and analyze their solutions is important, for example, in determining boundaries between equilibrium and nonequilibrium biology. For instance, the Kermack-McKendrick threshold theorem gives a dimensionless parameter that is useful in determining when a population is at risk for propagation of a disease resulting in an epidemic [28, 29, 30]. Similar problems are ubiquitous where risk analyses are derived and applied, for example to pesticides [21, 31].

Third, a mix of analysis and geometry brings to biological problems methods that are useful for the study and visualization of higher dimensional structures. For example, joint work on tomography by mathematicians and radiologists has been and continues to be highly successful [32, 33].

Finally, (for this list at least) mathematical models make it possible to bring high-speed computers to bear on biology problems. Large scale applications at present are in the design of drugs and analysis of genome organization [33, 34].

How to get into mathematical biology? Fortunately for us, biology is more descriptive than mathematics, and most of us can pick up a general biology text and understand the underlying ideas and concepts presented there. This is not the case for many biologists with regard to books on differential equations or probability theory, for example. Sensitivity to these issues facilitates collaborations with life scientists.

Here are some suggestions for starting work on problems in mathematical biology.

Why might a biologist be interested in working with a mathematician? It was once put to me this way—You don't know [much] about the experiments so you won't get in my way, and you can probably write great lab reports! Expect some good-humored abuse, but find a biologist who is interested in the possibilities that mathematics might offer to his or her area of research. Do some homework on the area to lay a basis for communication. While this sometimes doesn't work at all (maybe at best you are asked to perform a chi-squared analysis of some data or to write a computer program to do least squares estimations), often it pays off handsomely. A good place to start for leads might be with the chairperson of the local biology department.

What areas of mathematics might be useful in biology? Essentially all areas. Traditional areas arising in mathematical models include bifurcation, perturbation, and stability methods for
A good book series that introduces new mathematics.

in torus flows related to phase-locking of oscillators are important. In addition, input-output analysis of systems (e.g., energy budgets, ecology, physiology, systematics), pattern recognition algorithms (e.g., medical diagnosis), mechanics of artificial limbs, continuum mechanics of organs (e.g., visco-elasticity, fluid flows), electronic circuits to replace parts of our nervous systems (TV vision, electronic hearing, artificial olfaction, etc.), and even quantum mechanical aspects of brain function as noted earlier are rich areas for mathematical investigation.

Start joint seminars for people from both sides (math and biology). A mathematical biology seminar for undergraduates is usually very popular with students, and there are useful texts available [38, 39, 40, 41, 42]. Also, consider organizing a meeting for the American Mathematical Society, the Society for Industrial and Applied Mathematics, or the Society for Mathematical Biology.

Select projects that have interesting mathematics in them and that address significant biological problems. While this is often difficult to see, there are many significant biology problems that can benefit from high-level mathematical results and at the same time generate new mathematics.

Once a problem area is identified that interests you, invest some time in seriously studying the biology. This can be done by sitting in appropriate courses, working together with postdocs or students in biology labs, or in collaboration with faculty, or by yourself in the library. A good book series that introduces mathematical topics in a wide variety of life science areas is the *Cambridge Studies in Mathematical Biology* [37]. You can also get ideas for where to go for problems and references by contacting friends through e-mail or telephone.

Try to publish in journals dealing with the biological area of interest. This is not easy, but it sets high standards for biological content. This might require learning new ways to write mathematics, for example, deferring derivations to a technical appendix, and it often requires co-authorship with a biologist.

It is interesting and useful to learn new areas and to meet other scientists who approach problems from points of view different from mathematicians. It is also interesting to see how their laboratories, departments, and funding sources function. Mathematical biology provides unusual opportunities for making contact with biologists in ways that can result in useful new knowledge about us and where we live.

The areas touched on in this article are not meant to be exhaustive. I am happy to say that such a project is virtually impossible because of the huge literature involved. Also, the choice of references in this article is rather idiosyncratic. It is done by design to indicate some contributions and directions that are not widely known among mathematicians. The default in many people's minds about mathematical biology is the Volterra-Lotka-Kolmogoroff system or results from Rashevsky's school. We see here that there are many other people involved in mathematical biology. You could be too.

**References**


Why are most children bored by math—or worse, frightened of it—when its beauties are so many and its pleasures so great? Probably because it is usually taught by people who fear it, and who therefore teach their fear.

To counter this (locally, but with hope of disseminating the ideas), three of us—my wife Ellen, Tomás Guillermo and I—have begun a Saturday morning Math Circle in space given us by Northeastern University in Boston (thanks to Andrei Zelevinsky), for interested 8-to-18 year-olds. Word of mouth alone brought us twenty-nine students for the first semester and forty for the second. Their giving up Saturday mornings of sleep, sports or music lessons is a sign of how much enthusiasm there is for math done with intensity and delight. We’ve now had to add a Thursday afternoon session at Harvard (thanks to Danny Goroff) for the overflow.

Our approach in The Math Circle is to pose questions and let congenial conversation take over. Conjectures emerge from a free-for-all, examples and counterexamples from the conjectures. Two steps forward are followed by a step back. What really is at issue here? How will we know when we’ve understood something? Is proving different from seeing? Where and with what should proofs begin, and how validate these beginnings? And if we get it, need we formalize it? Yes—following my old fencing-master’s adage about holding the foil like a bird: tightly enough not to let it get away, not so tightly as to crush it. We don’t want a ‘60s feel-good sense of math as expressive hand-waving. We explain that rigor without mortis consists in fluency at making a connected path back to foundations that will stand up to scrutiny. In our exchanges the students are developing the knack of pushing insight adventurously ahead while protecting the supply-lines that fuel it.

Here’s an example of what happens, from the Thursday afternoon sessions with 8- to 11-year-olds. I began by asking them each to give me very large numbers, and a rather conservative list of integers developed on the board (Littlewood calculated that the gigantic stretches of time in Indian mythology “only” amounted to years—for example, for kids, 250 is, as it should be, way out there). Was there a last integer? Of course not, said 8-year-old Anna at once: if there were, just add one to it. I was struck by this instantaneous freeing of imagination with the passage to the general. They all took easily to one-one correspondences, via the need to show Martians who count 1, 2, 3, many; that a heap of thirteen pencils contains a larger “many” than a pile of eight coins (some sorted by threes, some paired up, all relished the Martian astonishment that there were two sizes of ‘many’). By the end of the first hour each was pairing up the naturals with the evens or the odds or multiples of 7 (“Let’s walk through the numbers in seven-league boots!” said one) or the negatives and positives, or the integers (a puzzling moment, followed by a cry of “Shift!”). The children left that first session in two minds: they saw and could not but assent to the results of their work, but they “knew” it couldn’t be right—there were clearly only half as many even numbers as naturals.
I was glad to see one boy return to the second session who had come to the first the way you go to a horror movie: frozen between fascination and flight. He had been brooding about the infinite, his mother told me, and found it terrifying, and had signed up for this class to overcome his fear. As you might expect, his were the most daring conjectures in what followed.

Could the positive rationals be counted? Passionate arguments raged about the lack of a starting place (the abyss of density opened, for the first time, for several there). I put the first few rows and columns on the board to claims ringing through the room that we could never get out of the row we once committed ourselves to—until a girl, quiet before this, asked if she could come up and began spinning a drunken spider's web from the upper left-hand comer. Another girl suggested how we might regularize the pattern and despair turning to glee, each now constructed a bus-route through these streets and avenues (to the accompaniment of popping insights and questions: "Look! Those diagonals are all repeats!" "But how can we tell ahead of time that the sixteenth stop will be 2/3?"") The diagonal proof belongs now to each of them, for as Locke pointed out, "Property is that with which one has commingled one's labor."

We headed toward Cantor's second diagonal proof through the largely unfamiliar territory of decimals, browsing among repeating and non-repeating growths (much ingenuity here, on their part, in concocting and explaining). Then a long digression on what it would mean not to have a one-one correspondence between two sets, and on proof by contradiction (this pushes the limits of how much can equably be held in mind), heralding the metaphorical entrance of a figure modeled on the late and unlamented Senator McCarthy, patting his jacket-pocket: "I have in my pocket a list of all the card-carrying decimals between 0 and 1", each card bearing its ordinal. They followed the proof complaining all the way, arguing with and explaining it to one another, ending up as flabbergasted as I am every time I think it through.

By the time I arrived for the next class, a girl with an uncannily precise mind was explaining Cantor's proof to a die-hard skeptic, countering his attempts to put "our decimal made up of 5s and 6s 'at the end of the list'". Now the pace accelerated as we came back to the visual: they called the proof they devised of the one-one correspondence between points on closed segments of different lengths "the circus tent". Giving names, as Adam first knew, is a sign of confidence. Since I'd told them about, they christened our new cardinality "zig-zag null".

And the open interval and the real line? This led to the greatest frustrations as well as ingenuity. At last, exhausted, with time running out and skepticism about everything creeping out of every corner, the boy who feared infinity had the saving insight. Tremendous relief, appreciation, exhilaration. But the last note was struck by the girl with the precise mind: "I see the proof and I accept it", she said, "and at the same time I don't. It doesn't tell us, does it, just which real number goes with the decimal we choose in (0, 1)? That makes me uneasy." A good note to end—and begin afresh—on.

The topics we chose—but more particularly the ways we worked on them—were designed to avoid two things which tend to go wrong with accelerated or "enrichment" math courses. One is children being taught the punch-lines without having worked their own way up to them ("I've already had Pascal's Triangle", says the child who knows neither its genesis nor implications). The second is teaching the magic that looks like math: Pavlovian training of ten-year-olds to push the right symbols to take derivatives of polynomials.

Why did we choose infinite sets for the youngest group? Because little kids love large numbers, the way they like elephants and dinosaurs: powerful friends in high places, but a liking tinged with titillating fear. Children have no reputations to protect—because they don't even know yet about reputation—so they are much better than older students at making and getting far-fetched ideas—not a card is held close to a chest. Unlike philosophy, math begins with awe and ends with wonder.

Ellen chose to work on polygon construction with the 8-to-11 year-olds. Polygon construction meant using actual straight-edges and compasses; and while the hands were busy, a casual conversation about constructability steadily moved from the context to the content of the course. One student to another: "What do you mean, you can't trisect all angles? If you can trisect a 90° angle by copying 30° angles, can't you copy some angle twice to get any angle?" The crux of the matter is to seize on such assertions so as to let the students find out for themselves what's at stake (coming to grips with, among other things, the mysteries of quantification).

A generation brought up with calculators has difficulty manipulating fractions. Instead of addressing this directly, Ellen led them to construct an equilateral triangle and a regular pentagon in the same circle, and to figure out how to construct a regular 15-gon—thus discovering that 1/3 minus 1/5 could be seen as the useful 2/15 rather than the unenlightening .13333... The confidence that followed this self-won competence made them feel this world was their oyster: they could construct whole series of regular polygons. Then, why were the heptagon and...
The 11-to-14 year-olds Ellen worked on polyhedra. Conversation accompanying scissors-and-paste constructions led very quickly to the discovery of the Euler characteristic. They tested it with Schlegel diagrams, studied and were convinced by Cauchy’s proof, then read Lakatos’ dialogue *Proofs and Refutations* (about the Euler characteristic), taking parts, and stepping out of character again and again to argue with the protagonists. They were startled to recognize in themselves the traits of monster-barrer and monster-adjustor, skeptic and omni-ameliorator. As in the dialogue, the semester ended with everything up in the air. Should things be neatly tied up?

With the same group, I worked on number theory beginning with this peculiarity: why do the digits in half the period of the decimal expansion of $1/7$ yield, when added to the other half, all 9s? (One 11-year-old immediately said: “You mean, one less than a power of 10?”). And look, it’s true of $1/13$ too, and $1/101$; but not of $1/2$ or $1/5$, much less $1/3$ or $1/8$. This took us on two long excursions: into geometric series and, through the idea of congruence, to Fermat’s Little Theorem (which again they came up with themselves, just by messin’ around). The far-shining goal of our initial puzzle got us through difficult stretches. There is a push-me-pull-you rhythm to the best of these classes: convictions put together the week before turn out to have been soldered, not welded, together, and come apart with flexing (how was it we got the sum of an infinite series?). We reconstruct them more solidly under the pressure of doubt.

The 14-to-18 year-olds worked on infinite sequences and series with Guillermo, then did projective geometry with me. These were the most hard-fought of all the classes: they wanted nothing told them, all was to be invented. They came up with convergence criteria of their own (named after their new inventors), approximating ever more closely to the curve of the topic’s history. By judicious choice of examples and nudges at critical moments I moved them to where they could—and did—come up with Desargues’ Theorem, followed by their vigorous, critical role as sous-chefs in cooking up its proof. Because they were very puzzled by the maneuver of having to pass out of the plane and back to it, some doubting the validity of the proof, others the universality of the theorem, we had to digress to the free projective plane on four points—which they found startling and disturbing. They took an inventor’s pride in coming up with a proof of the uniqueness of the fourth harmonic point, and that left us, at the end (ten sessions are too few), able to conjecture the Fundamental Theorem and prove its existence part. A real advantage of projective geometry for students whose graphing calculators usually do their visualizing for them is that their spatial imagination is awakened and exercised.

Our Saturday format has been two one-hour classes (milk and cookies in between), followed by guest lecturers (for example, Mazur on the ABC conjecture, Diaconis on the card-shuffling that led him to become a mathematician). A good high school mathematics course brings a student up to the eighteenth century. Here they could see contemporary mathematicians working on the frontier in the same manner that they had been developing for the last two hours.

Because our clientele is growing for next year we’ll be taking on another hand. We’re thinking too of branching out to other cities. What may be hard to export is our style: we entertain all conjectures and questions with equal seriousness, letting them follow their conversational course and turning the current of that conversation into fruitful directions as unobtrusively as possible. If a line of inquiry hits a wall we tend to let it lie and strike off in another direction, rather than throwing our students a sophisticated assortment of scaling-ladders. What’s left fallow one week tends to produce a flurry of ingenious growths by the next (and these dead ends are the material of the week’s homework). We do our best to hold off introducing a symbol until its abbreviatory power is welcomed for packaging up what had become an unwieldy complex of relations. Best when the students come up with the symbol—and the need for it—themselves.

What have we learned from this? That the appetite for real math, done neither competitively nor scholastically but as the most exciting of the arts, is enormous. I see no limits to what children can learn, and am convinced that if you want to teach them A, and A implies B, work on B with them; A will be mastered en passant, painlessly, absorbed in the bones. I’m certain too that removing any question of time—or achievement—pressure lets understanding and technique blossom, as well as developing a delightfully collegial feeling in those involved and a sense of the enterprise as contained within larger frameworks of question and significance. The students come away certain that math is mysterious, equally certain that its mysteries are accessible; unsure whether we discover or invent it; confident in their growing competence, and with that heightened threshold of frustration, that odd combination of watchfulness and willfulness, that characterizes the practitioners of our craft.
The Mathematician and Pre-College Education

Humans are rarely in control of their own institutions. However much we prize freedom of action, we are often constrained to behave in ways which are dictated by our institutions' needs rather than our own.

The role of mathematicians in education illustrates this clearly. While many mathematicians are interested in pre-college education, there is a scarcity of opportunities for mathematicians to contribute to the national effort in education. When these opportunities do arise, the rewards structure attached to such work often makes it difficult to take advantage of them.

John Kenelly illustrates this with a striking anecdote. He had worked for several years to increase participation in his state in the Advanced Placement program in mathematics. When his efforts resulted in a major increase in enrollment in the program, he reported this to the chair of his department. The reaction? "Yes, such volunteer work is good. Your colleague in the next office is a scoutmaster. But we don't credit community service in our evaluations." Happily, the president of the university, hearing this, disagreed. And, happily, the growth in mathematical knowledge of the students and teachers in the state continued, bolstered by the efforts of several mathematicians.

Our institutions do not dictate our individual actions, but they often do set our priorities. To achieve the rewards of tenure and promotion, the college professor must get her or his name out there in publication. The university must become a center of research, a producer of new knowledge, as measured by research articles, and graduate programs. The issue of individual mortality—of nurturing new mathematicians to take over from the current generation—is one that The University largely ignores.

Ignored, too, is the issue of seeking out mathematical ability in those who don't know they possess it. The gifted graduate student was once the insecure undergraduate, and before that the uncertain high school student, and before that the child, with a mind awaiting inspiration. It's a severe series of filters to pass through. We can only guess at how much mathematical ability remains untapped. We need this ability not only to create mathematicians, but also across the spectrum of a growing number of fields which use mathematics. The narrow view of university mathematics does not contribute to this effort.

Priorities in pre-college education differ vastly from those on the university level. The classroom teacher must maintain order and show student achievement. The administrator must show that The District is progressing, and that this progress is due to his or her own actions. The teacher who publishes, who "produces new knowledge", is an exception. Indeed, there are cases in which a teacher's publications have roused the jealousy of colleagues, and threatened the pride of unenlightened administrators. The District is often
unaware that the transfer of expertise among teachers benefits everyone. And so our institutions perpetuate the caricature of the other-worldly professor and the circumscribed teacher. They attempt to mold research mathematicians into elitist strivers, and pre-college teachers into docile workers. The situation is not unlike that of the Edwardian household in the television series whose title I have borrowed: two social systems in proximity, struggling to reach a personal working relationship against the grain of the roles cast them by society.

Faculty members of schools of education find themselves pinched especially painfully in this vise. While they are charged with investigating the processes of pre-college education, and by extension doing something about it, the institutions they work with keep them out of the classroom and away from the most fertile source of knowledge. When they do interact with students and teachers, they are often coming "down" from upstairs to do so, and report their results in journals read mainly by other researchers. The unfortunate result is that much of this research is of little interest either to mathematicians or to mathematics teachers.

It is also true that the field of education is changing rapidly, so that mathematicians who want to help find themselves aiming at a moving target. We are more and more aware of our crisis situation in pre-college mathematics education and more willing to try new ideas. It is inevitable that some of these ideas will not succeed and that the system will experience a certain amount of "thrashing". The message this sends to some mathematicians is that education is a mess with which they should not dirty themselves.

Of course, none of these descriptions is fair to those individuals of good will who reach across institutional barriers, who leave the campus for the classroom or the classroom for the library. The point is that the work of these individuals to bind us together runs counter to the institutional forces that tear us apart.

Translated to the national level, these forces produce several anomalies. Most conspicuously, our graduate and research programs in mathematics, often deemed the finest in the world, attract the best students from all over the globe. Victims of our own success, American-born graduates students are outnumbered by gifted immigrants. Yet our pre-college programs, and particularly our public schools, suffer with perhaps the lowest level of mathematical achievement of any of the industrialized countries.

Another related anomaly: we have a surplus of Ph.D.s in mathematics, but a major shortage of teachers on the pre-college level with strong mathematical backgrounds. There is an obvious solution, but most people who have recently earned the Ph.D. in mathematics would rather perform respectable manual labor—or study law—than take a job in public education. Their mentors and advisors, anxious for their departments to achieve where it counts, often discourage such a step.

There are alternatives. For example, the end of the Cold War has fortuitously presented us with a different model, in the mathematical culture of Eastern Europe and the former Soviet Union. Readers of this journal are perhaps the only group in the country who can appreciate the successes of Russian mathematicians in the Soviet era. These extraordinary achievements were the product of a society in which rewards and status were assigned in very different ways from those we are used to. A second outstanding program was the "correspondence school" started by I. M. Gelfand, and which he is continuing in the United States (for more information on this, see Mark Saul: "Love Among the Ruins: The Education of High-Ability Mathematics Students in the USSR," Focus, Vol. 12, No. 1, February, 1992). His program ultimately reached tens of thousands of students in small towns and cities across the expanse of the Soviet Union. College admissions programs recognized participation in the Gelfand school as indicating both a deep interest and careful training in mathematics. Of the many remarkable features of this program, we may note first that the tremendous labor required to assess and respond to student assignments was undertaken by graduate students of mathematics, by faculty members and by high school teachers, each of

However much we prize freedom of action, we are often constrained to behave in ways which are dictated by our institutions' needs rather than our own.
whom played closely coordinated roles. Also noteworthy was the personal interest Gelfand took in the program. One of the great mathematicians of the century routinely took time out of his research career to write books and construct exercises for high school students. The care and thought that Gelfand put into this effort was entirely commensurate with the efforts he put into his mathematical (and biological) research. While we must not copy the Soviet system, with its many faults (and probably cannot copy any system at all from abroad), we can learn and borrow from their practices.

The Russian "mathematical circles" are an example of a practice from which we can learn. It was fairly common for the faculty of Russian universities, from well-established professors to younger faculty and graduate students, to go into the high schools and organize study groups for students who were interested in mathematics. Often these were the high schools that the mathematicians had graduated from, or which their own children attended. Out of these circles grew a body of popular mathematical literature on a very high level, written by some of the most accomplished Soviet mathematicians. Kolmogorov, Yaglom, Markushewitch, Khinchin, Dinkin, and many others spent significant parts of their careers considering mathematics curricula or writing books that bring rather advanced materials within reach of high school students. This body of literature constitutes a Russian national treasure, only some of which has been made accessible in English.

The organization of mathematical circles was closely connected with the Russian system of mathematical competitions. Russian contests involved almost exclusively long-answer questions requiring experimentation and proof (American contests are usually based on short-answer or multiple choice questions). The expertise of university faculty was routinely tapped, both to construct questions and to grade papers. This led to a healthy interaction among professors, graduate and undergraduate students, and high school staff and students. In turn, this massive effort forged new links among members of the mathematics community and led to still more cooperative activity, including mathematical summer camps and evening schools. High schools for students specializing in mathematics and the sciences were opened across the Soviet Union, often motivated by the actions of a well-known physicist or mathematician.

Amid this ferment of educational and mathematical activity, two particular programs stand out. The first is the journal Kvant, founded in 1970 by a group of mathematicians and physicists, including teachers on the secondary level. This remarkable journal presented articles in these two areas written by researchers or graduate students, and accessible to high school students. Its style was interactive, with exercises and examples posed throughout the expositions. Russian mathematics has thus given us a rich set of models on which to build, and there have been several fine beginnings. In 1988, the editors of Kvant reached an agreement with the National Science Teachers' Association to publish a parallel journal in America, called Quantum. A marvelous but under-utilized resource, Quantum presents monthly translations of Russian articles, problems and brainteasers. Some American mathematicians and teachers have contributed articles (indeed, some American authors had already published in Kvant). But it has been difficult to find suitable contributions from American authors. Perhaps in the future, publication in Quantum will become an accepted and perhaps rewarded academic activity.

American mathematical contests have also been influenced by foreign models, from Russia and elsewhere. To the older short-answer contests, some of whose histories reach back to the early years of the century, we have added the USA
Mathematical Olympiad, administered to about 150 of the country's most talented high school mathematics students. The Olympiad consists of five long-answer questions, and is essentially modeled after numerous Eastern European competitions (the International Mathematical Olympiad originated in Eastern Europe when it was the Soviet Bloc). From Hungary has come the model for the American Mathematical Talent Search, run by George Berszenyi out of Rose-Hulman Institute of Technology. This contest, with an associated NSF-funded summer program, offers sets of long-answer questions to almost 1,000 students. The American Regions Mathematics League, composed mainly of high school teachers, is about to launch a Power Contest, in which groups of high school students will cooperate in solving olympiad-style questions. In each case, the struggle has been to find mathematicians who would be willing to write questions and grade solutions. Support for these enterprises has come from government agencies, from research laboratories, and from mathematicians employed in the high schools, but it has been difficult to find university faculty who are free to engage in this kind of work.

I. M. Gelfand, now at Rutgers University, has been working to establish a form of his correspondence school in the United States. This effort, called the Gelfand Outreach Program in Mathematics, has been remarkably successful on a local level. Gelfand has published three texts on elementary mathematics, and plans a full English-language series. As with the Russian materials, he takes the same care in preparing these as in preparing his research articles for publication. Using resources offered by Rutgers University, personal connections, and private funding, Gelfand has set up a program serving 400 students, a remarkable number of whom are female or come from minority backgrounds. The effort to duplicate this model in other localities has proven difficult: American mathematicians are rarely supported in this by their institutions.

Not all the involvement of American mathematicians in education has its roots in foreign influences. There are a number of striking American originals. David Kelly has been running a summer program at Hampshire College which attracts interested mathematicians and creates a support network of peers and teachers for students interested in mathematics. Arnold Ross has been doing much the same thing since before Sputnik at Ohio State University. Ross's work is being continued by Glenn Stevens at Boston University. Other instances of mathematicians working with high school teachers or students include the Westinghouse contest, which is judged partly by mathematicians, and the Research Science Institute at MIT. Started by Admiral Rick-
The 1995 Arnold Ross Lectures

Each year, the AMS sponsors the Arnold Ross Lectures, a special one-day program of talks by outstanding mathematicians presented to an audience of high school students. The aim of the program is to reveal to young people the beauty and excitement of mathematics and its uses.

The 1995 AMS Arnold Ross Lectures were presented on April 22 at Rice University. The lecturers were Fan R. K. Chung of the University of Pennsylvania, John Tate of the University of Texas at Austin, and Rice's own Frank Jones. The lectures were attended by gifted students from high schools in the Houston area. Their teachers, plus a few Rice students, were also in attendance. One teacher came from Tyler, Texas, which is nearly 200 miles from Houston.

John C. Polking of Rice University, the local organizer for the program, says that the students who were there "got three wonderful lectures." Chung spoke on the mathematics of buckyballs, which was particularly appropriate because buckyballs were discovered at Rice University. Apart from the connection the buckyballs provide between mathematics and chemistry, they have a wealth of interesting combinatorial, topological, and geometrical aspects, which Chung described.

Tate's talk about Fermat's Last Theorem was "animated and informative," says Polking. "I've heard several people give talks on this subject in the past couple of years, and this one was among the best." Tate discussed the recent proof of Fermat, begun by Andrew Wiles and completed by Wiles and Richard Taylor. The students found Tate's recollections about the personalities and the stories surrounding the mysterious theorem to be particularly intriguing.

It seems that Jones brought down the house with his lecture on Ford circles and Farey fractions. Ford circles are a family of mutually tangent circles in the half-plane, all tangent to the x-axis, and their points of tangency on the x-axis form a set of rational numbers called Farey fractions. Starting with very elementary ideas, some surprisingly interesting mathematics results. One measure of the success of this lecture is the fact that Jones's assignment of a "homework" problem was met with great enthusiasm. Jones, a master teacher, "gets that reaction every day in his classes," Polking remarks.

The lectures were organized by an AMS committee consisting of Harvey B. Keynes of the University of Minnesota, Paul J. Sally of the University of Chicago, and Jean E. Taylor of Rutgers University. The AMS has sponsored such lectures for high school students in Boston (1988), San Diego (1990), Chicago (1992), Columbus, Ohio (1993), and Minneapolis (1994). In 1993, the AMS named the lectures in honor of Arnold Ross of the Ohio State University. Ross is the director of the Horizons Unlimited Program for inner-city students and the Young Scholars Summer Program. His programs have inspired some to pursue careers in mathematics research and fostered in many others a lifelong love of mathematics.

The Arnold Ross Lectures have been made possible in part through funding by the Exxon Education Foundation. For more information about the program, contact Timothy Goggins, AMS Development Officer, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248.

—Allyn Jackson
In April, the Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Research Council (NRC) released a report presenting the results of a one-and-a-half year study of graduate education in science and engineering. The report, entitled *Reshaping the Graduate Education of Scientists and Engineers*, examines the trends behind shifts in employment of science and engineering doctorates and makes recommendations for ways in which graduate programs can respond to the changing climate.

In the last few years, many new science and engineering doctorates have had trouble finding permanent employment, especially in academia. The frustration of many of these young people is apparent on the e-mail networks, such as the Young Scientists' Network and the Young Mathematicians' Network, that have sprung up since the job market began to sour.

Cautious in its approach, the NRC study sounds no alarm bells about the job market. It says that the unemployment rate of scientists and engineers, around 1.5% during the 1990s, "comparably" with the rate of 6% for the nation as a whole. But the report does acknowledge that much of the pain of the job market has concentrated on new doctorates, a group which in some fields has experienced double-digit unemployment rates. These young people "eventually do find employment, but in some fields process is taking much longer than it did for their predecessors," the report says. Data from the AMS-IMS-MAA Annual Survey are cited in support of this observation.

The report examines long-term trends in where new science and engineering Ph.D.'s are being employed. One surprising conclusion: The percentage of recent Ph.D.'s who are employed in academia fell from 51% in 1977 to 43% in 1991. However, this trend was not borne out in the mathematical sciences, where the analogous figures are 74% and 76%. (The report mentions that the 76% figure was a one-year rise that followed "years of decline", though just how large a decline is not indicated.) The percentage of new science and engineering doctorates employed in industry increased from 26% in 1977 to 34% in 1991; the percentages in the mathematical sciences were 12% and 19%, respectively.

On the strength of such data, the report asserts that job opportunities in business and industry will grow. "Over the long term, demand for graduate scientists and engineers in business and industry is increasing," the report states. "[M]ore employment options are available to graduate scientists and engineers who have multiple disciplines, minor degrees, personal communication skills, and entrepreneurial skills."

In collecting information for the study, the committee sent out a call for comments to graduate students, postdocs, professors, academic administrators, industry scientists and executives, and representatives of scientific societies—over 1,000 individuals in all. More than half of the 100 responses came from people in industry, and the report emphasizes their comments. Generally, industry seems to value science and engineering doctorates not so much for specific knowledge but more because they are trained to be analytical, pragmatic, and flexible problem-solvers. The narrow specialization necessary for a Ph.D. was sometimes cited as a drawback, for
industry prefers generalists with a wide range of scientific and analytical tools at their command. Excellent interpersonal and communication skills and the ability to be a "team player" were also deemed desirable.

Perhaps a new type of degree, requiring less original research and more breadth, is in order? The report rejects this idea, saying that such a degree would likely be viewed as a sort of "Ph.D.-lite." Instead, the report advocates adapting the doctorate to include broader academic preparation, especially coursework in areas outside one's specialty, and more opportunities for industrial internships and interdisciplinary research. The report also emphasizes the importance of maintaining high-quality standards for the doctorate and not increasing the already long time-to-degree. No specifics are offered on how to accomplish this. Instead, the report stresses "local initiative": individual institutions coming up with ideas and standards that work within their own local conditions and that build upon their strengths and interests.

One of the few concrete suggestions in the report is the idea of "education/training grants" to support graduate students. These grants would be made to departments or programs, rather than to individual faculty members. Proposers would have to describe a plan to improve the versatility of the students and to upgrade the advice that faculty give about the full range of employment options. As an example of what a "winning" proposal for an education/training grant might include, the report suggests "an interdisciplinary degree program that [allows] a mathematics Ph.D. student to obtain an MS in engineering."

The report's executive summary lays out a number of formal recommendations which are elaborated in the final chapter. The first recommendation is to offer a broader range of academic options; this would be achieved through changes in graduate programs as well as adjustments on the part of funding agencies in support mechanisms for graduate study. The report emphasizes that individual institutions should take the initiative for change, building on their own strengths and interests, but offers no specifics on what kinds of changes should be made.

The second recommendation is to make better career information available to graduate students. The report envisions a "concerted nationwide effort" to build a national electronic database on employment options and trends that both students and their advisers could tap into. The report also suggests that, when students have completed their qualifying examinations and are about to start the research phase, advisers should encourage students to examine three options: stopping with a master's degree, working toward a Ph.D. with the goal of continuing research, and preparing for work in a non-traditional field by designing an original dissertation that would take less time than a traditional one. "We believe that the first option is typically undervalued and the third option often neglected," the report states.

The final recommendation is to devise a national "human-resource policy for advanced scientists and engineers." To this end, the report calls for a "searching national discussion" about the nation's needs for science and engineering doctorates so that goals and policies can be established for graduate education in these areas. COSEPUP chair Phillip A. Griffiths, director of the Institute for Advanced Study, says that the Government-University-Industry Roundtable, the American Association of Universities, and the Council of Graduate Schools are among the organizations that might lead such a national discussion.

**Does the Report Apply to Mathematics?**

One question being asked in the mathematical sciences community is how well the report applies to mathematics. For example, the report shows that, of all fields of science and engineering, mathematics has historically had one of the lowest percentages of new Ph.D.s going into industry and one of the highest going into academia. Against this backdrop, does the report's conclusion that growth in jobs is to be found in business and industry apply to mathematics? Griffiths replies: "It could apply a lot better." Currently, doctoral training in mathematics does not prepare students to contemplate a wide range of options for what they might do after the Ph.D. "The mathematical community is as isolated from what mathematicians might do as any of the other scientific communities," he added. "Compared with other scientific fields, mathematics has been among those that most emphasize preparation for traditional academic research careers. A number of universities, such as Duke, are now actively explaining ways of broadening career options, and this is a very healthy trend." Indeed, Griffiths says he heard the reaction, "This report does not apply to us," from all fields. While recognizing the enormous variation among fields, he believes that the report focused on some common patterns that appeared across the board.

In fact, the report concludes that when it comes to jobs in business and industry, the particular field is not so important. "To some extent the actual area of specialization of a Ph.D. may not be the essential point in the years to come," Griffiths notes. "An in-depth, independent research experience is what's valued, and it
sometimes matters less whether it's in physics or chemistry, or mathematics.” However, says Griffiths, it is important that, for example, all mathematics Ph.D.s do not come out of graduate school with the expectation that their main professional activity will be to prove theorems.

COSEPUP member Felix Browder of Rutgers University says he has not heard many reactions to the report, except the comment that it doesn't contain any “sensational” recommendations. “But I don't know if there are any sensational recommendations to be made,” he notes. “There is no panacea, no magical solution to these problems.” Some of the ideas for recommendations the committee considered and rejected would probably have done little good and might very well have done damage. Pointing to the “deplorable state” of the academic job market, he states, “People had better be aware and be open to all possibilities. That's about the only moral one can draw.”

Indeed, as Browder sees it, the causes of the job market crunch are far beyond the reach of an NRC committee. They stem from a far-reaching depression in academia and from state budget policies that call for such priority shifts as reducing higher education to build more prisons. “To put it bluntly, I think [mathematics is] in a terrible state as far as jobs are concerned,” says Browder, “and I don't see it changing.” Although the report portrays business and industry as an expanding job market for science and engineering doctorates, he is “not terribly sanguine” about such prospects for mathematics Ph.D.s. For example, many of the large industrial laboratories that once hired mathematics doctorates are now cutting back, while the growth is expected to be in such areas as biotechnology.

Griffiths is more upbeat about the prospects in business and industry. As an example of what a mathematics Ph.D. might do as an alternative career, Griffiths pointed to the area of corporate finance. The “mathematician on Wall Street” has become fairly common with the proliferation of new financial instruments such as derivatives. In a similar way, corporate finance is becoming more complex. “Corporate finance used to be glorified accounting,” says Griffiths, “but now it's applied mathematics.” For example, if a corporation is considering building a new plant, the prospect needs to be formulated and priced as an option, not just in terms of the present cost of materials, labor, etc. “This is a huge potential area of employment for mathematicians, provided one has some exposure to the business world,” Griffiths maintains. He says the consensus seems to be that for such work it may be better to get a mathematics doctorate and have some business training on the side, than to get a business degree and pick up some mathematics. (A statement with almost the opposite meaning was attributed to Griffiths in a New York Times article about the report. Calling the Times reporting “awful”, Griffiths says the reporter bungled the quote.)

Some who have been on the job market recently praised some parts of the report and expressed skepticism about others. “All the talk of versatility is really an implicit admission that the job you're being prepared for is likely not to materialize when you're ready to enter the market,” says David Atkinson of Western Kentucky University. Although Atkinson, who received his Ph.D. in 1992, recently joined an insurance firm, he says he did not find it at all easy to attract interest outside academia. “The simple fact is that the skills a pure mathematician learns in grad school are not in high demand in industry,” he says. Of the report’s call for graduate programs to broaden training of their students, Edward Aboufadel says, “I'm not optimistic that this change can occur, given that graduate programs are staffed primarily by academic researchers.”

Aboufadel, who received his doctorate in 1992 and has been active in the Young Mathematicians' Network, has taken a tenure-track position at Grand Valley State University in Michigan. Joseph Lipman of Purdue University, a member of the AMS Committee on the Profession, says that the mathematical community has slowly and for a very long time been “broadening” the training of mathematicians. “But whenever we succeeded too well, that piece of the department split off and became a Department of Statistics, or of Computer Science, or of some kind of Engineering,” he says. “It will continue to happen, not by fiat, and not because some blue-ribbon group meets a few times and gives expression to some megalomaniacal fantasy about formulating national policy, but because talented individuals will discover and act on the opportunities afforded by the circumstances of their time.”

Lipman says that there are some good examples of mathematical programs that have successfully reached out to business and industry. “But you can't just say to any math department, 'Let's start an industrial program and broaden our students,'” he maintains. “Few people know what to do or have the right background.” The report says all the right things, “but we've heard an awful lot of that sort of exhortation in the past few years. So what else is new? It's that we're also seeing some action, both from the professional societies and from some dedicated individuals. That's what I'd like to see publicized.”

The report has been criticized in some quarters for carrying the message that the job market for science and engineering doctorates is
not so bad. Atkinson says statistics understate the severity of the problem because they do not take into account the many new Ph.D.s who are underemployed, take jobs at their Ph.D. institutions, or have a series of temporary positions. "It's hard to give much credence to reports of low unemployment when I have seen and experienced so much difficulty," he says. Aboufadel questions the report's assumption that job growth outside academia is sufficient to absorb recent Ph.D.s. "I have been under the impression that jobs in industry were scarce," just as they are in academia, he says. "What reliable data are they using for [such statements]? Why is there such faith in the nonacademic employment market?"

Griffiths says that COSEPUP wanted the report to make a strong statement about the difficulty and dislocation that occurs when science and engineering Ph.D.s leave graduate school. "It's a giant nightmare," he says. But on the other hand, with a 2% unemployment rate for science and engineering doctorates overall, one cannot complain too loudly. "If you go into the world outside of the academic research community and you say you only have a one-year position with no benefits, you wouldn't get a lot of sympathy," he notes. He says one must look at the world at large, where there is a great deal of upheaval in terms of employment.

The report discusses the issue of foreign graduate students, which has been the subject of sometimes heated debate within the science and engineering community. Some say that foreign students provide a larger pool from which to draw the most talented potential scientists, while others argue that foreign doctorates end up competing with U.S. citizens for jobs or return home to work for economic competitors of the U.S. The report does a good job of presenting both sides of the issue and concludes that limits on the number of foreign students is not a good idea. The report then goes on to say that its recommendations would "make graduate education more attractive, more effective, and accessible to a larger group of qualified American applicants."

If the job market is open to all the top talent in the world, Atkinson says, it makes little sense to encourage more Americans to go to graduate school. "We must accept that Americans are only five or six percent of the world population, and therefore only the most spectacularly talented Americans should expect prosperous science careers in their home country... Encouraging more Americans to enter graduate school when the job market is open to all the top talent in the world seems to me some mixture of foolish nationalism and cruelty."

Offering a different view, John Polking of Rice University agrees with the report's conclusion that no limits should be placed on the number of foreign graduate students. Foreign doctorates contribute a great deal to the U.S., he notes, and in many cases the political conditions in some countries that led to a large influx of foreign graduate students have stabilized. In addition, as other countries continue to develop their own graduate schools, students will stay in their home countries to study. Polking also agrees with the report's conclusion that attempting to cap graduate enrollments is a bad idea. If information on the job market is made available to potential students, "the students themselves would then do an efficient job of controlling the number," he states. "It is difficult for me to see how any governmental or professional organization could do a better job."

Amid all the concern about expanding opportunities for new Ph.D.s outside of academia, little attention has been paid to the impact the job crisis could have on the field of mathematics. Browder says that mathematics has never had an employment crisis like this one, not even in the 1970s. He views the recent, small decline in numbers of graduate students and Ph.D.s in mathematics with a mixture of relief and wariness. "I am very concerned—apart from a humanitarian concern for young people—that the net effect will be to drive people out of mathematics," he says. "Can we get enough bright young people into the field? If we can't do that, then mathematics will diminish if not disappear in this country."

—Allyn Jackson
When I read Donald McClure's article ("Employment Experiences of 1990–1991 U.S. Institution Doctoral Recipients in the Mathematical Sciences"), I do so as someone who is very concerned with the continuing employment crisis facing new and recent Ph.D.s on the job market. In particular, I look to the data in McClure's article to shed light on two questions: How severe is the current employment crisis for doctoral recipients in mathematics, and what approaches can we take to help alleviate that crisis?

There is substantial evidence that starting in 1990-1991, doctoral recipients in the mathematical sciences have faced a declining job market. The data in Table 3A shows that out of 891 1990-1991 doctoral recipients whose employment status was known in the first fall after the receipt of their doctorate (Fall 1), 63 (7%) were still seeking employment. For comparison, previous Annual Surveys show a fairly steady rate of 2% still seeking employment. As McClure notes, the 7% figure is somewhat deceptive, as it fails to include part-time positions as well as "mercy hires," individuals hired for one year by the department awarding them their degree in hopes that they will do better in the job market the following year. These people, as well as those taking one-year positions at institutions other than those that awarded their degree, start looking for their next job in October, almost immediately after the start of the school year. Because of this, it seems to me more realistic to combine this group with those still seeking employment. Borrowing a term from McClure, I call the combined group "underemployed." According to the 1991 Annual Survey, forty-five individuals held a position in the department that awarded their degree. Most of these are probably mercy hires, so the underemployment rate is at least 11%. Including part-timers and those in other one-year positions would yield an even higher estimate of the underemployment rate, perhaps 20% or even higher. This statistic indicates the magnitude of the crisis in employment for doctoral recipients in the mathematical sciences.

Tables 4A and 4B show where the 1990-1991 doctoral recipients were employed in Fall 1993. Out of 798 people whose employment status in Fall 1993 is known, 86 (11%) are listed as still seeking employment. McClure states that most of the data were collected before Fall 1993 and so almost certainly some of the people in this category subsequently found employment. However, a high rate is alarming and seems to indicate that even with two years of experience, employment prospects remain dim for a large percentage of doctoral recipients.

Among the 686 doctoral recipients who were employed in the U.S. in Fall 1993, 193 (29%) were employed by doctorate granting academic departments or research institutes. The remaining 487 (71%) were employed by other academic departments, government, or industry. These figures stand in stark contrast to the fact that most
In both faculty and students in doctorate granting large number of doctoral recipients end up work
necessary duty that one should spend as little time as possible on because it interferes with re
search. The figures above also indicate that a large number of doctoral recipients end up working for government or in industry; however, there is virtually no information available to doctoral students on opportunities outside of academia. In addition, there is severe prejudice among both faculty and staff in doctoral programs against positions outside of academia and a student who is interested in pursuing a nonacademic career will be shunned or met with blank stares. It seems likely that the distribution of jobs taken by doctoral recipients will not change very much over the next few years; in fact, if we wish to lower the unemployment rate for doctoral recipients, it seems clear that the additional jobs will not be in academia, but in industry. Doctoral programs need to adapt themselves to the reality of the job market by preparing students for the wide variety of employment options they will face and by guiding students to career paths other than doctorate granting academics if it best suits their talents and interests. Specifically, faculty in doctorate granting departments need to educate themselves about all of the different employment opportunities for Ph.D.s and take a broader view of the profession so that they can better serve the students they supervise through their program.

As a quick side note, the poor response rate (38%) by nonacademics in the survey as reported in Table 2 is indicative of the communication gap between academia and industry. The negative attitude of academics towards industry that I mentioned above is, in my opinion, a strong contributing factor to this gap. Mathematicians in academia and in industry need to cooperate and bridge this gap. In addition to generally strengthening the profession, there is a good chance that stronger connections between academia and industry will provide more employment opportunities for doctoral recipients.

Table 5 provides more evidence for the need for graduate programs to adapt to the changing realities of the job market. Out of 176 people who had employment in doctorate granting department or research institutes in the first fall after receiving their doctorate and who changed emp
ployment by Fall 1993, 111 no longer held a position in this category. On the other hand, out of 225 people who started with employment somewhere other than a doctorate granting department or research institute, and who changed employment by Fall 1993, only eleven had moved to positions in such a department or institute. The conclusion is that even if your first job is in a doctorate granting department, it is likely that your second job won't be—and when you go through that second search, it would be invaluable to have the breadth of training necessary to compete for a wide variety of jobs.

Tables 6A and 6B report the tenure status of our doctoral recipients both in the first fall after receipt of doctorate and in Fall 1993. During this period, the number of people in non-tenure eligible positions dropped by 153 (from 264 to 111). Even if we assume that some of the people in this group had three-year positions and left to pursue another employment opportunity, the indication is that many of these people had one- or two-year positions and then either found a tenure-eligible position, a nonacademic position, or became unemployed. Among the remaining 111 people who had non-tenure-eligible positions in both the first fall and in Fall 1993, there are undoubtedly a great many who had a one- or two-year temporary position and just moved to another temporary position. These short term, temporary positions are damaging to the professional development of the employee (who must spend much of the time in that position looking for a new job) and to the profession as a whole (because the efforts of talented, young mathematicians are spent job hunting rather than contributing to mathematics). Departments should do whatever they can to shift these positions to longer terms, preferably three years.

As a final note, I would like to add that I believe that this kind of follow-up employment survey is valuable and should be continued and even expanded. For example, it would be useful to have data on the types of positions that doctoral recipients have at various points after receiving their degrees, allowing one to distinguish between, say, a prestigious postdoctoral position with a reduced teaching load and an exploitative temporary position with an inflated teaching load. It would also be useful to know what has happened to our group of 1990–1991 doctoral recipients in the two years since this survey was taken.

—as

Benjamin Lotto

Benjamin Lotto is assistant professor of mathematics at Vassar College, Poughkeepsie, NY. His e-mail ad
ress is belotto@vassar.edu.
I will address two issues raised by the careful, systematic study of Donald McClure. The first is my interpretation of the broad implications for the mathematics community, and the second is a suggestion for further study.

The McClure survey provides a useful picture of the employment situation for Ph.D. mathematicians. It provides information that has not been available heretofore and therefore adds to our knowledge of the problem we are facing. However, the primary interpretation to be made is no different than the interpretation of previous surveys, and that is that there is a severe mismatch between the numbers of Ph.D.s we are producing and the numbers of academic jobs available.

The U.S. mathematics community will have to adjust to this reality by decreasing the number of Ph.D.s granted and by better preparing our Ph.D.s for nonacademic jobs. The most effective way of decreasing the number of Ph.D.s is by advising our undergraduate students of the realities of the job market. This is occurring already, but we will not see the full effects for a couple more years because of the length of time it takes to get a Ph.D.

The strategy of better preparing our students for non-academic jobs is harder to implement, since most of us have no idea of what will be required. Nevertheless it is the one that I think has more merit, simply because, if we are successful, the possibility of non-academic jobs will provide a buffer which will prevent the occasional increase in Ph.D.s from causing the problems we currently face.

If you look at the problem in its best light, what we are trying to do is to find jobs in the U.S. economy for a couple of hundred people who have demonstrated their intelligence and problem solving capabilities in the process of getting a Ph.D. in mathematics. That doesn't sound too hard. Of course from a different point of view, our Ph.D.s are not trained in any way that prepares them for a non-academic position.

We can start by advising all of our prospective Ph.D.s to apply for non-academic jobs in addition to their academic applications. The process would increase the options of our graduates and, through the feedback we get, increase our own understanding of what needs to be done. We can start by taking advantage of those individuals who have found jobs outside of academia, and in this regard I want to commend the fine article by Mark Winstead in the June 23 issue of the Young Mathematicians Network Newsletter.

The real problem is that we do not know what is required to better prepare our students. Here is where the AMS can perform a useful task. Somewhere among our membership we must have the expertise needed to design a graduate program which will better suit the needs of the Ph.D. of the future.

While the McClure study is useful, it only partially answers the questions that I have about the dynamics of the job market for young Ph.D.s. In particular the study does not really come to grips with the impact of postdoctoral positions in mathematics. I include here the named Research Instructors/Assistant Professors at leading research departments, postdocs at the several institutes, and postdocs in academic departments, usually in areas of applied mathematics. These positions are among the most attractive for new Ph.D.s, and seem to provide an excellent start in a mathematical career. They share the features of being non-tenure-eligible, and of two or three years in duration.

It is my impression that the lucky individuals who start in postdoctoral positions usually have little difficulty finding appropriate jobs afterwards. They develop a sense of who they are and where they belong in the mathematics world. Those who want them seem to be able to find tenure-track jobs at appropriate schools. Many institutions limit their hiring for tenure-track positions to people currently holding postdoctoral positions, and frequently do not even look at new Ph.D.s. The result is that the new Ph.D.s who do not start in the postdoctoral positions have great difficulty, often ending up as academic nomads in a sequence of one-year positions.

If my impressions are correct, the situation would be improved by creating more postdoctoral positions to ease the way for a greater percentage of our new Ph.D.s. If these positions were created by using money currently being used to support graduate students, or by converting a senior position into two postdoctoral positions, there would also be an increase in jobs available. However, this effect would not be nearly enough to solve the entire employment problem.

I would like to see if my impressions are supported by the data. The McClure survey, coming only two years after the Ph.D., was too early to answer the questions that I raise. I think it would be a good idea to repeat the survey now, four years after the Ph.D., in order to get a realistic view of the job dynamics of new Ph.D.s.

—John C. Polking

John C. Polking is professor of mathematics at Rice University, Houston, TX. His e-mail address is polking@rice.edu.
What’s Happening in Congress, and What Can We Do About It?

Jean E. Taylor

In my multiple roles as a member of JPBM, the AMS Committee on Science Policy, the Board of Directors of AAAS, and the AMS representative to the recent AAAS Affiliates meeting in Washington, I have been deluged with a great deal of information about what’s going on in Congress. Things are really changing. Members of the staff of the House Science Committee speak in terms of war and revolution. Other longtime observers of Congress qualify this by saying it isn’t a revolution on, for example, the scale of the Great Depression or World War II, but it is still very significant.

I’ve come to believe that adequate support of science is in real danger. Leaders of both parties in Congress voice strong support for science and mathematics. But even so, when there is severe budget cutting pressure it is difficult for them to “put their money where their mouth is.” The AAAS analysis of the budget resolution shows that, in constant dollars (that is, accounting for inflation), support for science would decrease by 33% by 2002; even NSF, which fares among the best, would decrease by 18%.

In addition, there are a great many new members of Congress, and many of them do not know very much about science and mathematics, or why it is an investment instead of an entitlement, or what the federal government’s role is and should be. Many of them do not support science even to the extent that their leaders do.

So what should you do? EVERYONE who has been informing us (Republican or Democrat, in Congress or representatives of funding agencies, or whatever) has advocated that we WRITE to our own representatives and senators and MEET with them when they are in their home districts (this is more effective than going to Washington, as well as simpler).

Everyone has also emphasized that the purpose should be to inform, and that the effort should be long-term. Nevertheless, people fear a “train wreck” in October when it comes to the final parts of budget passing and reconciliation with other legislation, so there is no time like the present to get this long-term relationship started.

So what do you say? They say you should organize your letter into three paragraphs: In the first paragraph, state your reason for writing and your “credentials.” (You want to inform him or her of the importance of federal support of science in your district or state, and you are a math-
Nevertheless, people fear a “train wreck” in October...

and its impact on your institution or the field. If not, talk about how NSF funds enable your department to participate in important scientific work, educate its students, etc. (Yes, it would be much simpler if I wrote a sample paragraph here for you, but I’m told that it is MUCH more effective if each person writing a letter writes it individually. If this seems daunting, what is most important is writing at all; make your first letter short and promise to write more later—and keep the promise.)

In your third paragraph, request (not demand) a specific action, such as a vote for or against a bill; if you don’t have a bill number at hand, do not let that stop you—just be as specific as you can.

Address it to The Honorable …, U.S. House of Representatives, Washington, DC 20510 (or U.S. Senate, Washington, DC 20515), and use a salutation such as Dear Senator / Congressman / Congresswoman …

This has been fairly brief, in the hopes that you will read it and that it will get you moving. For further information, send email to jpbm@math.umd.edu. But the important thing is to write now. Members of Congress must hear from their constituents about the value of federal programs before they will support them.
Higson and Ward Receive Aisenstadt Prize

The Centre de Recherches Mathématiques has announced that the third and fourth André Aisenstadt Prizes have been awarded to Nigel D. Higson of Pennsylvania State University and Michael J. Ward of the University of British Columbia. The $3,000 prize, named for the philanthropist André Aisenstadt, is intended to recognize and reward talented young Canadian researchers in the mathematical sciences.

Nigel D. Higson was honored for his contributions in the area of operator algebras, particularly the algebraic K-theory of $C^*$-algebras. He is responsible for important developments in Kasparov’s KK-theory and in the index theory for operator algebras. Higson received his B.A., M.Sc., and Ph.D. (1986) from Dalhousie University in Halifax, where his thesis advisor was P.A. Fillmore. Higson was at the University of Pennsylvania from 1986 to 1990. He then moved to Pennsylvania State, where he is currently an associate professor. He has held a Sloan Foundation Research Fellowship.

Michael J. Ward was honored for his work in asymptotics, scientific computing, and mathematical modeling with emphasis on modern applications of physical applied mathematics. His research has applications to semiconductor device modeling, steady-state combustion theory, diffusion in singularly perturbed domains, reaction diffusion models exhibiting interfacial dynamics and metastable behavior, and strong localized inhomogeneities in various physical systems. Ward received his B.Sc. in mathematics at UBC and his Ph.D. in applied mathematics in 1988 at the California Institute of Technology, under the direction of Donald S. Cohen. After stays at Stanford University and the Courant Institute, Ward returned in 1992 to UBC, where he is currently an assistant professor.

The recipients of the Aisenstadt Prize were chosen by the following advisory panel: Raoul Bott, Donald Dawson, P.A. Fillmore, Martin Goldstein, Carl Herz, Jean-Pierre Kahane, Hershy Kisilevsky, Alistair H. Lachlan, Francois Lalonde, Yuri I. Manin, Robert Miura, Robert V. Moody, Jurgen Moser, Duong H. Phong, Nancy Reid, and Luc Vinet. The previous winners of the Aisenstadt Prize are Niky Kamran of McGill University and Ian F. Putnam of the University of Victoria.

— CRM Bulletin

Prizes of the Mathematical Society of Japan

The Mathematical Society of Japan (MSJ) has presented a number of prizes in recognition of outstanding contributions to mathematics.

The 1995 Spring Prize of the MSJ was presented to Mitsuhiro Shishikura of the University of Tokyo for his outstanding contributions to the theory of complex dynamical systems.

The 1995 Geometry Prize was presented to Masaaki Umehara of Osaka University and to Kotaro Yamada of Kumamoto University for their distinguished contribu-
Mañé Receives Third World Academy of Sciences Prize

Each year, the Third World Academy of Sciences (TWAS) awards five prizes of US$10,000 each to individual scientists from developing countries who have made outstanding contributions to the advancement of basic sciences (biology, chemistry, mathematics, physics, and basic medical sciences). RICARDO Mañé of the Instituto de Matemática Pura e Aplicada in Rio de Janeiro, Brazil, received the 1994 prize in mathematics.

Mañé was honored for his outstanding research on the ergodic theory of differentiable dynamical systems, through which he achieved fundamental contributions to various problems in this field. In particular, he solved the problem of characterizing structurally stable systems. Roughly speaking, a structurally stable dynamical system is one whose orbit structure remains topologically unchanged when the system is slightly perturbed. In the late 1960s, Palis and Smale made a conjecture about a necessary and sufficient condition for structural stability. The sufficiency was proved in the early 1970s, but the necessity remained open and came to be called the Stability Conjecture. After many partial results by other researchers, the Stability Conjecture for diffeomorphisms was proved by Mañé in 1986. He also worked on an analogue of the Stability Conjecture for rational maps. In more recent years, he worked on the variational ergodic theory of conservative dynamical systems.

Born in Uruguay in 1948, Mañé received his Ph.D. from IMPA in 1973, under the direction of Jacob Palis, and remained at IMPA throughout his academic career. He was an invited sectional speaker at the International Congress of Mathematicians in 1983 in Warsaw and in 1994 in Zurich. In 1994, he was elected to the Brazilian Academy of Sciences. Mañé died in March of 1995. An obituary is being prepared for a future issue of the Notices.

—Allyn Jackson

Palis Receives OAS Science Prize

JACOB PALIS of Instituto de Matemática Pura e Aplicada (IMPA) has been awarded the 1995 Bernardo A. Houssay Interamerican Prize for Science. The prize, given by the Organization of American States, carries a stipend of $30,000.

The award is named in honor of Nobel laureate Bernardo Houssay. The purpose of the prize is to perpetuate the memory of Houssay, a man whose life was a constant example of dedication to research, to the training of researchers, and to the advancement of education. At the same time, the prize also offers incentives to Latin American and Caribbean researchers who have made scientific contributions of outstanding importance for the social welfare and development of humanity. The prize is given each year in one of the following areas: biological sciences, exact sciences (physics, chemistry, mathematics, and related sciences), agricultural sciences, and technical research of importance to development.

Palis has made outstanding contributions to mathematics, especially to the field of dynamical systems. His fundamental work has proved important to an understanding of stable systems and, partially, their bifurcations. More recently he has been contributing to a global view of chaotic systems.

Palis helped to build IMPA, a remarkable institute in Rio de Janeiro which has become an international center for dynamical systems research. Over the past two decades, he has advised thirty-three Ph.D. students from ten different countries.

Palis was born in the interior of Brazil in 1940. He moved to Rio de Janeiro in 1956, and in 1962 he earned a bachelor's degree in engineering at the Federal University. Moving to Berkeley in 1964, he finished his doctorate in 1967 under the direction of Stephen Smale. Palis has been at IMPA since 1968. Elected to the Brazilian Academy of Sciences in 1973, he has also received the Brazilian Prize for Science and the Third World Academy of Sciences Prize for Mathematics. Palis was an invited speaker at the 1978 International Congress of Mathematicians in Helsinki. He has served as secretary for the International Mathematical Union since 1991.

—IMPA Announcement
Mathematics Opportunities

Workshop for Women Students and Postdocs

Over the past seven years, the Association for Women in Mathematics (AWM) has held a series of workshops for women graduate students and recent Ph.D.s (referred to as "postdocs" below) in conjunction with major mathematics meetings. With support from the Office of Naval Research the AWM will hold the next workshop in conjunction with the annual AMS-MAA Joint Mathematics Meetings in Orlando, Florida, January 10-13, 1996. The workshop will be held on Saturday, January 13, 1996.

Each participating graduate student is invited to present a poster on her thesis problem and each postdoc to present a talk on her research. A WM will offer funding for travel and two days subsistence for up to twenty participants. Participants will have the opportunity to present and discuss their research and to meet with other women mathematicians at all stages of their careers. Each workshop will also include a panel discussion on issues of career development, a luncheon, and a dinner banquet. All mathematicians (female and male) are invited to attend the entire program, even though funding is provided only for twenty women graduate students and postdocs. Departments are urged to help graduate students and postdocs obtain some institutional support to attend the workshop and the associated meetings.

To be eligible for funding, graduate students must have begun work on a thesis problem. The word "postdoc" refers to any mathematician who has received her Ph.D. within approximately the last five years, whether or not she currently holds a postdoctoral or other academic position. All non-U.S. citizens must have a current U.S. address. All applications should include a curriculum vitae and a concise description of research; letters of support are encouraged. Graduate students should include a letter of recommendation from their thesis advisors. Nominations by other mathematicians (along with the information described above) are also welcome.

Send five complete copies of the application materials (including the cover letter) to: Workshop Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, Maryland 20742-2461. For further information contact the AWM by telephone at 301-405-7892, or by e-mail at awm@math.umd.edu. (Applications via e-mail or fax are not acceptable.) The application deadline is October 1, 1995.

—AWM Announcement

News from the Institute for Mathematics and its Applications, University of Minnesota

The 1995-96 program at the IMA will be on the topic, Mathematical Methods in Materials Science. One goal of this year is to bring together materials scientists and mathematicians to talk to each other and to transfer problems, ideas and methods from one community to another, so as to enhance further progress in the understanding of ma-
terials. New mathematical ideas will be sought to help in improving modeling of materials, in deriving innovative and efficient numerical methods, and in developing approximate models which are amenable to mathematical analysis. The mathematical disciplines involved in the program will include partial differential equations, numerical analysis, homogenization and stochastic techniques, and geometric and topological methods for polymers.

A parallel goal of the IMA year is the enhancement and stimulation of the mathematics itself. In recent years, problems arising from certain areas of materials science have motivated mathematicians to pursue new mathematical topics in response to unexpected and unexplained materials phenomena. According to Richard James, one of the organizers, “there will be a huge variety of visitors at the IMA this coming year, representing many of the most prominent people in mathematics, physics, and materials science. I believe that, with such a group assembled, entirely new mathematical fields may be born, that will have a real impact on the practice of materials science. There are some rumblings of this possibility leading up to several of the workshops, particularly the first workshop on the direct passage of atomic to continuum theory. In short, I believe that this is a once-in-a-lifetime opportunity.”

The year’s program will focus on topics such as phase transitions, optimal materials, the passage from atomistic to continuum theory, disordered materials, materials for nonlinear optics, and polymers, each area of materials science being coupled with relevant areas of mathematical research.

The fall term will focus on Phase Transitions, Optimal Microstructures and Disordered Materials. Fall will begin with a September 5-8 tutorial on Microstructure, Weak Convergence and Atomic Forces. The following two weeks will feature workshops on Mechanical Response of Materials from Angstroms to Meters (September 11-15) and on Phase Transformations, Composite Materials and Microstructure (September 18-22). One focus of the first workshop will be on mathematical methods appropriate to the passage from one scale to another. In cases in which properties exhibit large spatial fluctuations on one scale governed by a certain set of partial differential equations, it is now becoming better understood how to derive equations appropriate to a larger scale. In these calculations weak-convergence methods, homogenization, Young measures and various notions of convergence of operators play a central role. The time appears ripe to exploit such methods in problems of change of scale, e.g. from quantum mechanics to density functional theory, from density functional theory to atomic forces, and from atomic forces to continuum response. The same body of mathematical techniques will be seen, in the September 18-22 workshop, to be important in three more specific areas of materials science with a strong commonality of themes.

October 23-27 will see a period of concentration on Microstructure and Turbulence, which will bring together two communities that are involved in small-scale computations: materials scientists and computational fluid dynamicists. These two groups do not ordinarily talk to each other and could greatly benefit by getting together.

The IMA will hold a workshop on Disordered Materials during the week November 13-17. The materials of interest range from polycrystalline metals and foams to sea ice. The overall themes which will be addressed include recent mathematical developments in percolation theory, including conformal invariance, and transport processes in disordered systems. Of special interest is the behavior of materials close to criticality, i.e., close to the percolation threshold. While most other analysis of random systems is related to perturbations about a dilute volume-fraction limit, or about a nearly homogeneous system, the results of analysis near the critical point are valid in the opposite regime of moderately large volume fractions and high-contrast materials. The predictions of renormalization-group theory suggest that some quantities such as exponents or amplitude ratios may have a universal value in the vicinity of the critical point.

The winter term will emphasize Thin Films, Particulate Flows and Nonlinear Optical Materials, while the spring will be devoted to Numerical Methods and Topological/Geometric Properties in Polymers. More detailed descriptions of the winter and spring terms will appear in future issues of the Notices.

For more information about IMA activities, see the Meetings and Conferences section of this issue or contact the IMA (at staff@ima.umn.edu). Also, weekly IMA seminar schedules are available by fingering seminar@ima.umn.edu. TeX files and .dvi files for the Newsletter and the quarterly Update are available via anonymous ftp (at ftp.ima.umn.edu) or through the World Wide Web (http://www.ima.umn.edu).

—IMA Announcement

News from the Mathematical Sciences Research Institute, Berkeley

In 1997–1998 there will be a year-long program in Stochastic Analysis at the Mathematical Sciences Research Institute (MSRI), Berkeley, California.

The last ten to fifteen years have seen explosive development in the theory of continuous-time stochastic processes which, loosely speaking, are highly singular. For example, the state space might be infinite dimensional or "fractal", or the evolution dynamics of the process might not be sufficiently smooth to permit study using classical tools such as partial differential equations. Probabilists have been led to study such processes by the requirements of physics, chemistry, biology, and engineering; by the desire to develop probabilistic tools for the solution of "non-stochastic" problems in analysis and geometry; and by the intrinsic mathematical interest of the subject. The modern theory of such processes and of related analytical tools has come to be called stochastic analysis.
The MSRI year will cover a substantial cross-section of the work being done in stochastic analysis and will encompass a diversity of approaches.

The following topics are to be covered in the year (it is expected that there will be substantial overlap between some of these topics):
1. Stochastic partial differential equations and related topics.
2. Infinite dimensional analysis: Malliavin calculus.
3. Dirichlet form techniques in stochastic analysis on finite and infinite dimensional state spaces.
4. Geometric stochastic analysis.
5. Euclidean stochastic geometry.

An organizing committee consisting of R. Banuelos, S. Evans, P. Fitzsimmons, E. Pardoux, D. Stroock, and R. Williams will oversee the year's program. Cochairs of this committee are S. Evans and R. Williams.

This is a preliminary announcement to enable researchers who may be interested in attending the MSRI year in Stochastic Analysis to take this into account in planning sabbaticals and other leaves. A formal announcement of the program, together with applications for Postdoctoral Fellowships, Research Professorships, and General Memberships, will be issued in the spring of 1996.

—from MSRI

NSF Early Career Development Program

The Division of Mathematical Sciences (DMS) of the National Science Foundation announces that this year's deadline for proposals to the Faculty Early Career Development (CAREER) Program will be October 17, 1995.

The CAREER program is intended for the support of excellent proposals from junior faculty who combine strong research activity with a genuine and substantive involvement in education. Proposals will be evaluated on the basis of both research and education. The total award, including administrative costs, will not be less than $200,000 for a four-year award or less than $250,000 for a five-year award.

It is expected that DMS will make a small number of CAREER awards. It is appropriate for the budget request and proposal plan to reflect both the research and education components of the principal investigator's activity. The proposed activity and budget allocation will be considered in determining the merit of proposals. As always, the total impact and added value of an award will weigh heavily in the evaluation process.

The CAREER program announcement (NSF-95118) is available on the NSF electronic information system STIS, which can be accessed through the World-Wide Web at http://www.nsf.gov, or via the STIS Gopher at stis.nsf.gov. Those considering submitting a proposal should read the program announcement carefully.

The Division's disciplinary programs continue to encourage proposals that integrate research and education activity or that have significant education components, at all levels. Applicants may contact disciplinary program directors if they have any questions.

—DMS Announcement

Mathematics Opportunities
Call for Nominations for AWM Hay Award

The Executive Committee of the Association for Women in Mathematics (AWM) has established the Louise Hay Award for Contributions to Mathematics Education, to be given annually to a woman at the January Business Meeting. The purpose of this award is to recognize outstanding achievements in any area of mathematics education, to be interpreted in the broadest possible sense. While Louise Hay was widely recognized for her contributions to mathematical logic and for her strong leadership as head of the Department of Mathematics, Statistics, and Computer Science at the University of Illinois at Chicago, her devotion to students and her lifelong commitment to nurturing the talent of young women and men secure her reputation as a consummate educator. The annual presentation of this award is intended to highlight the importance of mathematics education and to evoke the memory of all that Hay exemplified as a teacher, scholar, administrator, and human being.

The letter(s) of nomination should outline the nominees' contributions, and indicate both the quality and depth of these contributions. Letters of support from colleagues and/or students are encouraged.

Send five complete copies of nominations for this award to: The Hay Award Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, Maryland 20742-2461. For further information, telephone the AWM at 301-405-7892, or send e-mail to awm@math.umd.edu. (Nominations via e-mail or fax are not acceptable.) The nomination deadline is October 1, 1995.

—AWM Announcement

1995 BMS Chairs’ Colloquium

The tenth anniversary Board on Mathematical Sciences Chairs’ Colloquium will be held October 20-21, 1995, in Arlington, Virginia. The theme is "Managing While Science and Education Evolve". Highlights include a keynote address by George E. Brown, Jr., Ranking Minority Member, Committee on Science, U.S. House of Representatives, and sessions on the view from Harvard University, the University of Michigan, Stanford University, and the University of Texas at Austin.

Topics for discussion include the American Association for Higher Education's project on evolving assessment of faculty teaching, an administrator's view of mathematical sciences departments, mathematical sciences employment opportunities, federal research and education programs, successes in encouraging underrepresented groups, statistics departments and statistics within other departments, successes in undergraduate calculus reform programs, the annual employment survey, and a discussion of strategies to increase employment opportunities for mathematicians.

Among the speakers and panelists are: John Alexander, Efraim Armendariz, Hyman Bass, Ralph Cohen, John B. Conway, Joan Ferrini-Mundy, Marvin Freedman, Avner Friedman, John Fulton, Seymour Geisser, Patricia Hutchings, John Jenkins, James Lightbourne, Morton Lowengrub, David Lutzer, Melvyn Nathanson, Anil Nerode, Samuel Rankin, Randall Robinson, Hugo Rossi, Wilfried Schmid, Ron Stern, Christine Stevens, William Strawderman, Michael Tabor, Alan Taylor, Chuu-Lian Terng, Alan Tucker, and James C. Turner.

The goal of the colloquium is to provide department chairs, chair-candidates, and department leaders with...
timely, practical information they can use as the mathematical sciences adjust and adapt in education and research to the manifold changes taking place.

The registration fee is $160. More information is available from: Board on Mathematical Sciences, National Research Council, NAS 315, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2421; fax 202-334-1684; e-mail bms@nas.edu. The registration deadline is October 9; the deadline to reserve hotel rooms at a special rate is September 27.

—from BMS Announcement

Mathematics Newsletter Available

The IMU Canberra Circular (IMUCC) is a newsletter distributed free of charge to over 1,000 mathematicians worldwide. Compiled by B. H. Neumann of Australian National University, the IMUCC contains a variety of information of interest to the international mathematical community, particularly information about upcoming meetings. Electronic access to the IMUCC will soon be set up by the Australian Mathematical Society.

To subscribe to the IMUCC, or to submit information for publication, contact: B. H. Neumann, School of Mathematical Sciences, Australian National University, ACT 0200, Australia; fax 61-6-249-5549; e-mail bhn102@phys.anu.edu.au.

—from IMUCC
1995 AMS Elections
Special Section

VOTE! 1995 AMS Elections

The policy and business practices of the Society are determined by the Council and Board of Trustees. Twenty members of the Council are elected in contested elections. Five members of the Board of Trustees are elected in contested elections.

The Nominating Committee, which makes recommendations to the Council for nominations of these candidates, is elected in contested elections. The Editorial Boards Committee, which makes recommendations to the Council for candidates who are elected, by the Council, to the eight editorial boards which have membership on the Council, is elected in contested elections.

Amendments to the bylaws are ratified by the membership in this election. The bylaws state that such ratification can occur only if 10 percent of the membership votes. In the last election fewer than 10 percent of the membership returned ballots. Whether or not you agree with an amendment recommended by the Council, you should at least vote on the recommendation.

The material presented here in the Notices will also be mailed to each member along with the ballots. Look for the special envelope containing the election material which should arrive soon in your mailbox. Study the biographies of the candidates. Examine the suggested changes in the bylaws. Make your choices, fill out your ballot, place it in the return envelope. Please sign the envelope. Ballots returned in unsigned envelopes are NOT counted. Then mail your ballot.

—Robert Fossum
Secretary

List of Candidates

OFFICERS

President-Elect (one to be elected)
Frederick W. Gehring
Arthur M. Jaffe

Vice-President (one to be elected)
Michael Aschbacher
Spencer J. Bloch

Member-at-Large of the Council
(five to be elected)
Curtis D. Bennett
David M. Bressoud
Gail A. Carpenter
John R. Conway

Isom H. Herron
Krystyna M. Kuperberg
Joshua A. Leslie
Andrew Odlyzko
George C. Papanicolaou
Mary Lou Zeeman

Board of Trustees
(one to be elected)
Michael G. Crandall
Fan R. K. Chung

NOMINATING COMMITTEE FOR 1996
(three to be elected)
Sylvain Cappell
Eric M. Friedlander
Jane P. Gilman
Daniel J. Kleitman
James V. Ralston
Joel Spruck

EDITORIAL BOARDS COMMITTEE
FOR 1996 (two to be elected)
Sun-Yung Alice Chang
Jennifer Tour Chayes
Andrew Granville
Joel Spencer

Election Information

The ballot for election of officers, members of the Council, and a trustee and ratification of amendments to the bylaws will be mailed on or shortly after September 10, 1995, in order for members to receive their ballots well in advance of the November 10, 1995, deadline. Members are urged to consult the following articles and sections of the Bylaws of the Society: Article I, Section 1; Article II, Sections 1, 2, 4; Article III, Section 1; Article IV, Sections 1, 2, 4; Article VII, Sections 1, 2, 5. The complete text of the Bylaws appears on pages 1266-1270 of November 1993, Volume 40, Number 9, issue of the Notices. A list of members of the Council and Board of Trustees serving terms during 1995 appears in the "AMS Officers and Committee Members" section of this issue of the Notices (and will be mailed with the election material sent to all members in September).
REPLACEMENT BALLOTS

There has been a small but recurring and distressing problem concerning members who state that they have not received ballots in the annual election. It occurs for several reasons, including failure of local delivery systems on university or corporate properties, failure of members to give timely notice of changes of address to the Providence office, failures of postal services, and other human errors.

To help alleviate this problem, the following replacement procedure has been devised: A member who has not received a ballot by October 10, 1995, or who has received a ballot but has accidentally spoiled it, may write after that date to the Secretary of the AMS, Post Office Box 6248, Providence, RI 02940, asking for a second ballot. The request should include the individual's member code and the address to which the replacement ballot should be sent. Immediately upon receipt of the request in the Providence office, a second ballot, which will be indistinguishable from the original, will be sent by first class or air mail. It must be returned in an inner envelope, which will be supplied, on the outside of which is the following statement to be signed by the member:

The ballot in this envelope is the only ballot that I am submitting in this election. I understand that if this statement is not correct then no ballot of mine will be counted.

Although a second ballot will be supplied on request and will be sent by first class or air mail, the deadline for receipt of ballots will not be extended to accommodate these special cases.

SUGGESTIONS FOR 1996 NOMINATIONS

Each year the members of the Society are given the opportunity to propose for nomination the names of those individuals they deem both qualified and responsive to their views and needs as part of the mathematical community. Candidates will be nominated by the Council to fill positions on the Council and Board of Trustees to replace those whose terms expire January 31, 1996. See the "AMS Officers and Committee Members" section of this issue for the list of current members of the Council and Board of Trustees. Members are requested to write their suggestions for such candidates in the appropriate spaces to the right.

COUNCIL AND BOARD OF TRUSTEES

Vice-President (1)

Members-at-large of the Council (5)

Member of the Board of Trustees (1)

The completed form should be addressed to AMS Nominating Committee, Post Office Box 6248, Providence, RI 02940, to arrive no later than November 10, 1995.

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Nomination for Frederick W. Gehring

Clifford J. Earle and Franklin P. Peterson

It is an honor and a great pleasure to place Frederick W. Gehring's name in nomination for the presidency of the American Mathematical Society.

Fred is very well qualified for this important post. He has done ground-breaking mathematical research, some of which we shall describe in the following paragraphs, and has been an inspiring mentor of numerous graduate students and young Ph.D.s. He has been an invited speaker at three International Congresses of Mathematicians, a sign of widespread respect both for his research and for his lecturing skills. Fred's good judgment is also widely respected, and his advice and leadership are often in demand. For example, he has served three terms as chair of the Mathematics Department of the University of Michigan in Ann Arbor and has served on fifteen external visiting committees for other mathematics departments. His past service to the Society includes ten years on the Board of Trustees, two of them as its chair.

Fred received his Ph.D. from the University of Cambridge in 1952, under the supervision of J. C. Burkill. His earliest papers deal with the theory of measure and integration. His first paper about complex analytic functions appeared in 1958. Since then, complex analysis has been one of Fred's major interests, and his papers in that subject make him arguably the premier geometric function theorist of his generation. However, even more of Fred's impressive stock of creative energy has gone into his pioneering work on the theory of quasiconformal mappings in higher-dimensional Euclidean spaces.

Let \( \mathbb{R}^n = \mathbb{R}^n \cup \{\infty\} \) be the one-point compactification of \( \mathbb{R}^n, n \geq 2 \), and let \( V \) be a subregion of \( \mathbb{R}^n \). By definition, a homeomorphism \( f \) of \( V \) into \( \mathbb{R}^n \) is a quasiconformal map (a qc map for short) if there is a finite number \( M \) such that

\[
H_f(x) = \limsup_{r \to 0^+} \frac{\max \{|f(y) - f(x)| : |y - x| = r\}}{\min \{|f(y) - f(x)| : |y - x| = r\}} \leq M \quad \text{for all } x \in V \setminus \{\infty, f^{-1}(\infty)\}.
\]

Theqc map \( f \) is \( K \)-quasiconformal (\( K \)-qc) if and only if \( H_f \leq K \) almost everywhere in \( V \setminus \{\infty, f^{-1}(\infty)\} \). (Warning: When \( n > 2 \), there are several different definitions of \( K \)-quasiconformality. This is not the most common one, but it gives the usual set of 1-qc maps.)

Complex analysis provides a powerful tool for the study of qc maps in two dimensions because the orientation-preserving 1-qc maps from a subregion \( V \) of \( \mathbb{C} = \mathbb{R}^2 \) into \( \mathbb{C} \) are precisely the injective complex analytic functions on \( V \). The theory in higher dimensions is harder and requires
tools from geometric measure theory and partial differential equations. Two fundamental papers by Fred Gehring in 1961 and 1962 developed a comprehensive theory of qc maps in dimension three and laid the foundation for the theory in higher dimensions. The 1961 paper studies the conformal capacity of ring domains in $\mathbb{R}^3$. Gehring uses spherical symmetrization and the then-new co-area formula of H. Federer and L. C. Young to determine certain extremal ring domains. The second paper uses these extremal rings to establish the properties of qc maps in $\mathbb{R}^3$.

Two theorems in this 1962 paper deserve special attention. A Möbius transformation in $\mathbb{R}^n$ is a member of the group of homeomorphisms of $\mathbb{R}^n$ generated by the translations $x \rightarrow x + a, \ a \in \mathbb{R}^n$, and the inversion $x \rightarrow -x/|x|^2$. Every Möbius transformation is a 1-qc map. In a remarkable generalization of a classical theorem of Liouville, Gehring proved that if $V \subset \mathbb{R}^3$ then every 1-qc map of $\mathbb{V}$ into $\mathbb{R}^3$ is the restriction to $V$ of some Möbius transformation. Gehring's proof of this beautiful result is based on the fact that a 1-qc mapping preserves the conformal capacity of ring domains. It carries over to subregions of $\mathbb{R}^n$ in every dimension $n \geq 3$. Note the striking contrast with $n = 2$, where every injective complex analytic function is 1-qc.

A second important result concerns boundary values of qc maps. Let $f$ be a qc map of the half space $H^+ = \{(x, y, z) \in \mathbb{R}^3 : z > 0\}$ onto itself. Gehring proves that $f$ extends to a qc map of $\mathbb{R}^3$ onto itself. Furthermore the restriction of $f$ to the boundary of $H^+ \subset \mathbb{R}^3$ is a qc map of $\mathbb{R}^2$ onto itself. This is a strong regularity statement about the boundary values of $f$. G. D. Mostow discovered that it can be used to help prove that any qc map of one finite-volume hyperbolic 3-manifold onto another is homotopic to an isometry. Mostow then extended Gehring's theory to all $n \geq 3$ as part of the proof of his famous rigidity theorem.

Gehring's theorem about the boundary values of a qc self-map of $H^+$ raises a converse question. Can every qc self-map of $\mathbb{R}^3$ be extended to a qc self-map of $\mathbb{R}^3$? Ahlfors gave a positive answer to this question in 1963. Using Ahlfors's result Gehring proved in a remarkable 1965 paper that a topological 2-sphere $S$ in $\mathbb{R}^3$ is the image of the standard sphere $S^2$ under a qc self-map of $\mathbb{R}^3$ if and only if each component of $\mathbb{R}^3 \setminus S$ can be mapped quasiconformally onto the 3-ball. The problem of determining exactly which regions in $\mathbb{R}^n$ can be mapped quasiconformally onto the n-ball is still unsolved. Gehring has the best partial results.

Gehring's criterion for $S$ to be a qc image of $S^2$ in $\mathbb{R}^3$ (which has since been extended to all $n \geq 3$) reveals another striking contrast between two dimensions and higher dimensions. By the Riemann mapping theorem and the Jordan curve theorem, every Jordan curve $C$ in $\mathbb{R}^2$ has the property that both components of $\mathbb{R}^2 \setminus C$ are conformally equivalent to the 2-ball, but only very special Jordan curves are the images of $S^1$ under a qc self-map of $\mathbb{R}^2$. These curves are called quasicircles and are characterized by a number of equivalent good properties. One of the most remarkable characterizations is due to Gehring who proved in a 1977 paper that a simply connected region $D \subset \mathbb{C}$ is bounded by a quasicircle (in $\mathbb{R}^2$) if and only if there is a positive number $\varepsilon$ such that every holomorphic function $f$ on $D$ that satisfies the inequality

$$|S_f(z)d(z)| < \varepsilon \quad \text{ for all } z \in D$$

is injective. (Here $S_f = (f'')^2 - \frac{1}{4}(f')^2$ and $d(z)$ is the distance from $z$ to the boundary of $D$.) This result is only one of many indications that qc maps are intimately related to very classical ideas in complex function theory.

The geometric properties of qc maps in $\mathbb{R}^n$ lead rather directly to the conclusion that their first partial derivatives in the sense of distributions are measurable functions locally of the Lebesgue class $L^p$ for $p = n$. The properties of the Beltrami equation and the two-dimensional Hilbert transform imply that the first partial derivatives of a qc map in $\mathbb{R}^2$ are locally in $L^p$ for some $p > 2$. That is a significant conclusion since it makes Sobolev's regularity theorems available. In an important 1973 paper Fred Gehring solved the difficult problem of proving for all $n$ that the first partial derivatives of a qc map in $\mathbb{R}^n$ are locally in $L^p$ for some $p > n$. New methods are required. Gehring based his proof on a lemma involving reversed Hölder inequalities, a result that has useful applications to partial differential equations.

In recent years Fred and his former student Gaven Martin have jointly studied discrete groups of Möbius transformations acting on the 3-ball. They have had impressive success in finding sharp geometric inequalities for such groups. In addition, they have introduced the important new concept of a convergence group, which captures many of the crucial properties of Möbius groups. Let $\text{Homeo}(\mathbb{S}^n)$ be the homeomorphism group of $\mathbb{S}^n$. By definition a subgroup $G$ of $\text{Homeo}(\mathbb{S}^n)$ is a convergence group if every sequence of distinct elements of $G$ has a subsequence $(g_n)$ such that either (a) there is a $g$ in $\text{Homeo}(\mathbb{S}^n)$ such that $g_n \rightarrow g$ in the compact-open topology, or (b) there are points $x$ and $y$ on $\mathbb{S}^n$ such that $g_n[(\mathbb{S}^n \setminus \{x\}) - y]$ and $g_n[(\mathbb{S}^n \setminus \{y\}) - x]$ in the compact-open topology. The convergence group $G$ is called discrete if possibility (a) never occurs. D. Gabai and, independently, A. Casson and D. Jungreis have proved that every discrete convergence group on $\mathbb{S}^1$ is conjugate in $\text{Homeo}(\mathbb{S}^1)$ to a group of Möbius transformations of $\mathbb{R}^2$ (restricted to $\mathbb{S}^1$). That fact has important applications to the topology of surfaces and 3-manifolds.

Fred Gehring's contributions to the theory of quasiconformal maps and geometric function theory go far beyond his own research. He has been a vigorous and enthusiastic leader in shaping these theories, working closely with senior mathematicians and with young mathematicians as a teacher and mentor. He recently won the prestigious Sokol Prize awarded by the University of Michigan for excellence in graduate teaching. He has had twenty-six Ph.D. students, now spread around the world, and has been the sponsor of forty foreign visitors who have come to work with him in Ann Arbor.

Fred has served the AMS in a number of important capacities. He was on the Mathematical Reviews Editorial Committee from 1969–1975, on the Executive Committee
of the Council from 1973-1975 and from 1981-1983, and was a Trustee from 1983-1992. During this period, the Society had many difficult problems to resolve and Fred’s advice on scientific and financial matters was always well thought out and very much appreciated by his colleagues. He was chair of some very sensitive committees such as the Search Committee for the Executive Director in 1987 and the Committee on Governance in 1993. He did a wonderful job of organizing the work of these committees and contributed substantially to their reports.

In addition to his service to the Society and on external visiting committees for mathematics departments, Fred has helped many other organizations govern themselves, for example, the Institute for Mathematics and Applications and the Geometry Center in Minneapolis.

Having seen the high quality of advice he gives, we can easily understand why so many organizations seek to benefit from Fred Gehring’s advice and judgment. He is an excellent person to lead the AMS in the upcoming years as its president.

Nomination for Arthur Jaffe

Barry Mazur and Vaughan Jones

Happily, the enterprise of mathematics is enriched by the presence of a number of people who have the talent, the energy, and the generosity of spirit to be at the same time deeply devoted mathematicians and equally gifted and effective organizers. Arthur Jaffe is one of these people, and we enthusiastically nominate him for the presidency of the American Mathematical Society.

Arthur Jaffe was born in 1937, and he received his Ph.D. from Princeton University in 1966. He is currently the Landon T. Clay Professor of Mathematics and Theoretical Science at Harvard University.

Arthur Jaffe has played an important role in bringing the mathematics and physics communities together. This resulted not only from his groundbreaking research, but also from his organization of stimulating seminars, workshops, and conferences, by his editing a seminal journal, by his encouragement of young students and coworkers, and through his presidency of the mathematical-physics association. For his work in mathematical physics, Arthur Jaffe received the Dannie Heinemann Prize in 1980 for mathematically “demonstrating the compatibility of relativistic invariance, quantum mechanics, and local field theory.”

The field of mathematical physics enjoyed a period of rapid development in the late sixties and early seventies, attracting the attention of many mathematicians and physicists including E. Nelson, I. Segal, K. Symanzik, A. Wightman, and others. In a series of ground-breaking papers and continued over a span of 14 years, Jaffe and Glimm established the discipline of Constructive Field Theory, which remains the most significant approach to answering the question: “Can quantization as predicted by renormalized perturbation theory of physics be implemented mathematically?” Even if Jaffe had done nothing else, his and Glimm’s heroic and successful construction of a nontrivial quantum field in 3-dimensional space-time would have assured him an honored place in the mathematical physics literature. But Jaffe’s contributions are hardly limited to one field, and his general attitude towards research is marked by an openness to diverse ideas and interests: He has made important contributions, for example, to classical gauge theory and cyclic cohomology.

With Jaffe’s enthusiasm, his congeniality, and his mathematical ideas, it is no wonder that he is always surrounded by young bright students. Many of Jaffe’s students are now leaders in the field of mathematical physics; but some have become leading figures in quite different branches of pure mathematics; some have made their mark in applied mathematics.

Jaffe’s manifold activities and organizational innovations show him to be keenly interested in the well-being of the mathematical community. Besides serving on numerous AMS committees, Jaffe has recently completed terms on the Council and on the Executive Committee of the Council.

He has served as president of the International Association of Mathematical Physics (IAMP) for the period 1991-1996. He has done much to secure a future for that fledgling organization, including chairing the scientific committee for its successful 1994 Congress at UNESCO in Paris.

He helped organize numerous other conferences, and, in particular, was the co-founder of a series of successful Cargèse Summer Schools. Jaffe remains the moving force in America for these Summer Schools, which are widely known for the role that they play in facilitating communication between mathematicians and physicists.

Jaffe was an active member of the David Committee and was the author of the fine appendix to that report Ordering the Universe: the Role of Mathematics, which had the mission of explaining to a broader public the unique character of mathematics. This article played an influential role, both in this country and abroad, in justifying increased government support for mathematics.

Jaffe’s advice has been sought by many groups and organizations. He has served on numerous boards, advisory committees, and visiting committees, and currently he is a trustee of the Mathematical Sciences Research Institute in Berkeley.

Barry Mazur is William C. Petchek Professor of Mathematics at Harvard University. His e-mail address is mazur@math.harvard.edu. Vaughan Jones is professor of mathematics at the University of California, Berkeley.
Jaffe's wise appointment of editors, his own editorial talents, and his energetic devotion to the journal *Communications in Mathematical Physics* (CMP) have been key in making that journal play the inspirational role that it does play in the subject. Jaffe's enthusiasm and scientific openness is a great factor in maintaining the high level of CMP. He is always on the lookout for exciting new papers; he vigorously solicits articles which contain advances in a range of subjects, keeping that journal fresh, and keeping its scope broad.

His controversial piece *Theoretical Mathematics*, coauthored with Frank Quinn, displays the lively concern that Jaffe has for the status of our subject, and the desire he has to understand the trends within it, and to stimulate meaningful discussion about it. Indeed the responses of Atiyah, et al. in the *Bulletin of the AMS* (April 1994) show the sensitivity and importance of the issue raised by Jaffe and Quinn. No matter where one stands on the issues of rigor, one must admire Jaffe and Quinn for taking a position and publicly defending it.

In a more parochial arena, Jaffe served as chair of the Harvard Mathematics Department (1987–1990), during which period he did much to win from Harvard's administration a level of respect for his energy and for his innovative ideas, which included a significant expansion of department space and the establishment of an extensive visitor's program.

Let us now discuss the main work of Jaffe's career—Constructive Field Theory. The physicists' perturbative approach to Quantum Field Theory is to begin with the Lagrangian of a classical field theory, which in a very simple case might look like

$$\mathcal{L}(\phi) = \partial_\mu \phi \partial^\mu \phi + m^2 \phi^2 + \lambda \phi^4.$$  

One then calculates observable quantities using the Feynman path integral

$$\int [D\phi] e^{i\int \mathcal{L}(\phi) d^4x}.$$  

One does "calculate" despite the fact that the integral is mathematically ill-defined (for starters, one has not defined a measure on the path space over which the integration is to be performed). The integral can nevertheless be approached by expanding it as a perturbation series (formal power series) in the parameter $\lambda$. Alternatively in "non-perturbative" quantum field theory one would seek a Hilbert space of "states", where "observables" are given by self-adjoint linear operators on that space. Both approaches, perturbative and non-perturbative, are fraught with problems due to the infinite dimensionality of the path space and due to an incompatibility of ordinary (several-particle) quantum mechanics with special relativity. In the perturbative approach, even the coefficients of the expansion may diverge. The physicists deal with divergences that occur by methods which go under the name of "renormalization." Though apparently ad hoc, techniques of renormalization have been extraordinarily successful and have given the best agreements between theory and experiment in all of science. Quantum field theory has also led to profound insight into purely mathematical questions (witness operator algebras, analysis of infinite-dimensional spaces, the work of Atiyah and Singer, and Witten's many recent successes in geometry). There must be a broad and deep structure at work here and its rigorous elucidation is one of the big mathematical challenges of our time.

The Constructive Field Theory program tackles the problem head-on by constructing path space measures, i.e., measures on distributions in space-time (and as a consequence, the program constructs Hilbert spaces and observables) for specific interesting Lagrangians. This theory is tremendously difficult, and highly original, mathematics. We recommend the book *Quantum Physics*, by Glimm and Jaffe themselves. The central difficulties lie in the initial construction of the measure, and (in the course of studying properties of the constructed measure) understanding the spectrum of the corresponding Laplacian. This is equivalent to proving existence and establishing properties of the solutions to certain nonlinear, infinite-dimensional, and highly singular PDE's.

To begin, Jaffe and Glimm established the first existence theorem for a 2-dimensional nonlinear quantum field theory obeying the Wightman axioms. They also made a profound study of its properties. Later, in a true analytic *tour de force*, they went on to lay the foundations for the much more difficult 3-dimensional problem. In a series of papers written with Spencer, they analyzed the spectrum of the infinite-dimensional Laplacian in question, proving conjectures of physicists about phase transitions. The technique used in proving these results (cluster expansions) became a standard tool of mathematical physics. These tools have influenced most other work in constructive field theory, as well as mathematical analysis in related areas such as statistical physics and random systems.

But Jaffe's contribution is by no means limited to constructive field theory. His book with Taubes, *Vortices and Monopoles*, became a standard reference in the theory of classical, nonlinear field equations.

In the late eighties, Jaffe turned to the new subject of noncommutative differential geometry, originally introduced by Connes. In collaboration with Lesniewski and Osterwalder, he constructed a cocycle in entire cyclic cohomology. While motivated by his earlier work on quantum field theory, the cocycle condition arises from the interplay between algebraic and analytic aspects of supersymmetry. Now known as the JLO cocycle, it is a non-commutative generalization of the Chern character and has become a standard tool in index theory.

Arthur Jaffe has deep scientific accomplishments, has a firm commitment to the well-being of the mathematical community, and has the gift of being able to follow through successfully on his organizational ideas. We feel that Arthur Jaffe, with his energy, resourcefulness, and dedication, would make an excellent and highly successful president of the American Mathematical Society.
Meetings & Conferences

College Park, Maryland
University of Maryland in College Park
April 12-13, 1997

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1997

Deadlines
For organizers: July 12, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Milwaukee, Wisconsin
University of Wisconsin, Milwaukee
October 24-26, 1997

Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1997

Deadlines
For organizers: January 4, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions
Computability theory, Steffen Lempp, University of Wisconsin, Madison, and Robert I. Soare, University of Chicago.

Detroit, Michigan
Wayne State University
May 2-4, 1997

Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1997

Deadlines
For organizers: August 2, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Baltimore, Maryland
January 7-10, 1998
Joint Mathematics Meetings including the 104th Annual Meeting of the AMS, 81st Annual Meeting of the Mathematical Association of America (MAA), and annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: January 1998

Deadlines
For organizers: April 10, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Atlanta, Georgia
Georgia Institute of Technology
October 10-12, 1997

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1997

Deadlines
For organizers: January 4, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Manhattan, Kansas
Kansas State University
March 27-28, 1998

Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1998

Deadlines
For organizers: June 26, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
Biographical information about the candidates has been verified by the candidates, although in a few instances prior travel arrangements of the candidate at the time of assembly of the information made communication difficult or impossible. A candidate had the opportunity to make a statement of not more than 200 words on any subject matter without restriction and to list up to five of her or his research papers.

Abbreviations: American Association for the Advancement of Science (AAAS); American Mathematical Society (AMS); American Statistical Association (ASA); Association for Computing Machinery (ACM); Association for Symbolic Logic (ASL); Association for Women in Mathematics (AWM); Canadian Mathematical Society, Société Mathématique du Canada (CMS); Conference Board of the Mathematical Sciences (CBMS); Institute of Mathematical Statistics (IMS); International Mathematical Union (IMU); London Mathematical Society (LMS); Mathematical Association of America (MAA); National Academy of Sciences (NAS); National Academy of Sciences/National Research Council (NAS/NRC); National Aeronautics and Space Administration (NASA); National Council of Teachers of Mathematics (NCTM); National Science Foundation (NSF); Operations Research Society of America (ORSA); Society for Industrial and Applied Mathematics (SIAM); The Institute of Management Sciences (TIMS).

Each candidate had the opportunity to supply a photograph to accompany his or her biographical information.

President-Elect
Frederick W. Gehring

Born: August 7, 1925, Ann Arbor, Michigan.
Committee on Governance (Board of Trustees), 1993 (chair).  
Statement: American mathematics, which has experienced meteoric growth since 1945, faces serious problems. Immigrating scientists, plus considerable federal support following Sputnik, stimulated a flowering so dramatic that many prominent researchers from abroad now elect to spend time at American institutions. However, productive graduate programs, another influx of foreign mathematicians, and recent spending cuts at the federal, state, and local levels have resulted in a shrinking academic job market, reduced research budgets, and a decline in achievement levels of entering undergraduates. The Society has grown from 3,000 members and a $50,000 budget in 1945 to 30,000 members and a $19,000,000 budget; its activities have broadened from a focus on scholarship and research to include professional issues such as employment, mathematics education, research funding, public awareness, and representation of women and minorities in the profession. Unfortunately, the Society also faces a potentially serious problem, since current programs are supported by publication of journals and books, the income from which could change substantially with the advent of electronic publishing. All these problems must be addressed. If elected, my experience as department chair at a major public university, trustee, member of many governing and ad hoc committees, and consultant for two commercial publishers would prove useful.  
Arthur M. Jaffe  
Landon T. Clay Professor of Mathematics and Theoretical Science, Harvard University.  


Statement: This was a banner year for mathematics, with major mathematical progress made in many areas! We are certainly doing something right and justifiably might conclude that mathematics is fundamentally healthy. However, we face serious problems which affect us today and threaten the vitality of the future of mathematics. Paramount issues are declining research funds and a shortage of jobs. The AMS must address this situation by taking a leadership role in increasing recognition of mathematics and communicating its value, excitement, and vigor to the general public, to members of Congress, and to funding agencies. The AMS must also help mathematicians secure jobs as the academic market shrinks.

In addition, the AMS should encourage broad and inclusive participation in mathematics by all those interested and talented, regardless of gender, race, or economic status. The AMS should strengthen its role in mathematics education and help mathematicians with the new technologies, particularly with making an orderly transition to electronic publication while ensuring access to mathematical results now and in the future. AMS meetings should become even more valuable and engaging, and joint cooperation with the other mathematical organizations should be encouraged. The Society must develop new ways to foster a creative atmosphere for mathematical discovery.

Vice-President

Michael Aschbacher

Professor, California Institute of Technology.

Born: April 8, 1944, Little Rock, Arkansas.

AMS Committees: Ad Hoc Committee for the 1979 Summer Institute on Classification of Simple Groups and New Directions; Ad Hoc Committee for the 1985 Cole Prize (chair); Far Western Section Program Committee, 1990, and Western Section Program Committee, 1991; Nominating Committee, 1991-1993 (chair, 1992).

Selected Addresses: Invited Address, Toronto, August 1976; International Congress of Mathematicians, Helsinki, 1978; Special Session on Classification of Finite Simple Groups, San Francisco, January 1981; Special Session on Finite Geometries and Related Topics, East Lansing,
November 1982; Symposium on Mathematics into the Twenty-First Century, AMS Centennial, Providence, August 1988.


Statement: With the retreat of the NSF, the AMS will play an increasingly important service role for American mathematicians. In addition to its traditional functions running conferences and publishing research, the AMS should involve itself in fighting to reverse the decline in professional and research standards at American colleges and universities and in lobbying federal and state governments on behalf of mathematics.

Member-at-Large of the Council

Curtis D. Bennett
Assistant professor, Bowling Green State University.
Born: July 26, 1963, Madison, Wisconsin.

AMS Committees: Committee on the Profession Subcommittee on Employment Issues, 1993--.

Selected Addresses: Conference on Groups and Geometries, Oberwolfach, Germany, July 1991; Special Session on Groups and Geometries, Manhattan, Kansas, March 1994.


Statement: A major problem facing the mathematical community today is the employment crisis. This crisis has proven disheartening to many junior mathematicians and has led to difficul-
ties in launching a career for junior mathematicians. I would like to see the AMS Council continue to address this problem. The AMS is also lacking in representation of junior mathematicians. I feel the Council would benefit from having a member who has been directly affected by the job crisis and other problems faced by junior mathematicians.

David M. Bressoud
Professor of mathematics and computer science, Macalester College.


Gail A. Carpenter
Professor, Boston University.


neural network architecture for incremental supervised learning of analog multidimensional maps, IEEE Trans. Neural Networks 3 (1992), 698-713; 5. Spatial pattern learning, catastrophic forgetting, and optimal rules of synaptic transmission, Optimality in Biological and Artificial Networks (D. S. Levine and W. R. Elsberry, eds.), Lawrence Erlbaum Associates, Hillsdale, NJ, 1995. **Statement:** The AMS should maintain as its primary goal the support and dissemination of mathematical research. Another currently important task is to try to improve the employment prospects of young mathematicians. By offering conference workshops and helping universities design programs that prepare young mathematicians for nonacademic as well as academic employment, the AMS can help bridge the gap between traditional training and useful, challenging job opportunities. The AMS should continue to help parents of young children maintain their professional lives. **John B. Conway** Professor and chair, Department of Mathematics, University of Tennessee, Knoxville. **Born:** September 22, 1939, New Orleans, Louisiana. **Ph.D.:** Louisiana State University, 1965. **AMS Committees:** Proceedings Editorial Committee, 1985-1988 (Associate Editor, 1985-1986). **Selected Addresses:** Principal Speaker (four lectures), NATO Conference on Operators and Function Theory, University of Lancaster, England, 1984; AMS Summer Research Institute on Operator Theory/Operator Algebras and Applications, University of New Hampshire, Durham, July 1988; Steklov Institute of Mathematics, Leningrad, and Moscow University, 1989; Principal Speaker (two lectures), Southeastern Analysis Meeting, Charlotte, 1991; Shanks Lectures, Vanderbilt University, 1993; Hungarian Academy of Sciences Conference in Honor of Bela Sz. Nagy's 80th Birthday, 1993. **Additional Information:** NSF Research Grants, 1968-1989 and 1990-1993; NSF Sabbatical Grant, 1980-1981; Organizer, Special Session on Function Theoretic Operator Theory, Louisville, January 1984; Member, NSF Postdoctoral Fellowship Committee, 1984-1986; Indiana University Research Grant, 1984-1987; Recipient of NSF Grant and Argonne Universities Association Trust Fund Grant to conduct the Special Year in Operator Theory, Indiana University, 1985-1986; Organizer, Special Year in Operator Theory, Indiana University, 1985-1986; Professor and Head, Department of Mathematics, University of Tennessee, 1990-; NSF Undergraduate Science and Mathematics Education Evaluation Panel, 1991, 1993; University of Tennessee Science Alliance (Mathematics Division) Director, 1992-. **Selected Publications:** 1. Functions of one complex variable. Graduate Texts in Mathematics, Springer-Verlag, New York and Heidelberg, 1973. MR 56 #5843; 2. with R. F. Orlin, A functional calculus for subnormal operators. II, Mem. Amer. Math. Soc. 184 (1977). MR 55 #8864; 3. with B. E. Morrel, Roots and logarithms of bounded operators on a Hilbert space, J. Funct. Anal. 70 (1987), 171-193. MR B7m:47044; 4. The theory of subnormal operators. Math. Surveys Monographs, vol. 36, Amer. Math. Soc., Providence, RI, 1991. MR 92h:47026; 5. with N. Elias, Analytic bounded point evaluations for spaces of rational functions, J. Funct. Anal. 117 (1993), 1-24. **Statement:** I have concerns about the different directions in which our profession is being pulled. A close scrutiny of what we do as mathematicians is always profitable, whether the focus is on research direction, increasing our awareness of teaching responsibilities, studying the current state of the job market, or making our society politically and socially involved. The difficulty arises when we concentrate too closely on the problem of the moment and lose sight of the long-term development of mathematics. Complicating the whole process is the issue of funding. There seems to be a pattern of funding for the problems of yesterday that continues long after the crisis has diminished. An example is the increased federal funding of graduate education in mathematics to address an anticipated shortage and a continuation of that funding long after the job market for new mathematicians had hit the disaster level. I would like to see the Society set long-range goals to foster education and research in mathematics, to encourage further participation by women and minorities, to assist departments in achieving these goals, and to act as a steady influence on the direction of the funding agencies. **Isom H. Herron** Professor of mathematical sciences, Rensselaer Polytechnic Institute. **Born:** September 8, 1946, St. Louis, Missouri. **Ph.D.:** The Johns Hopkins University, 1973. **Selected Addresses:** Special Session on Function Theoretic Methods in Partial Differential Equations, Baltimore, January 1992; Special Session...
on Advances in Function Theoretic Methods, Cincinnati, January 1994.

Additional Information: Faculty Member, Department of Mathematics, Howard University, 1974–1994; Visiting Scientist, Universita di Napoli, 1984; Ford Foundation Senior Postdoctoral Fellowship, 1988–1989; Corporation Visiting Committee, Department of Mathematics, Massachusetts Institute of Technology, 1989–1990 and 1993--; Member: AMS, APS, NAM, SIAM.

Selected Publications:

Statement: Mathematics is an international enterprise. Within that framework, we must take account of our national needs to reinforce academic infrastructure and to empower intellectually those of diverse backgrounds. These are not easy tasks and ones that can only begin to be accomplished with a united will. Mathematicians should be enterprising in making our contributions known to society at large.

Krystyna M. Kuperberg
Alumni professor, Auburn University.

Born: July 17, 1944, Tarnow, Poland.

AMS Committees: Electronic Research Announcements Editorial Board, 1995--.


Additional Information: Visiting Member, Courant Institute of Mathematical Sciences, Fall 1987; Alabama EPSCoR Mathematics Infrastructure Committee, 1992–1994; Coorganizer (with P. Minc), Special Session on Modern Methods in Continuum Theory, Cincinnati, January 1994; Research Professor, Mathematical Sciences Research Institute, Fall 1994; Auburn University Alumni Professor, 1994–1999; Editor, Collected works of Witold Hurewicz, Amer. Math. Soc., Providence, RI, to appear; Member: AMS, AWM, Polish Mathematical Society.

Selected Publications:

Statement: While even the brightest young mathematicians are having difficulties finding academic positions, graduate students do most of the work involved in teaching calculus at many universities. There are typically more undergraduate students per professor in mathematics than there are in other areas. The AMS should offer advice to math departments about how to improve conditions for graduate students by decreasing their teaching duties and about ways to seek more tenure-track positions. The AMS could compile statistics to help the mathematical community ameliorate these problems. The AMS could also recognize those departments that make special efforts to create new positions. Every undergraduate deserves the opportunity to attend inspiring lectures, or to see a beautiful proof, or at least a rigorous argument. How many calculus students get that opportunity?

Joshua A. Leslie
Professor and chair, Department of Mathematics, Howard University.

Born: February 18, 1933, Jamaica.


Selected Addresses: Invited Address, Lehigh University, February 1988; Colloquium on Group Theory and Physics, Lie's Fundamental Theo-
rem in Infinite Dimensions, University of Georgia, July 1988; Annual Seminar of the Canadian Mathematical Society, Montreal, August 1989; Invited Address, Pennsylvania State University, University Park, October 1990; University of Marseille, 1991.

Additional Information: Board of Trustees, MSRI, 1994–; Member: AMS, MAA, NAM, AAAS, NYAS.


Statement: I am concerned that the putting in question of affirmative action in academia will be a setback for women and minority mathematicians long before its goals has been met.

Andrew Odlyzko

Head, Mathematics of Communication and Computer Systems Department, AT&T Bell Laboratories, and adjunct professor, Faculty of Mathematics, University of Waterloo.

Born: July 23, 1949, Tarnow, Poland.
Ph.D.: Massachusetts Institute of Technology, 1975.


Statement: Technological change and the end of rapid growth in funding for research are the chief causes of the problems facing mathematics. Mathematical research, the main mission of the AMS, can make important contributions to society, and we should make sure this is understood by the public and especially by policymakers. However, it is likely that we may have to survive with limited means, and we should prepare for that. In particular, while the AMS cannot do too much about the job situation, we should prepare and disseminate realistic projections about future job prospects. We also should position the AMS to survive the coming transition to electronic publication, which, if not managed well, may mean the loss of a large part of the funding for AMS activities that now comes from publications.

George C. Papanicolaou

Professor, Stanford University.

Born: January 23, 1943, Athens, Greece.


Selected Addresses: International Congress of Mathematicians, 1986; International Congress of
Mathematical Physics, 1994.

Additional Information: Sloan Fellow, 1974-1976; Guggenheim Fellow, 1983-1984; Member: AMS, SIAM.


Mary Lou Zeeman
Associate professor, Division of Mathematics and Statistics, University of Texas at San Antonio.


Additional Information: Graduate Student Instructor Teaching Award, University of California, Berkeley, 1986; Postdoctoral Member, The Institute for Mathematics and its Applications, Minneapolis, 1989-1990; C. L. E. Moore Instructor, Massachusetts Institute of Technology, 1990-1991; Coorganizer, Special Session on Low-Dimensional Geometric Dynamical Systems, San Antonio, January 1993; Coorganizer, Fall Midwest Dynamical Systems Conference, Berkeley, October 1993; University of Texas at San Antonio President's Distinguished Achievement Award for Excellence in Teaching, 1995; Member: AMS, AWM, LMS, MAA, SIAM.


Statement: The demographics of the American mathematical community are improving. There are more women and minorities entering the field, and one of the better consequences of the current job crisis is that talented young mathematicians are being distributed around the country at large and small colleges and universities alike. Now it is important to represent this diversity on the AMS Council and to ensure that all members of the community have equal opportunity to do research, to travel, and to achieve excellence in teaching.

Trustee

Fan R. K. Chung
Professor of mathematics, University of Pennsylvania.


Additional Information: Allendoerfer Award, 1990; Board of Mathematical Sciences, National Research Council, 1995–.


Statement: We are today in the midst of a technological revolution. Mathematics will play a vital role both in laying the foundation for this process and in making crucial contributions throughout the whole spectrum of this development. The AMS, as the major organization for mathematicians and to attract the best talent, including, in particular, women and minorities.

Michael G. Crandall
Professor, University of California, Santa Barbara.

Birth: November 29, 1940, Baton Rouge, Louisiana.


Statement: The Bylaws charge the Trustees to “receive and administer the funds of the Society”. If elected, I will put my experience with a broad range of mathematical environments and administrative responsibilities to vigorous use in playing my part in the sound, efficient, and forward-looking management of the fiscal operations of the Society. While the Bylaws state that it is the Council which “shall formulate the scientific policies of the Society”, a Trustee will also confront the many challenges the profes-
sion faces in a rapidly changing world. We must be simultaneously flexible, aggressive, and wise to ensure that we neither miss new opportunities nor ignore potential pitfalls. I feel that the contemporaneous phenomena of the underutilization and oversupply of mathematicians lie at the core of our profession's future, pointing to the opportunities and the pitfalls. I do not believe that the situation will improve in the foreseeable future if we wait passively, but I do believe that if we, all of us together, seize the opportunities, then the long-term future is bright. In the interim, we must be realistic and keep in mind that the circumstances most of those now entering the profession will encounter throughout their careers will differ in significant ways from the models to which we became accustomed.

Nominating Committee

Sylvain Cappell
Professor, Courant Institute of Mathematical Sciences, New York University.

Born: September 10, 1946, Brussels, Belgium.
Selected Addresses: Invited Address, Syracuse, October 1978; Principal Speaker, Conference Board of the Mathematical Sciences Lecture Series, Virginia Polytechnic University, 1987; Clifford Lectures, Tulane University, 1990; Conference on Symplectic Geometry and Its Applications, Cambridge University, 1994.

Statement: In view of the rapidly changing environment for research support in both academe and industry, in scientific education, in mathematical employment, and in publication and information exchange, the AMS will be facing large new challenges in carrying out its extraordinary record of helping its members develop and meet their scientific and professional goals. In discussing and planning with colleagues from many directions for these and in selecting candidates who would effectively lead the AMS and represent it in both public and scientific forums, I would draw on familiarity with these issues gained from my collegial experiences as an editor of research publications and book series, as chair of an AMS committee, and as many-year chair of my university's Research Challenge Fund Committee (awarding the internal research grants across all the sciences, social sciences, and humanities), and from supervising for many years the mathematical activities and workshops of the Faculty Resources Network (which created scholarly exchange opportunities for faculties from smaller and minority institutions), a recent term as associate director of the Courant Institute, and many-year chair of its Appointments and Promotions Committee.

I would also draw on the good counsel of many friends across the broad generational spectrum of mathematicians in university, college, and industrial employment (and in some cases, sadly, unemployment), and in many branches of pure and applied mathematics.

Eric M. Friedlander
Professor of mathematics, Northwestern University.

Born: January 7, 1944, Santurce, Puerto Rico.
Ph.D.: Massachusetts Institute of Technology, June 1970.


Statement: While continuing to address energetically the diverse concerns of the profession, the American Mathematical Society should not lose sight of its central mission to foster and disseminate mathematics.

Jane P. Gilman
Professor of mathematics, Rutgers University, Newark.

Born: April 17, 1945, Washington, D.C.


AMS Committees: Nominating Committee, 1988 and 1989 (chair); Nominating Committee Scheduling Committee, 1990.


Additional Information: Chair, Department of Mathematics and Computer Science, Rutgers University, Newark, 1982–1990; Member, Institute for Advanced Study, 1979-1980, and spring semester, 1992; Member, Mathematical Sciences Research Institute, January 1986–June 1986, and January 1996–June 1996; Supported short-term visitor; IHES, October and November 1995; Mittag-Leffler Institute, November 1989. Mathematical and educational reform activities include: Invited (with John Conway, Peter Doyle, and Bill Thurston) to give two-week intensive geometry and the imagination course at University of Minnesota Geometry Center, June 1991; invited to team-teach experimental graduate workshop in hyperbolic geometry and dynamical systems at MSRI, August 1994. Member: AWM, MAA.


Statement: The mathematical community is facing changes that affect virtually every aspect of the profession, and there are, no doubt, important decisions ahead for the AMS. The Nominating Committee should make a special effort to seek out thoughtful and informed candidates from all parts of the mathematical community.

Daniel J. Kleitman
Professor, Department of Mathematics, Massachusetts Institute of Technology.

Ph.D.: Harvard University, 1958.


James V. Ralston
Professor of mathematics,
University of California, Los Angeles.
Born: June 26, 1943, Elyria, Ohio.
Additional Information: Co-managing Editor, Communications in Partial Differential Equations, 1986–
Statement: If one accepts the fashionable but dubious proposition that outsiders are somehow better qualified for office, then I am an ideal candidate for this position. During my twenty-five years of membership, I have been cheerfully oblivious to the operations of the AMS. However, it is apparent even to me that the AMS increasingly needs to go beyond its traditional role of facilitating communication between and conferring honors on its members to the creation of mathematics curricula and the advocacy of federal support for mathematics. As a member of this committee, I would try to nominate people able to carry this out.

Joel Spruck
Professor of mathematics,
Johns Hopkins University.

Editorial Boards Committee

Sun-Yung Alice Chang
Professor, Department of Mathematics,
University of California, Los Angeles.
Born: March 24, 1948, Ci-an, China.


Statement: If elected, I will try my best to be well informed and even-handed in soliciting suggestions of nominations for each AMS editorial committee.

Jennifer Tour Chayes
Professor of mathematics,
University of California, Los Angeles.


Statement: The Editorial Boards Committee is charged with nominating mathematicians to serve on the editorial boards of AMS publications. In my view, the Committee has a dual purpose. First, it should make nominations reflecting the high standards of the AMS publications. Second, when consistent with the first goal, it should make nominations reflecting the broad interests and diversity of the mathematics community. I intend to pursue these goals by soliciting and carefully considering suggestions from the community at large.

Andrew Granville
David C. Barrow Professor of Mathematics,
University of Georgia.


From the AMS


Statement: Perhaps the biggest challenge that mathematical publishing and the AMS must face over the next few years is the inevitable changes brought on by electronic publication. Most industry experts believe that the quality of the “on-screen page” will improve to paper quality within the next few years. Moreover, electronic journals are far cheaper, more accessible (you may fetch articles without leaving your office), more flexible (for instance, you may make “links” to references and add “comments” after publication), and more immediate, allowing quicker dissemination of results and ideas. It seems inevitable that AMS journals must embrace this new era, but, at the same time, we must safeguard quality while these changes take place. Since most of its current income derives from paper publication, the Society has adopted a cautious attitude toward electronic publication, probably because it feels threatened by a deep cut in revenues. Nonetheless, the AMS’s mission is to serve the interests of its members and the cause of mathematics, while also being responsible financially; and, as a founding editor of two of the existing electronic journals, I will make sure that the Editorial Boards Committee and the AMS seek to take advantage of the tremendous opportunities that electronic publication offers while maintaining the traditional high standards of its journals.

Joel H. Spencer
Professor of mathematics and computer science, Courant Institute of Mathematical Sciences, New York University.
AMS Committees: Program Committee for National Meetings, 1994– (chair, 1995–).
Proposed Amendments to the Bylaws

The Council has approved several amendments to the bylaws for ratification by the membership in the election this fall (October 1995). These amendments will be printed in the election material that will be sent to all members of the Society in September 1995. The full text of the bylaws of the Society appears in the November issue of the *Notices* in odd-numbered years. The most recent copy, that of November 1993, was also amended in the 1993 election to reflect changes in the membership of the Council. The amendments approved in that November election are not reflected in the printed version of the bylaws.

There are three sets of amendments reported below. The first amendment, approved by the Council in August 1994, removes from the bylaws any mention of the Editorial Committee for the *American Journal of Mathematics*, a journal published by The Johns Hopkins University Press. This reflects the fact that the Editorial Board of the *American Journal of Mathematics* and the Society have terminated the relationship between the two organizations, so there is no representative of the Society appointed to that editorial board.

The second set of amendments, approved by the January 1994 Council but rejected by the membership in the 1994 election due to voter apathy (not enough members voted), modifies slightly the definition of the duties of the executive director and the relationship between the executive director and the Board of Trustees. It enlarges the so-called liaison committee to include the chair of the Board of Trustees, and it makes clear that the performance of the executive director is evaluated by the Board of Trustees. This set of amendments was approved again by the January 1995 Council for ratification by the membership in the upcoming election.

The third set of amendments concerns the Business Meeting of the Society. It was approved by the January 1995 Council for ratification by the members in the next election. The amendment attempts to resolve several problems with regard to Business Meetings.

It provides that a Business Meeting should be held only at the Annual Meeting of the Society, usually held in January. So there will no longer be Business Meetings at summer meetings, if the amendment passes. Furthermore, it addresses the question as to how items for action can reach a Business Meeting. The amendment would allow two methods for action items to come to a Business Meeting. An action item would reach a Business Meeting if it is recommended for action by both the Council of the Society and the Board of Trustees of the Society. Or an action item could reach a Business Meeting if a previous Business Meeting moves such an item on to the next Business Meeting. In order that an item put on the agenda for action by a previous Business Meeting can be approved, it must receive a majority of the votes of those who vote at a meeting where at least 400 members are present.

Amending the bylaws of the Society is usually a simple process. The Council recommends amendments for ratification by the membership. Approval by the membership consists of an affirmative vote by two-thirds of the members present at a Business Meeting or of two-thirds of the members voting in a mail ballot in which at least ten percent of the members vote. The alternative is designated by the Council when it recommends amendments for approval. In recent times, the Council has always designated approval by mail ballot, since attendance at Business Meetings has been rather sparse of late.

—Robert Fossum
Secretary
Amendment Concerning the American Journal of Mathematics Editorial Committee of the AMS

Article III. Committees
OLD Section 1. There shall be nine editorial committees as follows: committees for the Bulletin, for the Proceedings, for the Colloquium Publications, for the Journal, for Mathematical Surveys and Monographs, for Mathematical Reviews; a joint committee for the Transactions and the Memoirs; a committee consisting of the representatives of the Society on the Board of Editors of the American Journal of Mathematics; and a committee for Mathematics of Computation.

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

Amendment Concerning the Executive Director

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

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

OLD Section 2. The Executive Director shall be appointed by the Board of Trustees with the consent of the Council. The terms and conditions of employment shall be fixed by the Board of Trustees.

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

OLD Section 3 (first part). The Executive Director shall work under the immediate direction of a committee consisting of the president, the secretary, and the treasurer, of which the president shall be chairman ex officio.

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

OLD Section 3 (second part). The Executive Director shall attend meetings of the Board of Trustees, the Council, and the Executive Committee, but shall not be a member of any of these bodies.

Amendment Concerning Meetings

Article X. Meetings
OLD Section 1. The annual meeting of the Society shall be held between the fifteenth of December and the tenth of February next following. Notice of the time and place of this meeting shall be mailed by the secretary or an associate secretary to the last known post office address of each member of the Society. The times and places of the annual and other meetings of the Society shall be designated by the Council. There shall be a business meeting of the Society at the annual meeting and at the summer meeting.

NEW Section 1. The annual meeting of the Society shall be held between the fifteenth of December and the tenth of February next following. Notice of the time and place of this meeting shall be mailed by the secretary or an associate secretary to the last known post office address of each member of the Society. The times and places of the annual and other meetings of the Society shall be designated by the Council. There shall be a business meeting of the Society only at the annual meeting. The agenda for the business meeting shall be determined by the Council. A business meeting of the Society can take action only on items notified to the full membership of the Society in the call for the meeting. A business meeting can act on items recommended to it jointly by the Council and the Board of Trustees; a majority of members present and voting is required for passage of such an item. A business meeting of the Society can place action items on the agenda for a future business meeting. Final action on an item proposed by a previous business meeting can be taken only provided there is a quorum of 400 members, a majority of members at a business meeting with a quorum being required for passage of such an item.

The remaining sections in this article will be renumbered accordingly.
Thiel Named Director of AMS-SIAM Employment Project

The AMS and the Society for Industrial and Applied Mathematics (SIAM) have announced that Linda C. Thiel of Ursinus College has been named Project Director of a joint AMS-SIAM project funded by the Alfred P. Sloan Foundation. The goal of the project is to provide information and develop services for exploring nontraditional career opportunities in the mathematical sciences. The project is part of an ongoing effort by the Sloan Foundation to provide better resources to scientists seeking employment in nonacademic environments.

“Students are very concerned about their prospects for careers in mathematics,” Thiel notes. She points out that mathematics faculty are often asked the question, “What can I do with mathematics?” “Even those headed for careers in academia are beginning to realize the need to be aware of how mathematics is used in industry and how mathematicians work in industry.”

The project aims to assist students of mathematics at the graduate and undergraduate levels in making educated career plans and choices by providing them with a wide range of information. Among the services will be an interactive career bulletin board, accessible through the Internet, describing the careers of selected individual mathematicians. For a set period of time, five to six mathematicians will be featured on the bulletin board and students will be able to direct queries to them about their careers. Another part of this effort will be an extensive survey of mathematical scientists at the baccalaureate, master’s, and doctoral levels. This survey will provide information on the career paths of these individuals and more generally on the demands of the technical workplace.

The Sloan Foundation has also granted funds to several other scientific organizations to pursue similar projects. Among these are the American Institute of Physics and the American Society of Mechanical Engineers. AMS and SIAM are also investigating the idea of producing an interactive CD-ROM and hope to collaborate with the other organizations receiving funding from Sloan. If produced, the CD-ROM would bring together all of the information generated in the project, as well as perhaps a dozen video interviews with individuals from different scientific areas who have pursued nontraditional career paths. It is expected that colleges and universities would use the CD-ROMs when advising students on career choices and opportunities.

Although near-term concerns about the tight job market make this project especially timely, Thiel points out that the motivations are broader. “There are jobs in industry that mathematicians could do very well, but they are not specified as jobs for mathematicians,” Thiel explains. “In some cases a mathematician is clearly the right person for the job. But in other cases, we have to convince industry that mathematicians could do certain jobs very well.” One of the goals of the project is two-way communication in which mathematics faculty and students gain insight into how mathematics can be used in industry, and industry develops better understanding of what mathematicians can contribute.

An applied mathematician, Thiel received her Ph.D. from Drexel University. She was a senior operations research analyst with QUANTICS Incorporated before taking a position as an assistant professor at Ursinus College two
AMS Renovates Headquarters Building

The American Mathematical Society recently completed a major renovation of its headquarters building in Providence. The $3.4 million renovation project took four years to plan and execute. In addition to a complete remodeling of the headquarters building, the project included the purchase and renovation of a second building to accommodate the Society's printshop, warehouse, and distribution facilities. The AMS building was purpose-built for the Society in 1974.

The entrance and lobby were moved from the west side of the building to the northern end. About fifteen additional windows were put in, offices were constructed and reconfigured, two sets of restrooms were added, and new carpets were installed. Prior to the renovation, a maze of high-walled cubicles dominated the main part of the building. Today, moderate-height cubicles allow for privacy but still encourage interaction among employees.

The ventilation system was replaced by a completely new, state-of-the-art computer-controlled system, and a new access and security system was installed. The decor now features a color scheme of wine, teal, and gray, and red was added as an accent in fixtures and furniture. Full-spectrum lighting, installed throughout the building, closely resembles daylight. The new lobby area is an open, inviting space with a large display of AMS publications.

The newly renovated conference room was named in honor of Einar Hille, AMS President during 1947-1948. The room was renovated, furnished, and equipped through a generous bequest donated in memory of Hille by the estate of Mary K. Peabody. A commemorative plaque was installed outside of the Hille Conference Room. In addition, all individuals who now donate an aggregate amount of $1,000 annually are recognized in a special way. Their names are affixed to a marble plaque denoted “American Mathematical Society Benefactors,” which hangs in the lobby.

Artwork features prominently in the building. A marble sculpture, entitled “Cross Cap and Vector Field,” was created by mathematician Helaman Ferguson and donated by the MAA on the occasion of the AMS Centennial. The sculpture is in the new lobby area. The lunchroom has a two-canvas painting by the Puerto Rican artist Cybelle Cartagena. Rhode Island artist and AMS employee John Riedel was commissioned to create a painting for the AMS. The painting, entitled “Mathematical Stillife,” plays on themes from mathematics and astronomy.

The Society will continue to upgrade its facilities by installing more modular furniture suitable to the workspaces created in the renovation. In addition, the AMS will enhance its computing facilities by equipping employees with workstations connected to central servers through which files can be shared. Larger mainframe machines will continue to be used for the Society’s various databases and for large publication production jobs.

The Society celebrated the completion of the renovations with a special Open House event on May 5, 1995. Attending the Open House were the Governor of Rhode Island, Lincoln Almond, and Providence Mayor Buddy Cianci. Friends and family of AMS employees also attended the affair, as did many former AMS employees. Mayor Cianci gave an impromptu speech during the Open House, adding some levity to the event. In response to Bus Jaco’s remark that the AMS was “Rhode Island’s best-kept secret,” Cianci joked about the building’s lack of windows before the renovation. The AMS was a secret, he said, because “you didn’t have any windows for twenty years, so no one could see in.” In fact, for years the mysterious, windowless look of the AMS building prompted rumors that it is a CIA front. Referring to the fact that the AMS pays no property taxes because it is a nonprofit organization, Cianci remarked: “It’s a beautiful building, and my only regret is that I can’t tax it.”

The AMS Executive Committee and Board of Trustees (ECBT) were also treated to a special Open House celebration during their meeting in Providence in late May. The ECBT passed a resolution of appreciation to the AMS staff for the success of the renovations and for completing the project on time and under budget. “The beautiful facility will be appreciated by all for years to come,” the resolution stated.

—Allyn Jackson
Officers and Committee Members

Numbers to the left of headings are used as points of reference in an index to AMS committees which follows this listing. Primary and secondary headings are:

1. Officers
   1.1. Liaison Committee
2. Council
   2.1. Executive Committee of the Council
3. Board of Trustees
4. Committees
   4.1. Committees of the Council
   4.2. Editorial Committees
   4.3. Committees of the Board of Trustees
   4.4. Committees of the Executive Committee and Board of Trustees
4.5. Internal Organization of the AMS
4.6. Program and Meetings
4.7. Status of the Profession
4.8. Prizes and Awards
4.9. Institutes and Symposia
4.10. Joint Committees
5. Representatives
6. Index

Terms of members expire on January 31 following the year given unless otherwise specified.

1. Officers

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<tr>
<th>Position</th>
<th>Name</th>
<th>Years</th>
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<tr>
<td>President</td>
<td>Cathleen S. Morawetz</td>
<td>1996</td>
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<td>Ex-President</td>
<td>Ronald L. Graham</td>
<td>1995</td>
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<td>Vice-Presidents</td>
<td>Anil Nerode</td>
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<td>Gian-Carlo Rota</td>
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<td>Jean E. Taylor</td>
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<td>Treasurer</td>
<td>Franklin P. Peterson</td>
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<td>Associate Treasurer</td>
<td>B. A. Taylor</td>
<td>1996</td>
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1.1. Liaison Committee

All members of this committee serve ex officio.

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<tr>
<th>Position</th>
<th>Name</th>
<th>Years</th>
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</thead>
<tbody>
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2. Council

2.0.1. Officers of the AMS

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<tr>
<th>Position</th>
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<tr>
<td>President</td>
<td>Cathleen S. Morawetz</td>
<td>1996</td>
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<tr>
<td>Ex-President</td>
<td>Ronald L. Graham</td>
<td>1995</td>
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<td>Vice-Presidents</td>
<td>Anil Nerode</td>
<td>1995</td>
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<td>Gian-Carlo Rota</td>
<td>1997</td>
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<td>Jean E. Taylor</td>
<td>1996</td>
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<td>Secretary</td>
<td>Robert M. Fossum</td>
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<td>Associate Secretaries</td>
<td>Robert J. Daverman</td>
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<td>Treasurer</td>
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2.0.2. Representatives of Committees

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<td>Bulletin</td>
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<td>Executive</td>
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<td>John M. Franks</td>
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<td>Marc A. Rieffel</td>
<td>1997</td>
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<td>Journal of the AMS</td>
<td>William Fulton</td>
<td>1995</td>
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<td>Mathematical Reviews</td>
<td>Hugh L. Montgomery</td>
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<td>Georgia M. Benkart</td>
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<td>Mathematics of Computation</td>
<td>Walter Gautschi</td>
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<td>Proceedings</td>
<td>Irwin Kra</td>
<td>1996</td>
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<td>Transactions and Memoirs</td>
<td>Peter B. Shalen</td>
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2.0.3. Members-at-Large

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<tr>
<td>David B. A. Epstein</td>
<td>1997 Frank Morgan 1996</td>
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<tr>
<td>James Hyman</td>
<td>1997 Cora S. Sadosky 1997</td>
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<tr>
<td>Svetlana R. Katok</td>
<td>1995 Norberto Salinas 1996</td>
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<tr>
<td>Steven George Krantz</td>
<td>1995 Alice Silverberg 1997</td>
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<td>James I. Lepowsky</td>
<td>1995 Susan Gayle Williams 1995</td>
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<td>Peter W. K. Li</td>
<td>1995 Robert J. Zimmer 1996</td>
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<td>Jerrold E. Marsden</td>
<td>1997</td>
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* Only one Associate Secretary at a time is a voting member of the Council, namely the cognizant Associate Secretary for the scientific sessions.
2.1. Executive Committee of the Council

Officer and Committee Members

<table>
<thead>
<tr>
<th>Name</th>
<th>1995</th>
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<td>Joan S. Birman</td>
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<td>Marc A. Rieffel</td>
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2.2. Executive Committee of the Council

Associate Editors for Research Reports

<table>
<thead>
<tr>
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<tr>
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<td>Robert K. Lazarsfeld</td>
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3. Board of Trustees

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<td>Roy L. Adler</td>
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4. Committees

4.1. Committees of the Council

Standing Committees

4.1.1. Editorial Boards

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4.1.2. Nominating Committee

Terms begin on January 1

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4.2. Editorial Committees

4.2.1. Abstracts Editorial Committee

All members of this committee serve ex officio.

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<td>William Fulton</td>
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<td>Andrew M. Odlyzko</td>
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<td>Clifford Taubes</td>
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Officers and Committee Members

Associate Editors

Alexander Beilinson 1997  Marina Ratner 1997
Persi W. Diaconis 1997  Richard P. Stanley 1997
Michael H. Freedman 1996  Gang Tian 1997
Joe T. Harris 1996  W. Hugh Woodin 1996
Dusa McDuff 1997

4.2.9. Mathematical Reviews
AMS staff contact: R. Keith Dennis.

Chair  Hugh L. Montgomery 1995
J. Rauch 1997
Persi W. Diaconis 1997
Richard P. Stanley 1997
Mary Rees 1997

4.2.10. Mathematical Surveys and Monographs
Chair  Georgia M. Benkart 1996
Robert E. Greene 1995
Howard A. Masur 1997
Tudor Stefan Ratiu 1997

4.2.11. Mathematics of Computation
Chair  Walter Gautschi 1995
Andrew M. Odlyzko 1997
Frank W. J. Olver 1996
Lars B. Wahlbin 1997

4.2.12. Notices Editorial Board
Editor  Hugo Rossi 1996

4.2.13. Proceedings
William W. Adams 1996
Dale Alspach 1995
J. Marshall Ash 1996
Albert Baernstein 1995
Eric D. Bedford 1995
Andreas Blass 1996
Christopher Croke 1995
Richard T. Durrett 1996
Clifford J. Earle, Jr. 1996
Eric M. Friedlander 1995
Theodore W. Gamelin 1998
James G. Glimm 1995
Kenneth R. Goodearl 1996
Roe Goodman 1995
Thomas Goodwillie 1995
Dennis A. Hejhal 1995
Palle E. T. Jorgensen 1996
Jeffry Kahn 1997
Linda Keen 1997
Irwin Kra 1996

4.2.14. Proceedings of Symposia in Applied Mathematics
Chair  Peter S. Constantin 1995
Robert Krasny 1995

4.2.15. Transactions and Memoirs
Chair  Robert L. Bryant 1996
Daniel M. Burns 1998
Gregory L. Chertin 1996
Richard T. Durrett 1998
Lawrence Ein 1998
Philip J. Hanlon 1995
Wen-Ching Winnie Li 1995
Mark Mahowald 1996
John J. Mallet-Paret 1995
Jill C. Pipher 1998
Daniel Jay Rudolph 1997
Peter B. Shalen 1995
Robert J. Stanton 1997
Efim Zelmanov 1997

4.2.16. Translation from Chinese
Chair  Sun-Yung Alice Chang 1996
Tsit-Yuen Lam 1996
Tai-Ping Liu 1996
Chung-Chun Yang 1996

4.2.17. Translation from Japanese
Chair  Shoshichi Kobayashi 1996
Katsumi Nomizu 1996

Standing Committees

4.2.18. Colloquium Lecture
Chair  William Browder 1995
Wolfgang M. Schmidt 1996
Shlomo Sternberg 1997

4.2.19. History of Mathematics
Chair  Bruce Chandler 1995
Paul R. Halmos 1996
George B. Seligman 1998
Guido L. Weiss 1995

4.2.20. Reprinted Books
Chair  Eugenio Calabi 1996
Charles W. Curtis 1995
Oscar S. Rothaus 1997

4.2.21. University Lecture Series
Chair  Jerry L. Bona 1996
Donald S. Ornstein 1995
Leonard L. Scott 1996

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NOTICES OF THE AMS
4.2.22. What's Happening, Advisory Board for AMS
staff contact: Donald G. Babbitt.

Noga Alon
Randolph E. Bank
Robert Osserman
Carl Pomerance
Herbert S. Wilf

Special Committee

4.2.23. Abstracts Revision Task Force
Chair
Tom Blythe
Robert J. Daverman
Andrew M. Odlyzko
Donna L. Saltzer
Ralph Youngen

4.3. Committees of the Board of Trustees

4.3.1. Agenda and Budget
All members of this committee serve ex officio.

Joan S. Birman
Robert M. Fossum
Maria M. Klawe
Cathleen S. Morawetz
Franklin P. Peterson
B. A. Taylor

4.3.2. Appeals Committee on Discounted Subscriptions
AMS staff contact: Cheryl Marino.

Chair
John H. Ewing
Morton Lowengrub
Consultant
Cheryl Marino
Consultant
Hugh L. Montgomery
M. Susan Montgomery
Franklin P. Peterson

4.3.3. Audit
All members of this committee serve ex officio.
AMS staff contact: Gary G. Brownell.

Maria M. Klawe
Franklin P. Peterson

4.3.4. Corporate Relations
Chair
Ramesh A. Gangolli
Maria M. Klawe
Oscar S. Rothaus

4.3.5. Endowment and Planned Giving
AMS staff contact: Timothy J. Goggins.

Chair
Arthur M. Jaffe
Maria Klawe
Cathleen S. Morawetz
T. Benny Rushing

1996
1996
1996
1996

Chair

1996

1997

4.3.6. Investment
AMS staff contact: Gary G. Brownell.

Chair
M. Susan Montgomery
Franklin P. Peterson
T. Benny Rushing
B. A. Taylor

1996
1997

4.3.7. Legal Aid
Chair
Todd Dupont
Murray Gerstenhaber
B. A. Taylor

4.3.8. Salaries
All members of this committee serve ex officio.

Chair
Roy L. Adler
Maria M. Klawe
Franklin P. Peterson
B. A. Taylor

4.3.9. Staff and Services
All members of this committee serve ex officio.

Chair
Roy L. Adler
Franklin P. Peterson
B. A. Taylor

Special Committee

4.3.10. Institutional Membership
Consultant
Carol Ann Blackwood
Paul Chambers
Ramesh A. Gangolli
Chair
Frederick W. Gehring
William A. Veech

4.4. Committees of the Executive Committee and Board of Trustees

4.4.1. Long Range Planning
All members of this committee serve ex officio.
AMS staff contact: Raquel E. Storti.

Chair
John H. Ewing
Robert M. Fossum
John M. Franks
Maria M. Klawe
Cathleen S. Morawetz
Franklin P. Peterson
Marc A. Rieffel

4.4.2. Nominating
All members of this committee serve ex officio.

Chair
Joan S. Birman
Morris W. Hirsch
M. Susan Montgomery
Marc A. Rieffel

4.5. Internal Organization of the American Mathematical Society

Standing Committees

4.5.1. Archives
Gert Almkvist (AMS) 1996
Chair
Everett Pitcher 1997
John W. Weigel III 1997

4.5.2. Committee on Committees
Eric D. Bedford 1996
Fan R. K. Chung 1996
Ingrid Daubechies 1996
Percy Deift 1996
James A. Donaldson 1996
Robert M. Fossum 1996
Chair
D. J. Lewis 1996
Cathleen S. Morawetz 1996
Amil Nerode 1996
Marc A. Rieffel 1996
Norberto Salinas 1996
Peter Sarnak 1996
Fred Y. M. Wan 1996
Robert J. Zimmer 1996
4.5.3. **Library Committee**

Co-chair: Nancy Anderson 1997  
George E. Andrews 1996  
Bruce C. Berndt 1997  
Felix E. Browder 1996  
Dorothy McGarry 1997  
Co-chair: James Rovnyak 1996  
Mary Ann Southern 1996  
John W. Weigel III 1996

4.6. **Program and Meetings**

4.6.1. **Meetings and Conferences**
AMS staff contact: H. Hope Daly.

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<td>Cathleen S. Morawetz</td>
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<td>Sylvia Wiegand</td>
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<td>Ruth J. Williams</td>
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4.6.2. **Program Committee for National Meetings**

Ingrid Daubechies 1997  
Robert M. Fossum 1996  
Jeffrey C. Lagarias 1996  
Joseph Lipman 1995  
Jerrold E. Marsden 1995  
Co-chair: Joel H. Spencer 1996  
Chuu-Lian Terng 1997

4.6.3. **Short Course Subcommittee**

Stefan Burr 1995  
Ingrid Daubechies 1995  
Robert L. Devaney 1995  
Lisa Novak Gaal 1995  
Jeffrey C. Lagarias 1997  
Patrick D. McCray 1997  
Co-chair: James J. Tattersall 1996

4.6.4. **Central Section Program Committee**

John Erik Fornæss 1995  
Andy Roy Magid 1997  
Louis Pigno 1996  
Chair: Mary Ellen Rudin 1995  
Mei-Chi Shaw 1996

4.6.5. **Eastern Section Program Committee**

Martin Golubitsky 1995  
Chair: Stephen S. Kudla 1995  
Erwin Lutwak 1996  
Lesley M. Sibner 1997  
Bened Sturmfels 1995  
Alphonse Vasquez 1996  
Chair: Robert J. Daverman 1996

4.6.6. **Southeastern Section Program Committee**

John R. Garrett 1995  
Chair: Michael G. Crandall 1995  
Svetlana R. Katok 1995  
Lesley M. Sibner 1997  
Robert K. Lazarsfeld 1996  
Elliott H. Lieb 1995  
Richard S. Palais 1995  
Gian-Carlo Rota 1997  
Jeffrey C. Lagarias 1996  
Lind Preiss Rothschild 1996  
Robert K. Lazarsfeld 1995  
Sylvia T. Bozeman 1996  
John H. Ewing 1995  
Chair: Peter Anton Perry 1996  
Gian-Carlo Rota 1995  
Sylvia Wiegand 1996  
Chair: Michelle L. Wachs 1995

4.6.7. **Western Section Program Committee**

William M. Kantor 1996  
Chair: Edward Witten 1995  
Daniel S. Freed 1995  
Lance W. Small 1996  
Chair: Robert M. Fossum 1996  
Martin Golubitsky 1995  
John Sylvester 1995  
Chair: Linda Preiss Rothschild 1996  
Cathleen S. Morawetz 1996  
Lai-Sang Young 1996

4.6.8. **Agenda for Business Meetings**

James A. Donaldson 1996  
Chair: Robert M. Fossum 1996  
Joel H. Spencer 1995  
Chuu-Lian Terng 1997  
Chair: Freshman D. Wright 1995

4.6.9. **Arnold Ross Lecture Series Committee**

Harvey B. Keynes 1997  
Chair: Robert M. Fossum 1996  
Karl Rubin 1997  
Jeffrey C. Lagarias 1996  
Paul J. Sally, Jr. 1995  
Jean E. Taylor 1996  
Chair: Robert M. Fossum 1996  
Jeffrey C. Lagarias 1996  
Joseph B. Keller 1996  
Chair: Edward Witten 1995

4.6.10. **Gibbs Lecturer for 1995 and 1996, Committee to Select**

Chair: Edward Witten 1995  
Joseph B. Keller 1995  
Andres M. Odlzyko 1995  
Chair: Edward Witten 1995

4.6.11. **Progress in Mathematics**

Michael Aschbacher 1997  
Chair: Edward Witten 1995  
Michael G. Crandall 1995  
Kenneth A. Ribet 1996  
Mary Ellen Rudin 1996  
Richard M. Schoen 1997

4.6.12. **Meetings Coordinating Committee for the Orlando Meeting, January 1996**

Chair: John E. Morgan 1996  
Donna L. Salter 1996  
Lance W. Small 1996  
Jerrold E. Marsden 1996

---

**Special Committee**
4.7. Status of the Profession

Standing Committees

4.7.1. Academic Freedom, Tenure, and Employment Security
Sheldon Axler 1997
Mary Elizabeth Flahive 1996
Murray Gerstenhaber 1995
Simon Hellerstein 1995
Rhonda J. Hughes 1995
Donald E. Myers 1996
Seymour Schuster 1997
Chair

4.7.2. Education
AMS staff contact: Samuel M. Rankin III.

Hyman Bass 1996
Jerry L. Bona 1995
Carl C. Cowen 1996
Chair
Ronald G. Douglas 1996
David B. A. Epstein 1997
John H. Ewing 1996
Robert M. Fossum 1996
Deborah Hughes Hallett 1995
James M. Hyman 1997
Harvey B. Keynes 1995
Maria M. Klawe 1996
William James Lewis 1996
Cathleen S. Morawetz 1996
Judith Roitman 1995
Alan H. Schoenfeld 1995
Alan C. Tucker 1996

4.7.3. Subcommittee on Graduate and Postdoctoral Affairs
Jerry L. Bona
Carl C. Cowen
Rebecca A. Herb
Roger Howe
Deborah Hughes Hallett
Donald J. Lewis

4.7.4. Subcommittee on Undergraduate Affairs
David A. Cox
Joseph A. Gallian
Harvey B. Keynes
Kenneth C. Millett
Judith Roitman
Alan H. Schoenfeld
Abdulalim A. Shabazz
Alan C. Tucker

4.7.5. Human Rights of Mathematicians
Harold M. Edwards 1997
Alfred Gray 1995
Chair
Neal I. Koblitz 1996
Joel L. Lebowitz 1996
Gordana Matic 1996
Murray H. Protter 1995
Cora S. Sadosky 1996
William Yslas Velez 1997
M. V. Wicherhauser 1997

4.7.6. International Affairs
Chair
Raymond G. Ayoub 1995
Lenore Blum 1995
Alice Fialowski 1995
Robin Harshorne 1997
A. O. Kuku 1996
Motoko Murase 1997
V. Kumar Murty 1995
Harold J. Stolberg 1997
Hung-Hsi Wu 1997

4.7.7. Pi Mu Epsilon Liaison Committee
Joseph P. Brennan 1995
Thomas Brylawski 1997
Chair
Dennis DeTurck 1996
Aparna W. Higgins 1996
Marcia A. Perlis 1997
Robert Seton Smith 1997
Elliot A. Tanimoto 1996

4.7.8. Profession
 AMS staff contact: James W. Maxwell.

Chair
M. Salah Baouendi 1995
Annalisa Crannell 1996
John H. Ewing 1996
Robert M. Fossum 1996
Frank L. Gilfeather 1995
Richard J. Griego 1995
Antoni Kosinski 1997
Joseph Lipman 1996
Donald E. McClure 1996
Cathleen S. Morawetz 1996
Cora S. Sadosky 1997
Ronald J. Stern 1995
Steven H. Weintraub 1997
Robert J. Zimmer 1996

4.7.9. Professional Ethics
David Eisenbud 1996
Jerry Kaminker 1997
Marin I. Pour-El 1997
Louise A. Raphael 1997
Chair
Claude L. Schochet 1996

4.7.10. Science Policy
AMS staff contact: John H. Ewing.

Hyman Bass 1996
Ronald G. Douglas 1996
John H. Ewing 1996
Richard Ewing 1995
Robert M. Fossum 1995
Ronald L. Graham 1996
James I. Lepowsky 1996
William James Lewis 1997
Cathleen S. Morawetz 1997
John W. Morgan 1995
Melvyn Nathanson 1995
Anil Nerode 1996
Jean E. Taylor 1995
Frederic Y. M. Wan 1997
Susan Gayle Williams 1996
4.7.11. **Federal Policy Agenda Subcommittee**

Hyman Bass  
Ivar Stakgold  
Arthur M. Jaffe  
Linda Keen  
John W. Morgan  
John C. Polking  
Frank W. Warner III  
Margaret H. Wright  
Robert J. Zimmer  

Chair: Hyman Bass  

**4.7.12. World Mathematical Year 2000, Blue Ribbon Committee for**

Chair: Felix E. Browder  
Robert M. Fossum  
Ronald L. Graham  
Peter D. Lax  
Audrey A. Terras  
William P. Thurston  

4.7.13. **Former Soviet Union Mathematics, Advisory Committee on**

AMS staff contact: Timothy J. Goggins.

Michael Artin  
Felix E. Browder  
John H. Ewing  
Susan J. Friedlander  
Ronald L. Graham  
David Kazhdan  
Robert D. MacPherson  
Cathleen S. Morawetz  
John C. Polking  
Linda Preiss Rothschild  
Daniel Stroock  

Chair: Michael Artin  

4.7.14. **Subcommittee of the Ad hoc Advisory Committee on Former Soviet Union Mathematicians**

Volodia Retakh  

4.7.15. **Handicapped, Accessibility for the**

Chair: David M. James  
Carlos E. Kenig  
Horacio A. Porta  
Norberto Salinas  

4.7.16. **Procedures for the Committee on Professional Ethics, Committee on**

Chandler Davis  
Leonard Gillman  
C. Kristina Gunalsus  
Linda Keen  
Irwin Kra  
Mary Ellen Rudin  
Claude L. Schochet  

Chair: Chandler Davis  

4.7.17. **Resource Needs for Excellence in Mathematics Instruction**

AMS staff contact: Raquel E. Storti.

Richard W. Beals  
Thomas R. Berger  
John B. Garnett  
Ettore Infante  
Raymond L. Johnson  
Barbara Lee Keyfitz  
Joan P. Leitzel  
William James Lewis  
Morton Lowengrub  
Donald E. McClure  
Alan Newell  
Alan C. Tucker  
David A. Vogan, Jr.  

Chair: Richard W. Beals  

4.7.18. **Task Force on Participation for Underrepresented Minorities**

Efraim P. Armendariz  
Rodrigo Banuelos  
Richard J. Griego  
Leonard Hafn  
Fern Y. Hunt  
Raymond L. Johnson  
William A. Massey  
William P. Thurston  
Philip Uri Treisman  
James Clarence Turner  
J. Ernest Wilkins  

Chair: Efraim P. Armendariz  

4.8. **Prizes and Awards**

**Standing Committees**

4.8.1. **Award for Public Service, Committee to Select the Winner of the**

Chair: William Browder  
Kenneth M. Hoffman  
Harvey B. Keynes  
Everett Pitcher  
Isadore M. Singer  

Eastern District  
Western District  

4.8.2. **Centennial Fellowships**

Terms expire on June 30

Robert C. Alperin  
Robert Calderbank  
Ruth M. Charney  
Vera S. Fless  
Daniel W. Stroock  
Gang Tian  

Chair: Robert C. Alperin  

4.8.3. **Menger Prize Committee**

Terms expire on May 31

Bettye Anne Case  
Jerome A. Goldstein  
Julian Palmore  

Chair: Bettye Anne Case  

4.8.4. **National Awards and Public Representation**

Robert M. Fossum (ex officio)  
Frederick W. Gehring  
Ronald L. Graham (ex officio)  
Cathleen S. Morawetz (ex officio)  
Gian-Carlo Rota  

Chair: Robert M. Fossum  

**NOTICES OF THE AMS**

VOLUME 42, NUMBER 9
### 4.8.5. Subcommittee on Appointments of the Committee on National Awards and Public Representation

<table>
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<td>Irwin Kra</td>
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### 4.8.6. Satter Prize for 1997, Committee to Select the Winner of the

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### 4.8.7. Steele Prizes

Terms expire on June 30

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### Special Committees

#### 4.8.8. Automatic Theorem Proving, Committee to Recommend Winners of Prizes for

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#### 4.8.9. Cole Prize for 1997, Committee to Select the Winner of the

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#### 4.8.10. Veblen Prize for 1996, Committee to Select the Winner of the

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### 4.9. Institutes and Symposia

#### Standing Committees

#### 4.9.1. Liaison Committee with AAAS

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<td>Joel H. Spencer</td>
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<td>Frances Yao</td>
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#### 4.9.2. Summer Institutes and Special Symposia

Terms expire on February 28

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### 4.10. Joint Committees

#### 4.10.1. AMS-AAAS-MAA Committee on Opportunities in Mathematics for Underrepresented Minorities

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<td>Shirley Malcom, ex officio</td>
<td>1995</td>
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#### 4.10.2. AMS-ASA-AWM-IMS-MAA-NCTM-SIAM Committee on Women in the Mathematical Sciences

NCTM members’ terms expire April 1 of the year given.

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<td>Kathryn M. Chaloner (ASA)</td>
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<td>Margaret B. Cozzens (SIAM)</td>
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#### 4.10.3. AMS-ASL-IMS-SIAM Committee on Translations from Russian and Other Slavic Languages

Terms expire on January 1

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AMS Subcommittee Members

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<td>V. I. Arnold'</td>
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<td>Askold' Georgievich Khovanskii</td>
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ASL Subcommittee Members

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IMS Subcommittee Members

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</table>
4.10.4. AMS-IMS-MAA Data Committee
AMS staff contact: James W. Maxwell.

Consultant
Chair
Paul W. Davis (AMS) 1996
Lorraine Denby (AMS) 1996
Lincoln K. Durst 1996
John D. Fulton (MAA) 1996
Don O. Loftsgaarden (MAA) 1996
James W. Maxwell (AMS) ex officio
S. Brent Morris (AMS) 1997
Donald E. Rubin (IMS) 1995
Donald C. Run (AMS) 1995
Ann K. Stehney (AMS) 1995
Ann E. Watkins (MAA) 1996

4.10.5. AMS-IMS-SIAM Committee on Joint Summer Research Conferences in the Mathematical Sciences
Terms expire on June 30

Chair
Katalin A. Benesath (AMS) 1997
Mary Ellen Bock (IMS) 1998
Percy Alec Deift (AMS) 1998
Alan F. Karr (AMS) 1996
Barbara L. Keyfitz (AMS) 1998
Andrzej Maniutius (SIAM) 1997
Bart S. Ng (SIAM) 1997
Doug Simpson (IMS) 1997
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Clifford Taubes (AMS) 1997
Sue Whitesides (AMS) 1996

4.10.6. AMS-IMU Joint Program Committee
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Miriam Cohen (IMU)
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4.10.7. AMS-MAA Committee on Research in Undergraduate Mathematics Education (CRUME)
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January 10-13, 1996
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Leon H. Seitelman (SIAM) 1997
Ivar Stakgold (SIAM) 1995
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4.10.20. AMS-MAA-SIAM Morgan Prize Committee for Outstanding Research in Mathematics by an Undergraduate Student

Kelly J. Black (SIAM) 1997
Gulbank D. Chakerian (MAA) 1996
Frank Morgan (AMS) 1997
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Martha J. Siegel (MAA) 1997
Gilbert Strang (SIAM) 1995
Lee J. Zia (SIAM) 1996

4.10.21. AMS-SIAM Committee on Applied Mathematics

Shui-Nee Chow 1996
James W. Demmel 1995
Tai-Ping Liu 1995
Juan C. Meza 1997
Dianne O'Leary 1996
Tamar Schlick 1997
Chair

4.10.22. AMS-SIAM-SMB Committee on Mathematics in the Life Sciences

Michael C. Mackey 1996
John M. Rindel 1996
Michael S. Waterman 1995
Carla Wofsy 1997
Chair

4.10.23. AMS-SMM Committee Joint Program Committee

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5.0.1. Advisory Board of the National Translations Center of the John Crerar Library

5.0.2. American Association for the Advancement of Science

Terms expire on February 21

Section A Lenore Blum 1998
Section B Evans M. Harrell 1998
Section L Karen H. Parshall 1998
Section Q Deborah Hughes Hallett 1998
Section T Frances Yao 1998

5.0.3. Commission on Professionals in Science and Technology

Ann K. Stehney 1996
6. Index

6.0.4. Committee on the American Mathematics Competition
Term expires on June 30
Richard P. Stanley  1997

6.0.5. Conference Board of the Mathematical Sciences
Catheleen S. Morawetz 1996

6.0.6. Fulkerson Prize Committee
Alan J. Hoffman

6.0.7. MAA Committee on Undergraduate Program in Mathematics
Theodore Shifrin 1996
Dorothy Wallace 1996

6.0.8. MAA-NCTM Task Force on Mathematical Competitions
Peter W. Shor

6.0.9. U.S. National Committee on Theoretical and Applied Mechanics
Term expires on October 31
Constantine M. Dafermos 1996

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SEPTEMBER 1995
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- promote mathematical research, its communication and uses,
- encourage and promote the transmission of mathematical understanding and skills,
- support mathematical education at all levels,
- advance the status of the profession of mathematics, encouraging and facilitating full participation of all individuals,
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Apply to: Peter Legiša, Dept. of Math., Jadranska 19, 61111 Ljubljana, Slovenia.

Dues: U.S. $30, payable to DMFA, Jadranska 19, P. P. 64, 61111 Ljubljana, Slovenia.

Privileges: Subscription to Obzornik Za Matematiko Inžinirko (surface mail).

Officers: Egon Zakrajšek (President), Nada Razpet (Vice-President), Polona Blumauer (Treasurer), Polona Blumauer (Secretary).

• Suomen matemaattinen yhdistys

Apply to: Hans-Olav Tylli, Secretary, Department of Mathematics, P. O. Box 4 (Hallituskatu 15), FIN-00014 University of Helsinki, Finland.

Dues: 80 FIM, payable to Aatos Lahtinen, Treasurer, Department of Mathematics, P. O. Box 4 (Hallituskatu 15), FIN-00014 Helsinki, Finland.

Privileges: Archimedes (four issues a year) and Euclides (newsletter), Mathematica Scandinavica at reduced rate.

Officers: Mika Seppälä (President), Sören Illman (Vice-President), Aatos Lahtinen (Treasurer), Hans-Olav Tylli (Secretary).

• Svenska Matematikersamfundet

Apply to: Ingemar Kaj, Dept. of Mathematics, University of Uppsala, Box 480, S-75106 Uppsala, Sweden.

Dues: 50 SKr., payable to Svenska Matematikersamfundet, Britt-Marie Stocke, Department of Mathematics, University of Umeå, S-90187 Umeå, Sweden.

Privileges: Mathematica Scandinavica and Nordisk Matematisk Tidskrift at reduced rate, information about the meetings of the Society.

Officers: Matts Essén (President), Lars-Erik Persson (Vice-President), Britt-Marie Stocke (Treasurer), Ingemar Kaj (Secretary).

• Union of Bulgarian Mathematicians

Apply to: Sava Ivanov Grozdev, Secretary, Union of Bulgarian Mathematicians, Acad. G. Bonchev Str., Block 8, P.O. Box 155, BG-1113 Sofia, Bulgaria.

Dues: Voluntary, payable to Union of Bulgarian Mathematicians, Account #185-7808, State Savings Bank/DSK-I/code 421-121-817-001-I, BNB, Sofia City Branch.

Privileges: The right to attend all events organized by the UBM free of registration fees and to present papers at them; the right to attend other events in Bulgaria with a 30% discount on registration fees, and the right to purchase all UMB editions with the same subscription discount.

Officers: Ch. Lozanov (President), L. Davidov (Treasurer), S. Grozdev (Secretary General).

• Unione Matematica Italiana*

Apply to: Enrico Obrecht, Treasurer, Segreteria della Unione Matematica Italiana, Dipartimento di Matematica, Piazza Porta S. Donato, 5-40126 Bologna, Italy.

Dues: 60,000 lire, payable to Unione Matematica Italiana.

Privileges: Free Notiziario dell'UMI (monthly), Bollettino dell'UMI, Ser. A (three issues a year), and membership list. 40,000 lire only for subscriptions to Bollettino dell'UMI, Ser. B (four issues per year).

Officers: Alessandro Figà-Talamani (President), Maurizio Cornalba (Vice-President), Enrico Obrecht (Treasurer), Giuseppe Anichini (Secretary).

Wiskundig Genootschap*

Address for mail: Wiskundig Genootschap, Delft University of Technology, Faculty of TWI, P. O. Box 5031, 2600 GA Delft, The Netherlands.

Apply to: Membership Department, Wiskundig Genootschap, University of Utrecht, Postbus 80010, 3508 TA Utrecht, The Netherlands.

Dues: Hfl 55., payable to Amro Bank, Utrecht, The Netherlands, account 45.65.88.167, Penningmeester Wiskundig Genootschap.

Privileges: Nieuw Archief Voor Wiskunde (three issues a year containing articles and a problem section), Mededelingen (nine issues a year containing announcements and book reviews), Proceedings of the Royal Academy of Sciences—"Indagationes Mathematicae" (can be obtained at a reduced subscription rate of Hfl 185-).

Officers: A. van der Sluis (President), E. G. F. Thomas (Vice-President), J. D. Stegeman (Treasurer), R. W. Goldbach (Secretary).

Latin America

• Sociedad Colombiana de Matemáticas*

Apply to: Ernesto Acosta, Sociedad Colombiana de Matemáticas, Apartado Aereo 2521, Bogotá, D.C., Colombia.

Dues: U.S. $22, payable to Sociedad Colombiana de Matemáticas.

Privileges: Either Revista Colombiana de Matemáticas (two issues a year) or Lecturas Matemáticas (two issues a year).

Officers: Ernesto Acosta (President), Diego Escobar (Vice-President), Joaquin Luna (Secretary) Fernando Bernal (Treasurer).
Reciprocity Agreements

Sociedad de Matemática de Chile*
Apply to: Secretario, Sociedad de Matemática de Chile, Casilla 16164, Correo 9 Santiago, Chile; e-mail: baguiyu@uchdci02.bitnet; fax (56) (2) 2258427.
Dues: U.S. $20, payable to Sociedad de Matemática de Chile.
Privileges: Receive Gaceta de la Sociedad, Notas de la Sociedad de Matemática de Chile (two issues per year).
Officers: Rolando Chuqui (President), Samuel Navarro (Vice-President), Patricio Felmer (Treasurer), Rodrigo Bamón (Secretary), José Aguayo, Carmen Cortázar, Eduardo Munoz (Directors).

Sociedad Matemática de la República Dominicana*
Apply to: Isidro Rodriguez, Sociedad Matemática de la República Dominicana, P. O. Box 797-2, Santo Domingo, Dominican Republic.
Dues: U.S. $10, payable to Isidro Rodriguez, Sociedad Matemática de la República Dominicana.
Privileges: Right to receive Notimat (bimonthly newsletter) and Revista Matemática Dominicana (twice a year).
Officers: Amado Reyes (President), David Castillo (Vice-President), Isidro Rodriguez (Treasurer), Luis Leclerk (Secretary).

Sociedad Matemática Mexicana
Apply to: Rosa Sánchez, Apartado Postal 70-450, 04510-Mexico, D. F. Mexico.
Dues: U.S. $25, payable to Sociedad Matemática Mexicana.
Privileges: To be a regular member paying half of the regular fee for persons living outside of Mexico. Newsletter, Bulletin of the Mexican Mathematical Society or Miscelanea Matemática.
Officers: José Carlos Gómez-Larrañaga (President), Roberto Martínez (Vice-President), Ernesto Vallejo (Treasurer), Federico Sabina (Executive Secretary), Francisco Mirabal (Secretary), Salvador García-Ferreira and Isabel Puga (Associate Secretaries).

Sociedade Brasileira de Matemática de Aplicada e Computacional*
Apply to: Comissão de Admissão da SBMAC, Rua Lauro Muller 455, 22290, Botafogo, Rio de Janeiro, RJ, Brasil.
Dues: U.S. $30, payable to Sociedade Brasileira de Matemática Aplicada e Computacional.
Privileges: SBMAC Bulletin and SBMAC Notices.
Officers: Ricardo S. Kubrusly (President), Cristina Cunha (Vice-President), Jaime M. Rivera (Treasurer), Rolci Cipolatti (Secretary).

Sociedade Paranaense de Matemática*
Apply to: C. Pereira da Silva, Sociedade Paranaense de Matemática, Caixa Postal 1261, 80001-970, Curitiba-PR, Brasil.
Dues: U.S. $12, payable to Sociedade Paranaense de Matemática.
Privileges: Boletim da Sociedade Paranaense de Matemática (two issues per year), Monografías da Sociedade Paranaense de Matemática.
Officers: C. Pereira da Silva (President), R. J. B. De Sampayo (Vice-President), E. Andretta (Treasurer), A. Moser (Secretary).

Unión Matemática Argentina
Apply to: Isabel Dotti, FaMAF Ciudad Universitaria, 5000 Córdoba, Argentina; tel. 54-51-690068; fax. 54-51-681862; e-mail: una@mate.uncor.edu.
Dues: U.S. $40, payable to Isabel Dotti, FaMAF Ciudad Universitaria, 5000 Córdoba, Argentina.
Privileges: Free subscription to Noticiero UMA, and one of either: Revista de la Unión Matemática Argentina or Revista de Educación Matemática.
Officers: Juan A. Tirao (President), Felipe Zo (Vice-President), Isabel Dotti (Treasurer), Jorge Vargas (Secretary).

Middle East

Iranian Mathematical Society*
Apply to: Ali Danaee, P.O. Box 13145-418, Tehran, Iran.
Dues: U.S. $20, payable by bank draft or cheque in the order of Prof. Ali Danaee, P.O. Box 13145-418, Tehran, Iran.
Privileges: Bulletin of the Iranian Mathematical Society, Farhang va Andisheh Reiazi (a mathematical journal in Persian, if applicable), newsletter (in Persian, if applicable), and, reduced rate for participation in the annual Iranian Mathematics conferences and other seminars organized by IMS.
Officers: Rahim Zaare-Nahandi (President), Ali Danaee (Treasurer), Rahim Zaare-Nahandi (Secretary).
Israel Mathematical Union

Apply to: Victor Vinnikov, Secretary, Israel Mathematical Union, Department of Theoretical Mathematics, Weizmann Institute of Science, Rehovot 76100, Israel.

Dues: U.S. $10, payable to Amnon Yekutieli, Treasurer, Israel Mathematical Union, at above address.

Privileges: Participation in meetings and all other privileges enjoyed by an ordinary member.

Officers: Stephen Gelbart (President), Amnon Yekutieli (Treasurer), Victor Vinnikov (Secretary).

Saudi Association for Mathematical Sciences*

Apply to: Sameer Klub, Secretary of SAMS, Department of Mathematics, College of Science, King Saud University, P. O. Box 2455, Riyadh 11451, Saudi Arabia.

Dues: U.S. $30, payable to Saudi Association for Mathematical Sciences, Dept. of Math., College of Science, King Saud University, at above address.

Privileges: Reduction in membership fee from U.S. $40 to U.S. $30; proceedings of conferences, symposia, and seminars arranged by the Association.

Officers: Fawzi A. Al-Thukair (President), Abdul Rahman Abu Ammah (Vice-President), Yousif Al-Khamees (Treasurer), Sameer Klub (Secretary).

South Pacific

Australian Mathematical Society

Address for mail: D. Elliott, Secretary, Australian Mathematical Society, Department of Mathematics, University of Tasmania, GPO Box 252C, Hobart, Tasmania 7001, Australia.

Apply to: A. Howe, Treasurer, Australian Mathematical Society, Mathematics Department, Australian National University, Canberra ACT 0200, Australia.

Dues: $A33, payable to the Australian Mathematical Society, c/o A. Howe at the above address.


Officers: D. W. Robinson (President), C. E. Praeger, P. J. Stacey, G. C. Wake (Vice-Presidents), A. Howe (Treasurer), D. Elliott (Secretary).

New Zealand Mathematical Society*

Address for mail: Department of Mathematics, University of Auckland, PB 92019, Auckland, New Zealand.

Apply to: J. A. Shanks, Department of Mathematics and Statistics, University of Otago, P. O. Box 56, Dunedin, New Zealand.

Dues: NZ $32, payable to John A. Shanks, Department of Mathematics and Statistics, University of Otago, P. O. Box 56, Dunedin, New Zealand.

Privileges: Newsletter of the NZMS (three per year).

Officers: M. D. E. Conder (President), D. A. Holton (Vice-President), M. McGuinness (Treasurer), M. J. Morton (Secretary).
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How to use this form
1. Using the facing page or a photocopy, (or a TeX version which can be downloaded from the e-math “Employment Information” menu), fill in the answers which apply to all of your academic applications. Make photocopies.

2. As you mail each application, fill in the remaining questions neatly on one cover sheet and include it on top of your application materials.

The Joint Committee on Employment Opportunities has adopted the cover sheet on the facing page as an aid to job applicants and prospective employers. The 1995-96 hiring season is the second year in which the cover form is being utilized. The form is now available on e-math in a TeX format which can be downloaded and edited. The purpose of the cover form is to aid department staff in tracking and responding to each application.

Mathematics Departments in Bachelor’s, Master’s and Doctorate granting institutions have been contacted and are expecting to receive the form from each applicant, along with any other application materials they require. Obviously, not all departments will utilize the cover form information in the same manner. Please direct all general questions and comments about the form to: dmm@math.ams.org or call the Professional Programs and Services Department, AMS, at 800-321-4267 extension 4105.

JCEO Recommendations for Professional Standards in Hiring Practices

The JCEO believes that every applicant is entitled to the courtesy of a prompt and accurate response that provides timely information about his/her status. Specifically, the JCEO urges all institutions to do the following after receiving an application:

(1) Acknowledge receipt of the application—immediately; and
(2) Provide information as to the current status of the application, as soon as possible.

The JCEO recommends a triage-based response, informing the applicant that he/she
(a) is not being considered further;
(b) is not among the top candidates; or
(c) is a strong match for the position.
This form is provided courtesy of the American Mathematical Society.

This cover sheet is provided as an aid to departments in processing job applications. It should be included with your application material.

Please print or type. Do not send this form to the AMS.

Academic Employment in Mathematics

AMS STANDARD COVER SHEET

Last Name
First Name
Middle Names
Social Security Number optional

Address through June 1996

Home Phone

Current Institutional Affiliation

e-mail Address

Work Phone

Highest Degree and Source

Ph.D. Advisor

If the Ph.D. is not presently held, date on which you expect to receive

Indicate the mathematical subject area(s) in which you have done research using the 1991 Mathematics Subject Classification printed on the back of this form. If listing more than one number, list first the one number which best describes your current primary interest.

Primary Interest

Secondary Interests optional

Give a brief synopsis of your current research interests (e.g. finite group actions on four-manifolds). Avoid special mathematical symbols and please do not write outside of the boxed area.

Most recent, if any, position held post Ph.D.

University or Company

Position Title Dates

Indicate the position for which you are applying and position posting code, if applicable

If unsuccessful for this position, would you like to be considered for a temporary position?

☐ Yes ☐ No If yes, please check the appropriate boxes.

☐ Postdoctoral Position ☐ 2+ Year Position ☐ 1 Year Position

List the names, affiliations, and e-mail addresses of up to four individuals who will provide letters of recommendation if asked. Mark the box provided for each individual whom you have already asked to send a letter.

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## 1991 Mathematics Subject Classification

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## Visiting Mathematicians

*(Supplementary List)*

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<th>Field of Special Interest</th>
<th>Period of Visit</th>
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<td>Burghelea, Dan (U.S.A.)</td>
<td>Institut des Hautes Études Scientifiques, France</td>
<td>Topology</td>
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<tr>
<td>Glover, Henry (U.S.A.)</td>
<td>ETH, Switzerland</td>
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<tr>
<td>Moscovici, Henri (U.S.A.)</td>
<td>Institut des Hautes Études Scientifiques, France</td>
<td>Harmonic Analysis</td>
<td>10/95; 3/96 - 9/96</td>
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<tr>
<td>Seress, Akos (U.S.A.)</td>
<td>Rheinisch-Westfälische Technische Hochschule, Germany</td>
<td>Combinatorics</td>
<td>1/96 - 2/96</td>
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<th>Name and Home Country</th>
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<th>Field of Special Interest</th>
<th>Period of Visit</th>
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<td><strong>Visiting Foreign Mathematicians</strong></td>
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<td>Andreev, Andre (Bulgaria)</td>
<td>University of South Carolina</td>
<td>Numerical Analysis</td>
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<td>Dancik, Vladimir (United Kingdom)</td>
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<td>Ding, Wei-Yue (People’s Republic of China)</td>
<td>University of Southern California</td>
<td>Global Analysis, Analysis on Manifolds</td>
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<td>Dym, Jonathan (Israel/U.S.A.)</td>
<td>University of Southern California</td>
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<td>Isola, Stefano (Italy)</td>
<td>University of Southern California</td>
<td>Dynamical Systems</td>
<td>1/95 - 8/96</td>
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<td>Januszkiewicz, Tadeusz (Poland)</td>
<td>Ohio State University</td>
<td>Topology</td>
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<tr>
<td>Lee, Jae Kyun (Korea)</td>
<td>University of Southern California</td>
<td>Statistics</td>
<td>8/95 - 6/96</td>
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<tr>
<td>Leviatan, Dany (Israel)</td>
<td>University of South Carolina</td>
<td>Approximation Theory</td>
<td>8/95 - 5/96</td>
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<tr>
<td>Leviatan, Talma (Israel)</td>
<td>University of South Carolina</td>
<td>Statistics</td>
<td>8/95 - 5/96</td>
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<tr>
<td>Malikov, Fedor (Russia)</td>
<td>University of Southern California</td>
<td>Topology Groups, Lie Groups</td>
<td>9/95 - 8/97</td>
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<tr>
<td>Marjoram, Paul (Great Britain)</td>
<td>University of Southern California</td>
<td>Statistics</td>
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<td>Petrushev, Pencho (Bulgaria)</td>
<td>University of South Carolina</td>
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<td>Promet, Alexander (United Kingdom)</td>
<td>Ohio State University</td>
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<td>Reinert, Gesine D. (Germany)</td>
<td>University of Southern California</td>
<td>Probability Theory and Stochastic Processes</td>
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<td>Renfer, Jean-Pierre (Switzerland)</td>
<td>University of Illinois at Urbana-Champaign</td>
<td>Robust Statistics</td>
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<tr>
<td>Roy, Rahul (India)</td>
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<td>Probability</td>
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<tr>
<td>Wu, Xian (China)</td>
<td>University of South Carolina</td>
<td>Number Theory</td>
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</tbody>
</table>

The list of visiting mathematicians includes both foreign mathematicians visiting in the United States and Canada, and Americans visiting abroad. Note that there are two separate lists.
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. When information is updated or otherwise changed, it will be noted in this section.

Upcoming Deadlines

**September 15, 1995:** Applications for NRC Twinning Program. Office for Central Europe and Eurasia (FO2014), National Research Council, 2101 Constitution Ave., N.W., Washington, DC 20418; e-mail ocee@nkas.edu.

**October 1, 1995:** Applications for AWM Travel Grants for Women.

Travel Grant Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Bldg., University of Maryland, College Park, MD 20742-2461; telephone 301-405-7892; e-mail awm@math.umd.org.

“The May, June, July, and August issues carried an incorrect deadline of August 1 for these grants. This program has three deadlines each year on Feb. 1, May 1, and Oct. 1. The Notices regrets this error and any confusion it may have caused.


**October 17, 1995:** Deadline for applications for NSF Mathematical Sciences Postdoctoral Research Fellowships. Infrastructure Program, Rm. 1025, DMS, NSF, 4201 Wilson Blvd., Arlington, VA 22230; e-mail msp@nsf.gov; or the AMS, e-mail nsfpostdocs@math.ams.org.

**November 9, 1995:** Target date for DMS (NSF) proposals in computational mathematics, geometric analysis, statistics & probability, topology & foundations, and mathematical biology. See address above.

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**Where to Find It**

A brief index to information which appeared in previous issues of the Notices.

- **Advanced Research Projects Agency, program officers in math**
  October 1994, p. 943

- **Air Force Office of Scientific Research, program officers in math**
  October 1994, p. 942

- **AMS e-mail addresses**
  October 1994, p. 935

- **AMS Ethical Guidelines**
  June 1995, p. 694

- **AMS Officers and Committee Members**
  September 5, p. 1026

- **AMS Proposed Amendments to the Bylaws**

- **Army Research Office, program officers in math**
  October 1994, p. 943

- **Board on Mathematical Sciences, National Research Council**
  February 1995, p. 277

- **Board on Mathematical Sciences Staff**
  February 1995, p. 277

- **Mathematics Research Institutes Contact Information:** The Fields Institute, The Geometry Center, Institute for Advanced Study, Institute for Mathematics and its Applications, Mathematical Sciences Institute, Mathematical Sciences Research Institute, Center for Discrete Mathematics and Theoretical Com-
September 1995

Organizer: Mathematical Institute of the Academy of Sciences, Praha.
Speakers: To be announced.
Information: J. Rákosník, Mathematical Institute, Žitná 25, 11567 Prague 1, Czech Republic; fax (+42 2) 24227633; e-mail: rakosnik@earn.cvut.cz.

3-10 Summer School on General Algebra and Ordered Sets, Blatný, Moravia. (May 1995, p. 594)

4-8 Vème colloque international de théorie des graphes et de combinatoire, CIRM, Marseille, France. (Aug. 1995, p. 902)

4-8 Differential Equations, Group Theory, Calculus of Variations, Hradec n. Moravici, Czech Republic. (July 1995, p. 793)

4-8 Linear Groups, Levico, Italy. (Apr. 1995, p. 481)

4-8 Conference on Algebraic K-Theory, Polish Academy of Sciences (PAN), Poznań, Poland. (Apr. 1995, p. 481)

4-9 Seventh Congress of European Women in Mathematics (EWM 95), Madrid, Spain. (Mar. 1995, p. 369)


5-8 IMA Tutorial on Microstructure, Weak Convergence and Atomic Forces, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., S.E., Minneapolis, MN 55455. (Mar. 1995, p. 370)

6-7 Theory and Methodology of Mathematics Teaching, Calcutta, India.
Information: Contact N. C. Ghosh (Director of the Seminar), Calcutta Mathematical Society, AE 374, Sector-I, Salt Lake City, Calcutta-700064.


11-12 Environment Pollution Caused by Power Plant: Mathematical Viewpoint, Calcutta, India.
Information: Contact N. C. Ghosh (Director of the Seminar), Calcutta Mathematical Society, AE 374, Sector-I, Salt Lake City, Calcutta-700064.

11-15 IMA Workshop on Mechanical Response of Materials from Angstroms to Meters, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., S.E., Minneapolis, MN 55455. (Mar. 1995, p. 370)

11-15 Problemes bien poses et stabilite en optimisation, CIRM, Marseille, France. (Aug. 1995, p. 902)


13-15 14th Symposium on Reliable Distributed Systems, Bad Neuenahr (near Bonn), Germany.
Supported By: Deutsche Telekom, IBM, Software Union, and Daimler Benz AG.
Theme: The focus of the symposium concerns the building and use of distributed and parallel systems, particularly with system properties such as reliability, availability.

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 listing of meetings of the Society, and of meetings sponsored by the Society, will be found on the first page of the Meetings and Conferences section.

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.

In order to allow participants to arrange their travel plans, organizers of meetings 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 six 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, 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 e-MATH on the World Wide Web. To access e-MATH, use the URL: http://e-math.ams.org/ (or http://www.ams.org/). (For those with VT100-type terminals or for those without WWW browsing software, connect to e-MATH via Telnet (telnet e-math.ams.org; login and password e-math) and use the Lynx option from the main menu.)
ity, and performance. Especially during the panels, the impact of important industrial applications will be discussed.

Information: M. Dresden, GMD-Schloss Birlin­ghoven, SET-RS, D-37545, Sankt Augustin, Germany; tel: +49-2241-142756; fax: +49-2241-142105; e-mail: dreessen@gmd.de; http://borneo.gmd.de/RS/SCS/14/ard/9/4.html.


18-24 8th International Symposium on Classical Analysis, Kazimierz Dolny, Poland. (Feb. 1995, p. 282)


22-30 Advanced Course on Complex Dynamics, Centre de Recerca Matematica (Barcel­ona). July 1995, p. 793)


25-29 Cryptographie, CIRM, Marseille, France. (Aug. 1995, p. 902)

26-28 MICROSIM 95, Southampton, UK. (May 1995, p. 594)


2-6 Introduction aux systemes d'Euler, CIRM, Marseille, France. (Aug. 1995, p. 902)

6-8 Midwest Dynamical Systems Seminar, University of Cincinnati. (Jun. 1995, p. 703)

7 Southern California Algebra Conference, California State University at Northridge, CA.

Program: The purpose of this conference is to honor J. Martindale who is retiring in January 1996.

Invited Speakers: C. Lanski (USC), J. Mar­tindale (U. Mass.-Amherst), S. Montgomery (USC), M. Schacher (UCLA), and L. Small (UCSD).

Information: Contact J. Rosen at e-mail: jrosen@uoregon.edu or write to Dept. of Mathematics, California State Univ. at Northridge, Northridge, CA, 91330-8313 or tel: 818-885-2721.

7-8 Eastern Section, Northeastern University, Boston, MA.

Information: C. Harkness, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: chh@math.ams.org.

9-11 Conference on Symzgies and Geometry, Northeastern University, Boston, MA. (July 1995, p. 794)

9-13 Fonctions zeta dynamiques, CIRM, Marseille, France. (Aug. 1995, p. 902)


13-14 Fifteenth Annual Meeting of the Southeast-Atlantic Regional Confer­ence on Differential Equations, North Carolina State University, Raleigh, NC. (Jun. 1995, p. 703)

16-20 Histoire de la lecture des an­cients en mathematiques, CIRM, Marseille, France. (Aug. 1995, p. 903)

17-20 The Second Asian Mathematics Conference (AMC '95), Nakhon Ratcha­sima, Thailand. (Oct. 1994, p. 1029)

19-21 Seventeenth Midwest Probabil­ity Colloquium, Northwestern University, Evanston, IL. (July 1995, p. 794)

19-23 New Directions in the Theory of Markets (Game Theory with Applications in the Social Sciences and Biology), The Fields Institute, Toronto, ON, Canada. (Jun. 1995, p. 703)

20-21 Stochastic Analysis Meeting, Lon­don, UK.


Information: London Mathematical Society, Burlington House, Piccadilly, London W1V ONL; tel: 171 437 5377; fax: 171 439 4629; e-mail: las@sk1.ac.uk.

20-21 10th Anniversary Board on Mathe­matical Sciences Department Chairs Col­loquium, Arlington, VA. (July 1995, p. 794)


30-November 1 The Tenth International Symposium on Computer and Information Sciences (ICSI C X), Ephesus, Izmir, Turkey. (May 1995, p. 594)

30-November 3 Harmonic functions on graphs, Graduate Center of CUNY in New York.


30-November 3 IEEE Visualization ’95, Atlanta Airport Hilton and Towers. (May 1995, p. 594)

30-November 4 Theorie des operateurs, CIRM, Marseille, France. (Aug. 1995, p. 903)

November 1995

3-4 Central Section, Kent State University, Kent, OH.

Information: C. Harkness AMS, P.O. Box 6887, Providence, RI 02940; e-mail: chh@math.ams.org.

4-5 Southern California Analysis and PDE Conference, University of California, River­side.

Invited Speakers: R. A. Askey (Univ. of Wisconsin), J. Bourgain* (L. S. Princeton), S.-Y. Alice Chang* (U. C. L. A.), A. L. Edelson (U. C. Davis), C. I. Foias (Indiana Univ.), M. W. Hirsch (U. C. Berkeley), J. B. Serrin (Univ. of Minnesota), J. A. Smoller (Univ. of Michigan), and E. M. Stein (Princeton Univ.). (* = to be confirmed)

Program: The fall meeting of the SCAPDE conference is dedicated to V. L. Shapiro upon his retirement and will focus on harm­monic analysis and nonlinear differential equations. Talks will start on the morning of Saturday the 4th and will end in the late afternoon of Sunday the 5th. There will be a banquet on Saturday evening the 4th.
December 1995
8-10 4th International Conference on Physiological Fluid Dynamics, Jawai University, Gwalior, India. (July 1995, p. 794)
18-21 1st Asian Technology Conference in Mathematics (ATCM), Singapore. (Oct. 1994, p. 1029)
18-22 International Conference on Harmonic Analysis, University of Delhi, Delhi, India. (May 1995, p. 59)

January 1996
3-6 International Conference on Discrete Mathematics and Number Theory, Tiruchirapalli, Tamil Nadu, India. (Jan. 1995, p. 78)
4-8 Materials for the History of Mathematics in the 20th Century, Nice, France. Dedication: Dedicated to the memory of J. A. Dieudonné, on the occasion of the inauguration of the J. A. Dieudonné Mathematics Building, Univ. of Nice Sophia-Antipolis.
Funding: There is a limited amount of funding available, primarily for graduate students and junior faculty.
Information: Contact: J. Luecke, Math Dept., Univ. of Texas, Austin, TX, 78712; tel: 512-471-4176; e-mail: luecke@math.utexas.edu.

February 1996
5-9 IMA Workshop on Interface and Thin Films, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., SE, Minneapolis, MN 55455. (Apr. 1995, p. 482)
28-29 IMA Tutorial on Nonlinear Optical Materials, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., SE, Minneapolis, MN 55455. (Apr. 1995, p. 482)

March 1996
4-8 IMA Workshop on Nonlinear Optical Materials, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., SE, Minneapolis, MN 55455. (Apr. 1995, p. 482)
14-16 Seminar in Stochastic Processes, Duke University, Durham, NC.
Program: The seminar is the sixteenth in a series of annual conferences in stochastic
processes including Brownian motion, superprocesses, stochastic analysis, potential theory, processes on discrete spaces, and applications to physics and biology. There will be five formal lectures and nine hours of shorter, more informal presentations.

**Information:** G. Lawler, Dept. of Math., Duke Univ., Box 90320, Durham, NC 27708-0320; e-mail: joe@math.duke.edu.

17-21 Prospects in Mathematics, Princeton, NJ. (July 1995, p. 794)

22-23 Central Section, University of IA, Iowa City, IA.

**Information:** C. Harkness, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: charkness@math.ams.org.

28-31 27th Annual Iranian Mathematics Conference, Shiraz University, Shiraz, Iran.

**Sponsors:** Mathematics Department of Shiraz University and the Iranian Mathematical Society.

**Information:** K. Seddighi, Dept. of Math., Shiraz Univ., Shiraz, Iran 71454; tel: 071-20027. E-mail: quyong@ox1.ios.ac.cn.

**23-25 Volterra Centennial Symposium.** The University of Texas at Arlington. Theme: The meeting is organized to celebrate the 100th anniversary of Volterra’s publications on integral equations. Participants from the United States and abroad are expected.

**Topics:** Integral and related equations (e.g., integro-differential, integro-functional), modeling by means of integral questions, theory of abstract Volterra operators (casual or nonanticipative), Volterra’s influence on nonlinear analysis, and miscellaneous related topics in theory and applications.

**Support:** Partial support will be provided for invited speakers from foreign countries. If outside financing will be available, support may be provided to foreign participants and young scientists from the USA.

**Call for Papers:** Interested persons should announce their intention to participate and present papers, by October 31, 1995. The second announcement will be sent out in November. Inquiries should be addressed to:

**Information:** Dept. of Math., Box 19408, Arlington, Texas 76019-0408; tel: 817-273-3261; fax: 817-794-5802; e-mail: cordum@utarlg.uta.edu.

15-May 3 School on Nonlinear Functional Analysis and Applications to Differential Equations, International Center for Theoretical Physics, Trieste, Italy. (July 1995, p. 794)

19-21 Southeastern Section, Baton Rouge, LA.

**Information:** C. Harkness, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: charkness@math.ams.org.


May 1996

**8-10 IMA Tutorial on Monte Carlo Methods.** Univ. of Minnesota, Minneapolis, MN.

**Contact:** Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St. SE, Minneapolis, MN 55455.

9-11 International Conference on Nonlinear Problems in Aviation and Aerospace, Dayton Beach, FL. (Jun. 1995, p. 79)

13-16 IMA Workshop on Numerical Methods for Polymeric Systems, Univ. of Minnesota, Minneapolis, MN.

**Contact:** Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St. SE, Minneapolis, MN 55455.

20-24 The 6th Asian Logic Conference, Beijing, P. R. China.

**Sponsor:** Institute of Software, Academia Sinica.

**Information:** The 6th Asian Logic Conference, Institute of Software, Academia Sinica, P. O. Box 8718, Beijing 100080, China; fax: (86)12562533; tel: (86)12559286; e-mail: quang@ox1.ios.ac.cn.

23-25 Volterra Centennial Symposium. The University of Texas at Arlington. Theme: The meeting is organized to celebrate the 100th anniversary of Volterra’s publications on integral equations. Participants from the United States and abroad are expected.

**Topics:** Integral and related equations (e.g., integro-differential, integro-functional), modeling by means of integral questions, theory of abstract Volterra operators (casual or nonanticipative), Volterra’s influence on nonlinear analysis, and miscellaneous related topics in theory and applications.

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13-16 IMA Workshop on Numerical Methods for Polymeric Systems, Univ. of Minnesota, Minneapolis, MN.

**Contact:** Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St. SE, Minneapolis, MN 55455.

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**Information:** The 6th Asian Logic Conference, Institute of Software, Academia Sinica, P. O. Box 8718, Beijing 100080, China; fax: (86)12562533; tel: (86)12559286; e-mail: quang@ox1.ios.ac.cn.

23-25 Volterra Centennial Symposium. The University of Texas at Arlington. Theme: The meeting is organized to celebrate the 100th anniversary of Volterra’s publications on integral equations. Participants from the United States and abroad are expected.

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**Information:** Dept. of Math., Box 19408, Arlington, Texas 76019-0408; tel: 817-273-3261; fax: 817-794-5802; e-mail: cordum@utarlg.uta.edu.

29-June 1 International Conference on Dynamical Systems and Differential Equations, Southwest Missouri State University, Springfield, MO. (Jun. 1995, p. 704)

**June 1996**

**3-6 IMA Tutorial on Topology and Statistical Mechanics of Polymers, Univ. of Minnesota, Minneapolis, MN.**

**Contact:** Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St. SE, Minneapolis, MN 55455.


**July 1996**

8-10 Heat Transfer 96 (Fourth International Conference on Advanced Computational Methods in Heat Transfer), Udine, Italy. (Jun. 1995, p. 704)

8-12 Prague Mathematical Conference 1996, Prague, Czech Republic. (Apr. 1995, p. 482)

10-17 The Second World Congress of
Nonlinear Analysis, Athens, Greece, or Istanbul or Ankara, Turkey. (Feb. 1995, p. 281)

14-19 The Seventh International Conference on Fibonacci Numbers and Their Applications, Technische Universität Graz, Austria. (Apr. 1995, p. 482)

14-21 ICM-8: 8th International Congress on Mathematical Education, Sevilla, Spain. (May 1995, p. 482)

*15-26 IMA Summer Program on Emerging Applications of Number Theory, Univ. of Minnesota, Minneapolis, MN. (Aug. 1995, p. 482)

Contact: Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St. SE, Minneapolis, MN 55455.

19-21 Analytic and Elementary Number Theory, University of Vienna and University of Natural Resources, Vienna, Austria. (Aug. 1995, p. 482)


August 1996

12-30 School on Algebraic Groups & Arithmetic Groups, International Centre for Theoretical Physics. (July 1995, p. 795)

13-17 Fifth International Colloquium on Numerical Analysis, Plovdiv, Bulgaria. (Apr. 1995, p. 482)

14-17 International Linear Algebra Society Meeting, Chemnitz, Germany. (Jul./Aug. 1994, p. 679)

18-23 Seventh International Colloquium on Differential Equations, Plovdiv, Bulgaria. (Apr. 1995, p. 482)

*18-24 8th Prague Topological Symposium on General Topology and its Relations to Modern Analysis and Algebra, Prague, Czech Republic. Theme: In addition to traditional topics reflected by the title of the conference, lectures on the interplay between general topology and computer science will be included.

Format: More than 200 participants, about 40 invited lectures and 120 contributed talks are anticipated.

Organizers: B. Balcar, M. Husek, J. Pelant, P. Simon, V. Trnkova (Mathematical Institute of the Czech Academy of Science, the Faculty of Mathematics and Physics of Charles Univ.).

Information: E-mail (strongly preferred): toposym@karlin.mff.cuni.cz; or the address Toposym, Math. Inst. of Acad. Sci. Zitna 25, 11667 Prague, Czech Republic. Updated information may be obtained through the World-Wide Web at URL: http://www.karlin.mff.cuni.cz/akce/toposym/toposym.html.

September 1996


November 1996

1-3 Central Section, University of Missouri at Columbia, Columbia, MO. Information: C. Harkness, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: chi@math.ams.org.

January 1997

10-13 Joint Mathematics Meetings, San Diego, CA (including the annual meetings of the AMS, AWM, MAA, and NAM). Information: H. Daly, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: meet@math.ams.org.

January 1998

10-13 Joint Mathematics Meetings, Baltimore, MD (including the annual meetings of the AMS, AWM, MAA, and NAM). Information: H. Daly, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: meet@math.ams.org.
New Publications Offered by the AMS

American Mathematical Society Translations—Series 2

Third Siberian School: Algebra and Analysis
L. A. Bokut', M. Hazewinkel, and Yu. G. Reshetnyak, Editors
Volume 163

This book contains papers presented at the Third Siberian School: Algebra and Analysis, held in Irkutsk in the summer of 1989. Drawing 130 participants from all over the former Soviet Union, the school sought to acquaint Siberian and other mathematicians with the latest achievements in a wide variety of mathematical areas and to give young researchers an opportunity to present their work. The papers presented here range over topics in algebra, analysis, geometry, and topology.

Contents

March 1995, 188 pages (hardcover), ISBN 0-8218-0286-0, LC 94-40144, ISSN 0065-9290

Lie Groups and Lie Algebras: E. B. Dynkin's Seminar
S. G. Gindikin and E. B. Vinberg, Editors
Volume 169

In celebration of E. B. Dynkin's 70th birthday, this book presents current papers by those who participated in Dynkin's seminar on Lie groups and Lie algebras in the late 1950s and early 1960s. Dynkin had a major influence not only on mathematics, but also on the students who attended his seminar—many of whom are today's leading mathematicians in Russia and in the U.S.

Dynkin's contributions to the theory of Lie groups is well known, and the survey paper by Karpelevich, Onishchik, and Vinberg allows readers to gain a deeper understanding of this work.

Features:
- Several aspects of modern developments in Lie groups and Lie algebras, including:
  - theory of invariants
  - superalgebras
  - arithmetic applications
  - connections with mathematical physics

Providing insight on the extraordinary mathematical traditions that grew out of this important seminar, Lie Groups and Lie Algebras is a fitting celebration of Dynkin's achievements.

Contents
Topics in Topology and Mathematical Physics
S. P. Novikov, Editor
Volume 170

The papers in this collection grew out of talks recently presented at S. P. Novikov's seminar on topology and mathematical physics in Moscow. They are devoted to various problems in the theory of completely integrable systems and relations to topology, algebra, and mathematical physics.

Contents

September 1995, 206 pages (hardcover), ISBN 0-8218-0455-3, LC 91-640741, ISSN 0065-9290
1991 Mathematics Subject Classification: 35Q40, 57Rxx, 58E05, 58F05, 58F07, 16W30
Individual member $53, List $89
To order, please specify TRANS2/170N

Conference Proceedings, Canadian Mathematical Society

Number Theory
Karl Dilcher, Editor
Volume 15

This book contains proceedings presented at the fourth Canadian Number Theory Association (CNTA) conference held at Dalhousie University in July 1994. The invited speakers focused on analytic, algebraic, and computational number theory. The contributed talks represented a wide variety of areas in number theory.

Paula Ribenboim gave an hour-long talk on Fermat's last theorem—which was wide open at the time of the conference. His lecture was entitled...

- "Fermat's Last Theorem, Before June 23, 1993."

This lecture was open to the public and attracted a large audience from outside the conference.

This book contains 34 written versions of the presentations. All papers were refereed.

Contents
A. Arenas, On the number of genera of positive-definite integral ternary quadratic forms; E. Bach, Improved approximations for Euler products; G. Bachman, On exponential sums with multiplicative coefficients; V. V. Batyrev and Yu. Tschinkel, Rational points on toric varieties; M. A. Bean, The number of solutions of the True inequality; M. A. Bennett, Simultaneous approximation to pairs of algebraic numbers; B. C. Berndt and P. Bialek, Five formulas of Ramanujan arising from Eisenstein series; A. Bremner, On sums of three cubes; L. Candelori, Construction of polynomials with some Frobenius groups as Galois groups; H. Cohen, Minimality bounds for traces of Markoff matrices; R. Cook, Factors of odd perfect numbers; T. Dokshitzer, On Wilf's conjecture and generalizations; A. G. Earnest, An application of character sum inequalities to quadratic forms; D. Goldfeld, Special values of derivatives of L-functions; Y. Goto, On the orders of the Brauer groups of some weighted diagonal surfaces; P. J. Grabner, P. Kiss, and R. F. Tichy, Diophantine approximation in terms of linear recurrent sequences; A. Granville, On the number of solutions to the generalized Fermat equation; H. S. Gunaratne, Periodicity of Kummer congruences; S. Gurak, On higher-order pseudoprimes of Lehmer type; O. Lecacheux, Unités de corps de nombres et courbes de genre un et deux; R. A. Mollin and L. C. Zhang, A new criterion for the determination of class numbers of real quadratic fields; V. K. Murty, Bounded and finite generation of arithmetic groups; M. R. Murty, The analytic rank of J_0(N)(Q); P. Ribenboim, Fermat's last theorem, before June 23, 1993; F. R. Villegas and D. Zagier, Which primes are sums of two cubes?; M. Rosen, Average value of class numbers in cyclic extensions of the rational function field; R. Rumely, An intersection pairing for curves, with analytic contributions from nonarchimedean places; Ph. Satgé, Questions arithmétiques liées au théorème de Poncelet; C. L. Stewart, Thue equations and elliptic curves; L. H. Walling, Explicit Siegel theory for quadratic forms; L. C. Washington, Siegel zeros for 2-adic L-functions; J. Watrous, A polynomial-time algorithm for the Artin-Whaples approximation theorem; K. S. Williams, Some refinements of an algorithm of Brillhart; C. J.
Williamson, On the algebraic construction of tri-diagonal matrices with given characteristic polynomial.

August 1995, 431 pages (softcover).
ISBN 0-8218-0312-3, LC 95-30722, ISSN 0731-1036
1991 Mathematics Subject Classification: 11-06
Individual member $53, List $89
To order, please specify CMSAMS/15N

Colloquium Publications

Fully Nonlinear Elliptic Equations
Luis A. Caffarelli and Xavier Cabré
Volume 43

This book provides a self-contained development of the regularity theory for solutions of fully nonlinear elliptic equations. Caffarelli and Cabré offer a detailed presentation of all techniques needed to extend the classical Schauder and Calderón-Zygmund regularity theories for linear elliptic equations to the fully nonlinear context.

The authors present the key ideas and prove all the results needed for the regularity theory of viscosity solutions of fully nonlinear equations. The book contains the study of convex fully nonlinear equations and fully nonlinear equations with variable coefficients.

This book is suitable as a text for graduate courses in nonlinear elliptic partial differential equations.

Contents
Introduction; Preliminaries; Viscosity solutions of elliptic equations; Alexandrov estimate and maximum principle; Harnack inequality; Uniqueness of solutions; Concave equations; $W^{2,p}$ regularity; Hölder regularity; The Dirichlet problem for concave equations; Bibliography; Index.

August 1995, 104 pages (hardcover), ISBN 0-8218-0437-5, LC 95-15024, ISSN 0065-9258
1991 Mathematics Subject Classification: 35J60; 35B45, 35B65
Individual member $23, List $39
To order, please specify COLL/43N

Contemporary Mathematics

Harmonic Analysis and Operator Theory
Volume 189

This book is a collection of papers reflecting the conference held in Caracas, Venezuela, in January 1994 in celebration of Professor Mischa Cotlar's eightieth birthday. Presenting an excellent account of recent advances in harmonic analysis and operator theory and their applications, many of the contributors are world leaders in their fields. The collection covers a broad spectrum of topics, including:

- wavelet analysis
- Haar scale operators
- multifractal measure
- the boundary behavior of the Bergman kernel
- interpolation theory
- Cotlar's Lemma on almost orthogonality in the context of $L^p$ spaces and more...

The range of topics in this volume promotes cross-pollination among the various fields covered. Such variety makes "Harmonic Analysis and Operator Theory" an inspiration for graduate students interested in this area of study.

Contents
Mathematical Analysis, Wavelets, and Signal Processing

Mourad E. H. Ismail, M. Zuhair Nashed, Ahmed I. Zayed, and Ahmed F. Ghaleb, Editors

This book contains the proceedings of an international conference held in Cairo, Egypt (January 1994). This glorious ancient city was the gathering place for mathematicians and engineers to exchange ideas and to discuss new research trends.

Mathematics and engineering discoveries, such as wavelets, multiresolution analysis, and subband coding schemes, caused rapid advancements in signal processing, necessitating an interdisciplinary approach.

Contributors to this conference demonstrated that some traditional areas of mathematical analysis—sampling theory, approximation theory, and orthogonal polynomials—have proven extremely useful in solving various signal processing problems.

Contents

P. L. Butzer, Mathematics in Egypt and Its Connections with the Court School of Charlemagne

With several articles discussing the most recent advances and new trends in mathematical analysis and signal processing, this book emphasizes interactions between mathematics and electrical engineering.

Memoirs of the AMS

Coherence for Tricategories

R. Gordon, A. J. Power, and Ross Street

Volume 117, Number 558

The need to address the appropriate three-dimensional generalization of category (tricategory) has been felt in homotopy theory, low-dimensional topology, cohomology theory, category theory, and quantum field theory. Benabou's bicategories provide the two-dimensional notion into which examples naturally fit. In developing the theory of bicategories it is very reassuring to know the coherence theorem: They can be replaced by the stricter 2-categories which are merely categories enriched in the category of categories.

In this book, the authors provide...

- the unique source of the full definition of tricategory
- a thorough and complete proof of the coherence theorem for tricategories
- a wholly modern source of material on Gray's tensor product of 2-categories

Contents

Introduction: The definition of tricategory; Trihomomorphisms, bi-equivalence, and Tricat(T, S); Cubical functors and tricategories, and the monoidal category Gray; Gray-categories, and Bicat as a tricategory; The Gray-category Prep(T) of prerepresentations of T; The "Yoneda Embedding"; The Main Theorem; Acknowledgements; References.


Individual member $19, List $31

To order, please specify MEMO/117/558N
Hilbert Modules over Operator Algebras
Paul S. Muhly and Baruch Solel
Volume 117, Number 559

This book gives a general systematic analysis of the notions of "projectivity" and "injectivity" in the context of Hilbert modules over operator algebras. A Hilbert module over an operator algebra A is simply the Hilbert space of a (contractive) representation of A viewed as a module over A in the usual way.

In this work, Muhly and Solel introduce various notions of projective Hilbert modules and use them to investigate dilation and commutant lifting problems over certain infinite dimensional analogues of incidence algebras.

The authors prove that commutant lifting holds for such an algebra if and only if the pattern indexing the algebra is a "tree" in the sense of computer directories.

Contents
Introduction; Definitions; Basic theory; Incidence algebras and generalizations; Trees and trees; References.

The Index Theorem for Minimal Surfaces of Higher Genus
F. Tomi and A. J. Tromba
Volume 117, Number 560

The question of estimating the number of minimal surfaces that bound a prescribed contour has been open since Douglas's solution of the Plateau problem in 1931. In this book, the authors formulate and prove an index theorem for minimal surfaces of higher topological type spanning one boundary contour. The Index Theorem for Minimal Surfaces of Higher Genus describes, in terms of Fredholm Index, a rough measure on the set of curves bounding minimal surfaces of prescribed branching type and genus.

Contents
Introduction; The differential geometric approach to Teichmüller theory; Minimal surfaces of higher genus as critical points of Dirichlet's functional; Review of some basic results in Riemann surface theory; Vector bundles over Teichmüller space; Minimal surfaces of higher genus as the zeros of a vector field and the conformality operators; The corank of the partial conformality operators; The corank of the complete conformality operators; Manifolds of harmonic surfaces of prescribed branching type; The index theorem; Appendix I. A supplement to the boundary regularity theorems for minimal surfaces; Appendix II. Maximal ideals in Sobolev algebras of holomorphic functions; References.

Triangular Algebras and Ideals of Nest Algebras
John Lindsay Orr
Volume 117, Number 562

Triangular algebras and nest algebras are two important classes of non-selfadjoint operator algebras. In this book, the author uses the new depth of understanding which the similarity theory for nests has opened up to study ideals of nest algebras.

In particular, a unique largest diagonal-disjoint ideal is identified for each nest algebra. Using a construction proposed by Kadison and Singer, this ideal can be used to construct new maximal triangular algebras. These new algebras are the first concrete descriptions of maximal triangular algebras that are not nest algebras.
Contents
Introduction; The diagonal seminorm function; The interpolation theorem; Maximal off-diagonal ideals; Maximal triangular algebras; Compressible maximal triangular algebras; References.

September 1995, 49 pages (softcover), ISBN 0-8218-0405-7, LC 95-382, ISSN 0065-9266
1991 Mathematics Subject Classification: 47C05; 47D25
Individual member $17, List $28
To order, please specify MEMO/117 /562N

Proceedings of Symposia in Applied Mathematics

Different Aspects of Coding Theory
Robert Calderbank, Editor
Volume 50

This book connects coding theory with actual applications in consumer electronics and with other areas of mathematics. Different Aspects of Coding Theory covers in detail the mathematical foundations of digital data storage and makes connections to symbolic dynamics, linear systems, and finite automata. It also explores the use of algebraic geometry within coding theory and examines links with finite geometry, statistics, and theoretical computer science.

Features:
- A unique combination of mathematical theory and engineering practice.
- Much diversity and variety among chapters, thus offering broad appeal.
- Topics relevant to mathematicians, statisticians, engineers, and computer scientists.
- Contributions by recognized scholars.

Contents
A. R. Calderbank, Coding theory as discrete applied mathematics; B. Marcus, R. M. Roth, and P. H. Siegel, Modulation codes for digital data storage; B. Marcus, Symbolic dynamics and connections to coding theory, automata theory, and system theory; D. Forney, B. Marcus, N. T. Sindhushayana, and M. Trott, Multilingual dictionary; H. Stichtenoth, Algebraic geometric codes; W. M. Kantor, Codes, quadratic forms and finite geometries; R. H. Hardin and N. J. A. Sloane, Codes (spherical) and designs (experimental); J. Feigenbaum, The use of coding theory in computational complexity; Index.

1991 Mathematics Subject Classification: 94A05, 93B15, 68Q68, 62K05, 68Q25; 94B12, 58F03, 94A14, 94A40, 94B27, 51A40, 05B25, 51A35, 68Q15, 68P25, 94A60
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Proceedings of the Steklov Institute of Mathematics

Limit Theorems for Functionals of Random Walks
A. N. Borodin and I. A. Ibragimov
Volume 195

Although the problems are traditional, the methods presented here are new. One of the methods involves expressing the functionals in terms of a suitable integral transform (such as the Fourier transform), and another method is based on results on convergence of processes generated by random walks to Brownian local time. These methods can be used to prove the convergence of functionals of random walks under very general assumptions about the functional and for a very broad class of random walks. The book is intended for experts in probability theory and its applications, as well as for undergraduate and graduate students specializing in these areas.

Contents
Preliminary facts; Distributions of functionals of Brownian local time; Limit theorems for functionals of normalized sums; Limit theorems for additive and multiadditive functionals of a random walk; Invariance principle for local times; Bibliographical comments; Bibliography.

September 1995, 259 pages (softcover), ISBN 0-8218-0438-3, ISSN 0081-5438
1991 Mathematics Subject Classification: 60-02, 60J15, 60J55, 60F17, 60J65; 60G50, 60E07, 60E10
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Translations of Mathematical Monographs

Modular Forms and Hecke Operators
A. N. Andrianov and V. G. Zhuravlev
Volume 145

The concept of Hecke operators was so simple and natural that, soon after Hecke's work, scholars made the attempt to develop a Hecke theory for modular forms, such as Siegel modular forms.

As this theory developed, the Hecke operators on spaces of modular forms in several variables were found to have arithmetic meaning. Specifically, the theory provided a framework for discovering certain multiplicative properties of the number of integer representations of quadratic forms by quadratic forms.

(continued)
New Publications Offered by the AMS

Now that the theory has matured, the time is right for this detailed and systematic exposition of its fundamental methods and results.

Features:
- The book starts with the basics and ends with the latest results, explaining the current status of the theory of Hecke operators on spaces of holomorphic modular forms of integer and half-integer weight congruence-subgroups of integral symplectic groups.
- Hecke operators are considered principally as an instrument for studying the multiplicative properties of the Fourier coefficients of modular forms.

It is the authors' intent that Modular Forms and Hecke Operators help attract young researchers to this beautiful and mysterious realm of number theory.

Contents
Introduction; Theta-series; Modular forms; Hecke rings; Hecke operators; Symmetric matrices over a field; Quadratic spaces; Modules in quadratic fields and binary quadratic forms; Notes; References; List of notation.

August 1995, 334 pages (hardcover), ISBN 0-8218-0277-1, LC 95-30915, ISSN 0065-9282
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AMS Publications Not in Series

Assistantships and Graduate Fellowships in the Mathematical Sciences, 1995–1996

This publication is an indispensable source of information for students seeking support for graduate study in the mathematical sciences. Providing data from a broad range of academic institutions, it is also a valuable resource for mathematical sciences departments and faculty.

Assistantships and Graduate Fellowships brings together a wealth of information about resources available for graduate study in mathematical sciences departments in the U.S. and Canada. Information on the number of faculty, graduate students, and degrees awarded (bachelor's, master's, and doctoral) is listed for each department when provided. Stipend amounts and the number of awards available are given, as well as information about foreign language requirements. Numerous display advertisements from mathematical sciences departments throughout the country provide additional information.

Also listed are sources of support for graduate study and travel, summer internships, and graduate study in the U.S. for foreign nationals. Finally, a list of reference publications for fellowship information makes Assistantships and Graduate Fellowships a centralized and comprehensive resource.

September 1995, approximately 125 pages (softcover), ISBN 0-8218-0188-0, ISSN 1040-7650
1991 Mathematics Subject Classification: 00
Individual member $11, List $19
To order, please specify ASST/95N

Panoramas et Synthèses

Billiards
Serge Tabachnikov
Number 1

Presented as a survey of the theory of billiards, this book reflects the present state of this active research area. In the book, Tabachnikov looks at billiards from a geometric viewpoint. He covers smooth convex billiards, billiards in polygons, and chaotic dispersing billiards. He also touches upon dual (outer) billiards. Intended for non-experts, Billiards provides a general mathematical background from which to approach this stimulating topic.

Titles in this series are published by the Société Mathématique de France and distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents
Introduction; General theory and mathematical background; Convex billiards; Billiards in polygons; Dual billiards; Hyperbolic billiards; Bibliography; Index.
1991 Mathematics Subject Classification: 58F, 70H
Individual AMS member $41, List $45
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Following are some of our more popular books and videotapes as well as some with similar topics to those appearing in the New Publications section of this issue.

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<td>Algebraic Curves and Riemann Surfaces</td>
<td>Rick Miranda</td>
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<td>390</td>
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<td>Daniel S. Freed, Karen K. Uhlenbeck</td>
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<td>459</td>
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<td>$44*</td>
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<td>D. Frank Hsu, Arnold L. Rosenberg, Dominique Sotteau</td>
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<td>K-theory and Algebraic Geometry: Connections with Quadratic Forms and Division Algebras, Part 2</td>
<td>Bill Jacob, Alex Rosenberg</td>
<td>1995</td>
<td>0-8218-0340-9</td>
<td>444</td>
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<td>Hal L. Smith</td>
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<td>Ingemar J. Cox, Pierre Hansen, Bela Julesz</td>
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<td>0-8218-6606-0</td>
<td>408</td>
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<td>Real Algebraic Geometry and Topology</td>
<td>Selman Akbulut</td>
<td>1995</td>
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<td>158</td>
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<td>Statistics and Control of Random Processes</td>
<td>A. A. Novikov, A. N. Shiryaev</td>
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<td>242</td>
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<td>Michael C. Cranston, Mark A. Pinsky</td>
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<td>0-8218-0289-5</td>
<td>621</td>
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Chapel Hill, Chapel Hill, NC 27599-3250. E0/AA Employer. Women and minorities are encouraged to identify themselves voluntarily. Completed applications received by November 1, 1995, are assured of full consideration.

We also request that you send us a completed AMS Application Cover Sheet (fall issue of the AMS Notices).

TEXAS

TEXAS A & M UNIVERSITY

Postdoctoral position—Algebraic Geometry or Related Field

The NSF has awarded a Math Sciences University–Industry Postdoctoral Research Fellowship to Texas A & M University with support from the David Sarnoff Research Center in Princeton, New Jersey. We are seeking applicants for this fellowship who are broadly trained in algebraic geometry, computational algebraic geometry, or geometric computation. The fellow will conduct research in these areas on problems motivated by questions in image recognition, image database indexing, and computer vision. It is expected that the fellow will spend a year at Texas A&M and a year at the David Sarnoff Research Center. Applicants must meet the eligibility requirements set out in the NSF program guidelines and will be expected to provide a biographical sketch, a list of publications, a thesis abstract, and three letters of recommendation, and a statement of their professional goals with an explanation of how this position fulfills those aims. Applications and inquiries should be directed to Dr. Peter F. Stiller, Professor of Mathematics and Computer Science, Department of Mathematics, Texas A & M University, College Station, Texas 77843-3368, e-mail: stiller@math.tamu.edu. Detailed information is available at http://www.math.tamu.edu/~peter.stiller. Members of historically underrepresented groups are encouraged to apply. Texas A & M is an Equal Opportunity/Affirmative Action Employer.

CANADA

UNIVERSITY OF WATERLOO

Department of Applied Mathematics

Tenure-Track Position

Applications are invited for a tenure-track faculty position in the Department of Applied Mathematics, University of Waterloo, Ontario, Canada, in the area of geophysical fluid dynamics, to begin in 1996, possibly as early as 1 January 1996. Applicants should have an established research record and a proven capability of attracting research funding. We are interested in people with expertise in the mathematical aspects of the area, especially in nonlinear wave dynamics. Candidates will also be expected to supervise graduate students at both the Master's and doctoral levels and to have a strong commitment to teaching, including the ability to teach both graduate and undergraduate courses in fluid mechanics and related disciplines of applied mathematics including partial differential equations. Salary and rank, at the assistant or associate professor level, will be commensurate with qualifications and experience. A letter of application, a curriculum vitae with a statement of research interests, and copies of two or three research papers considered to be most significant by the applicant should be sent to E. R. Vrscay, Acting Chairman, Department of Applied Mathematics, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1; fax: 519-746-4319; e-mail: amdept@jeeves.uwaterloo.ca. Applicants should also arrange for three letters of reference to be sent to the above address. The closing date for receipt of complete applications is 31 October 1995.

The Department of Applied Mathematics is one of five departments in the Faculty of Mathematics at the University of Waterloo. The department members have interests in a wide variety of areas, including control theory, dynamical systems, electroacoustics, fluid mechanics, ordinary and partial differential equations, quantum theory, relativity theory, and scientific computation. There are also close collaborations with the Faculties of Engineering and Science at the University.

In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents of Canada. The University of New Brunswick is committed to the principle of employment equity.

Applicants should provide their CVs and descriptions of their research and teaching interests, and three letters of reference. Application materials should be directed to:

Dr. Jon Thompson, Chair
Department of Mathematics & Statistics
University of New Brunswick
P.O. Box 4400
Fredericton, N.B.
E3B 5A3
e-mail: dept@math.ubn.ca; fax: 506-453-4705.
The deadline for receipt of applications is November 30, 1995.

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Wanted: Mathematical books, journals, reprints, ephemera. Contact R. K. Dennis, P.O. Box 8604, Ann Arbor, MI 48107; tel: 313-993-1993; fax: 313-996-2916; e-mail: dennis@math.cornell.edu.

Mathematics Books Purchased. Pure & appl., adv. & research level, any age, usable cond. Reprints OK. One box to whole libraries sought. Contact Collier Brown or Kirsten Berg at Powell’s Technical Bks., Portland, OR. Call 503-225-2911, fax 503-228-0505, or e-mail to krb@technical.powells.portland.or.us.

NOTICES OF THE AMS VOLUME 42, NUMBER 9
Opportunity/Affirmative Action Employer. Women and minorities are particularly encouraged to apply.

NORTHWESTERN UNIVERSITY
Department of Mathematics
2033 Sheridan Road
Evanston, Illinois 60208-2730

Applications are invited for an anticipated tenure-track assistant professor position starting September 1996. Priority will be given to exceptional research mathematicians. Fields of interest within the department include algebra, analysis, dynamical systems, probability, partial differential equations, and topology. Northwestern is an Affirmative Action, Equal Opportunity Employer committed to fostering a diverse faculty; women and minority candidates are especially encouraged to apply. Candidates should arrange to have the application material sent to Chairperson, Personnel Committee, Department of Mathematics, Northwestern University, Evanston, Illinois 60208-2730. Applications should include: (1) the American Mathematical Society's Application Cover Sheet for Academic Employment in Mathematics, (2) a curriculum vitae, and (3) at least three letters of recommendation. Inquiries may be sent via e-mail to hiring@math.nwu.edu. In order to receive full consideration, applications should be received by December 15, 1995.

NORTHWESTERN UNIVERSITY
Department of Mathematics
2033 Sheridan Road
Evanston, Illinois 60208-2730

The Mathematics Department will sponsor an Emphasis Year in algebraic topology. This program will include two two-year assistant professorships starting September 1996 and provide visiting positions for more senior mathematicians for part of the academic year 1996-97, contingent upon availability of funds. Applications should be sent to the Emphasis Year committee chair at the address below. The committee chair will continue to evaluate applications until the positions are filled. Priority will be given to candidates with research interests similar to those in the department.

Applications should be sent to:
Chairperson, Emphasis Year Committee
Department of Mathematics
Northwestern University
Evanston, Illinois 60208

Applications will be reviewed on an ongoing basis until the positions are filled.

ROCHESTER UNIVERSITY
Department of Mathematics
3435 Main Street
Buffalo, New York 14214-3093

The Department of Mathematics invites applications for an Assistant Professor of Mathematics with a Ph.D. in mathematics to begin July 1, 1996. The University is an Affirmative Action, Equal Opportunity Employer. Applications should be sent to:

Chairperson, Search Committee
Department of Mathematics
Rochester University
3435 Main Street
Buffalo, New York 14214-3093

Send a curriculum vitae and at least three letters of recommendation. Applications will be reviewed as received.

STATE UNIVERSITY OF NEW YORK
University at Buffalo
Diefendorf Hall
3435 Main Street
Buffalo, New York 14214-3093

The Mathematics Department invites applications for an Assistant Professor of Mathematics position to begin September 1996. Candidates must have a Ph.D. in mathematics, preferably in algebraic or analytic topology, with a strong commitment to teaching at the undergraduate level. Applications should be sent to:

Professor J. McLaughlin
Chair, Mathematics Search Committee
University at Buffalo
Diefendorf Hall, Box 398
Buffalo, New York 14214-3093

Applications will be reviewed as soon as possible until the position is filled.

NEW JERSEY

RUTGERS UNIVERSITY-NEWARK
Assistant Professor of Mathematics

The Department of Mathematics and Computer Science invites applications for an Assistant Professor of Mathematics position to begin September 1996. Candidates must have a Ph.D. and must be able to perform work at the level of an Assistant Professor. Please send curriculum vitae and at least four letters of reference directly to the Mathematics Search Committee, Department of Mathematics and Computer Science, Rutgers University, Newark, NJ 07102.

RUTGERS UNIVERSITY, CAMDEN

The Department of Mathematical Sciences invites applications for an assistant professor position in mathematics beginning in July 1996. At least two years of experience beyond the Ph.D. is required and candidates must have already established strong teaching and research records. Send a vitae and four letters of recommendation directly to G. Toth, Department of Mathematical Sciences, Rutgers University, Camden, NJ 08102. AA/EOE.

MASSACHUSETTS

WILLIAMS COLLEGE
Department of Mathematics
Williamstown, Massachusetts 01267

Two anticipated tenure-eligible positions in mathematics or applied mathematics, beginning fall 1996, probably at the rank of assistant professor; in exceptional cases, however, more advanced appointments may be considered. Excellence in both teaching and research is essential. For both positions, a Ph.D. in hand or a completed dissertation by September 1996 is required. For one of the positions, experience and strong interest in teaching pre-calculus/quantitative skills is a plus.

Please have a vita and three letters of recommendation on teaching and research sent to Hiring Committee, Mathematics Department, Williams College, Williamstown, MA 01267. Evaluation of applications will begin November 15 and continue until the position is filled. As an EEO/AA Employer, Williams especially welcomes applications from women and minority candidates.

NEW YORK

STATE UNIVERSITY OF NEW YORK
AT BUFFALO

The Department of Mathematics anticipates the appointment of tenured or tenure-track faculty members beginning September 1, 1996. Salary will be competitive. We seek applicants in all areas with excellent research accomplishments/potential and a strong commitment to teaching.

Applications should send supporting information, including a c.v. with a list of research interests, and four letters of recommendation to:

Search Committee Chairman
Department of Mathematics
SUNY/Buffalo
106 Diefendorf Hall
3435 Main Street
Buffalo, New York 14214-3093

No electronic applications will be accepted.

The deadline for applications is November 1, 1995. Late applications will be considered until positions are filled.

RUTGERS UNIVERSITY-NEWARK

Assistant Professor of Mathematics

The Department of Mathematics and Computer Science invites applications for an anticipated tenure-track assistant professor position to begin September 1996. Candidates must have a Ph.D., a strong research record, show outstanding promise for future work in mathematics, and demonstrate a commitment to effective teaching. Preference will be given to candidates with research interests similar to those in the department.

Applications should arrange for a curriculum vitae and at least four letters of recommendation, one of which addresses teaching, to be sent to:

Personnel Committee
Department of Mathematics and Computer Science
Rutgers University
Newark, NJ 07102

Responses may also be e-mailed to math@andromeda.rutgers.edu. Processing of applications will begin in December 1995.

Rutgers University is an Equal Opportunity/Affirmative Action Employer.

NORTH CAROLINA

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Department of Mathematics

Applications are invited for one faculty appointment in applied mathematics effective fall 1996. Candidates with research in computational partial differential equations and related areas are especially encouraged to apply. Rank and salary depend on qualifications and budget considerations. Ph.D. in mathematics and exceptionally strong research record and commitment to excellent teaching required. At least three years' experience beyond the Ph.D. preferred. Send curriculum vitae, abstract of current research program, and four letters of recommendation to Search Committee, Mathematics, CB #3250 Phillips Hall, UNC at Chapel Hill, NC 27599-3250. AA/EOE.

Rutgers University, an Equal Opportunity Affirmative Action Employer, welcomes applications from women and members of minority groups.

Classified Advertisements

September 1995 Notices of the AMS 1081
Texas

Texas A & M University
Postdoctoral Position—Algebraic Geometry or Related Field

The NSF has awarded a Math Sciences University—Industry Postdoctoral Research Fellowship to Texas A & M University with support from the David Sarnoff Research Center in Princeton, New Jersey. We are seeking applicants for this fellowship who are broadly trained in algebraic geometry, computational algebraic geometry, or geometric computation. The fellow will conduct research in these areas on problems motivated by questions in image recognition, image database indexing, and computer vision. It is expected that the fellow will spend a year at Texas A & M and a year at the David Sarnoff Research Center. Applicants must meet the eligibility requirements set out in the NSF program guidelines and will be expected to provide a biographical sketch, a list of publications, a thesis abstract, three letters of recommendation, and a statement of their professional goals with an explanation of how this position fulfills those aims. Applications and inquiries should be directed to Dr. Peter F. Stiller, Professor of Mathematics and Computer Science, Department of Mathematics, Texas A & M University, College Station, Texas 77843-3368, e-mail: stiller@math.tamu.edu. Detailed information is available at http://www.math.tamu.edu/~peter.stiller. Members of historically underrepresented groups are encouraged to apply. Texas A & M is an Equal Opportunity/Affirmative Action Employer.

Canada

University of Waterloo
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Tenure-Track Position

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Department of Mathematics & Statistics
University of New Brunswick
P.O. Box 4400
Fredericton, N.B.
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e-mail: dept@math.unb.ca; fax: 506-453-4705.

The deadline for receipt of applications is November 30, 1995.

Situations Wanted

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Publications Wanted

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J.T. Wloka, B. Rowley, and B. Lawruk
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Dear Fellow Mathematician,

Sometime in the spring of 1990, when it was already warm enough to lunch outside in Harvard Square, I met with David Mumford and suggested to him my idea for a journal of experimental mathematics. After thinking it over jointly for some time, we approached David Epstein, who we thought would make the ideal Chief Editor. The rest is history: Epstein’s standing in the community has made it possible to gain generous support from a distinguished editorial and advisory board, and Silvio Levy’s devotion and expertise as a mathematician and editor have helped establish the journal’s reputation for lucid exposition and its standards of excellence (see the article by Epstein and Levy in the June ’95 Notices). We at A K Peters are proud to be part of this venture, and we appreciate the contribution of so many outstanding authors who have already appeared in Experimental Mathematics. We also thank the many individual subscribers who support the journal. To make the journal widely accessible, we offer a special price to AMS members. And even the regular institutional subscription price is so low that librarians sometimes think they are paying for a single issue instead of a full year’s subscription! Our goal is to bring the journal into every scientific library: we hope you’ll make the small but repeated effort needed to place Experimental Mathematics in the library you use.

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Asymptotic Methods for Elastic Structures
Proceedings of the International Conference, held in Lisbon, Portugal, October 4-8, 1993
Editors: P.G. Ciarlet / L.L. Trabuco / J.M. Viaño
Cloth $128.95 ISBN 3-11-014731-9
The subject of these proceedings is the asymptotic analysis of lower dimensional models used in elastic structures which are characterized from the geometric point of view by a small parameter, such as the thickness in plates and shells or the cross sectional area in rods. The 21 contributions to this volume give an overall picture of the current developments in the field, and their relationship with other areas of applied mathematics, such as numerical analysis, controllability, homogenization and optimization theories.

Symposia Gaussiana
Conference A: Mathematics and Theoretical Physics
Proceedings of the 2nd Gauss Symposium, Munich, Germany, August 2-7, 1993
Editors: M. Behara / R. Fritsch / R.G. Lintz
1995. xx + 745 pages. With 76 figures.
Cloth $198.95 ISBN 3-11-014476-X
Contains 54 refereed papers presented on the occasion of the Second Gauss Symposium. Contributions are arranged by topics belonging to the following sections of the conference: mathematical education, history of mathematics, analysis of several complex variables, algebraic topology, quantum groups and q-deformation, computational physics, relativistic celestial mechanics: astrophysics and cosmology, Gauß and geomagnetism, general.

Symposia Gaussiana
Conference B: Statistical Sciences
Proceedings of the 2nd Gauss Symposium, Munich, Germany, August 2-7, 1993
Editors: V. Mammitzsch / H. Schneeweß
Cloth $148.95 ISBN 3-11-014412-3
Contains 24 refereed papers presented at Conference B of the Second Gauss Symposium. Contributions are arranged by topics belonging to the following sections of the conference: probability theory, probabilistic expert systems, statistical decision theory, simulation and resampling, linear models and design of experiments, general methods and applications.

Groups–Korea '94
Proceedings of the International Conference, held at Pusan National University, Pusan, Korea, August 18-25, 1994
Editors: A.C. Kim / D.L. Johnson
Cloth $99.95 ISBN 3-11-014737-0
Contains 34 contributions from leading experts in group theory and related areas. Particular emphasis is on geometric methods, triangle groups, Kleinian groups, Nielsen and Whitehead methods.

Dirichlet Forms and Stochastic Processes
Proceedings of the International Conference, held in Beijing, China, October 25-31, 1993
Editors: Z.M. Ma / M. Röckner / J.A. Yan
1995. xii + 444 pages.
Cloth $148.95 ISBN 3-11-014284-8
Contains 38 selected papers by participants at the international conference on Dirichlet Forms and Stochastic Processes and the School on Dirichlet Forms, both held in Beijing, China in October 1993. Gives an overview of the current stage of the theory of Dirichlet forms and applications to related areas of mathematics, mathematical physics and also biology.

Geometric Group Theory
Proceedings of a Special Research Quarter at the Ohio State University, Spring 1992
Editors: R. Charney / M. Davis / M. Shapiro
1995. x + 186 pages. With 34 figures.
Cloth $64.95 ISBN 3-11-014743-2
Contains 12 contributions from experts in geometric group theory. Recent developments in the area are reflected in the present volume, which includes papers on automatic groups, hyperbolic groups, complexes of groups, and metric curvature as well as more traditional areas of combinatorial group theory.

IN PREPARATION:

Groups, Difference Sets, and the Monster
Proceedings of a Special Research Quarter at the Ohio State University, Spring 1993
Cloth. ISBN 3-11-014791-2
This volume is addressed to specialists in finite simple groups, finite geometries, and combinatorial design and coding theories. It illuminates relationships between group theory and other fields such as number theory, Lie theory, and quantum physics.
The chief addition to the second revised edition of this graduate-level textbook on global Riemannian geometry is the presentation of a complete proof of a recent outstanding result by Bangert and Franks on the existence of infinitely many closed geodesics for every Riemannian metric on the sphere.

**IN PREPARATION:**

**VOLUME 21**

Alexander Bendikov

**Potential Theory on Infinite-Dimensional Abelian Groups**

1995. vi + 184 pages. 
Cloth ISBN 3-11-014283-X

A study on translation invariant potential theory on infinite-dimensional locally compact groups. This book contains an introductory and comprehensive account of the potential theory of elliptic and parabolic differential operators — an infinite-dimensional extension of classical potential theory and its probabilistic counterpart.

**VOLUME 22**

V. Nazaikinskii / B. Sternin

V. Shatalov

**Methods of Noncommutative Analysis: Theory and Applications**

Cloth ISBN 3-11-014632-0

Based on V.P. Maslov’s noncommutative operational calculus created in the early seventies, this book provides a systematic and modern introduction to the calculus of noncommuting operators. The subject is not only intimately related to traditional fields such as differential and pseudo-differential operators, functional analysis, and theoretical physics, but also to rapidly developing new areas such as asymptotic quantization, representation theory, and the theory of quantum groups.

**VOLUME 23**

H. Bauer

**Probability Theory**

*Translated from the German by R.B. Burckel*

Cloth ISBN 3-11-013935-9

This is the English translation of the author’s very successful German edition which has been a standard textbook in probability theory for a period of nearly 30 years. The translation is based on the German edition published in 1991.

**Prices are subject to change.**
Northwestern University invites nominations for the Frederic Esser Nemmers Prize in Mathematics, to be awarded during the 1995–96 academic year. The award includes payment to the recipient of $100,000. Made possible by a generous gift from the late Erwin Esser Nemmers and the late Frederic Esser Nemmers, the award is given every other year.

The recipient of the 1994 award was Yuri I. Manin (Max Planck Institute).

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

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Nominations for the Frederic Esser Nemmers Prize in Mathematics will be accepted until November 30, 1995. Nominating letters of no more than three pages should describe the nominee’s professional experience, accomplishments, and qualifications for the award. A brief curriculum vitae of the nominee is helpful but not required. Nominations from experts in the field are preferred to institutional nominations; direct applications will not be accepted.

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Department of Mathematics

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Enquiries of an academic nature can be made to the Acting Dean of Information and Mathematical Sciences, Professor Jeffrey Hunter telephone 64-6-350 5082, facsimile 64-6-350 5611.

Reference Number NAMS 63/95 must be quoted.

Closing date: 30 September 1995.

As a condition of application the University reserves the right to make enquiries of any person regarding any candidate's suitability for appointment. It also reserves the right not to make an appointment or to appoint by invitation.

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Shafarevich Maps and Automorphic Forms
János Kollár
The aim of this book is to study various geometric properties and algebraic invariants of smooth projective varieties with infinite fundamental groups. This approach allows for much interplay between methods of algebraic geometry, complex analysis, the theory of harmonic maps, and topology. Making systematic use of Shafarevich maps, this work isolates those varieties where the fundamental group influences global properties of the canonical class. The book is primarily geared toward researchers and graduate students in algebraic geometry who are interested in the structure and classification theory of algebraic varieties.
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Meetings & Conferences of the AMS

The following pages give 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. For some meetings the list may be incomplete.

Meetings:

1995
- October 7-8: Boston, Massachusetts
- November 3-4: Kent, Ohio
- November 11-12: Los Angeles, California
- November 17-18: Greensboro, North Carolina
- November 29-December 2: Guanajuato, Mexico

1996
- January 10-13: Orlando, Florida
- March 22-23: Iowa City, Iowa
- April 13-14: New York, New York
- April 19-21: Baton Rouge, Louisiana
- May 22-24: Antwerp, Belgium
- August 10-12: Seattle, Washington
- October 5-6: Lawrenceville, New Jersey
- October 11-12: Chattanooga, Tennessee
- November 1-3: Columbia, Missouri

1997
- January 8-11: San Diego, California
- March 21-22: Memphis, Tennessee
- April 12-13: College Park, Maryland

1998
- May 2-4: Detroit, Michigan
- October 10-12: Atlanta, Georgia
- October 24-26: Milwaukee, Wisconsin

1999
- January 7-10: Baltimore, Maryland
- March 27-28: Manhattan, Kansas

Conferences:

1996

Important Information Regarding AMS Meetings

Potential organizers and speakers should refer to the January issue of the Notices for guidelines on participation and abstract submission. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Requests for general information concerning abstracts may be sent to abs-misc@math.ams.org. Completed electronic abstracts should be submitted to abs-submit@math.ams.org; paper abstracts should be sent to the Abstracts Coordinator, AMS Meetings and Conferences Department, P. O. Box 6887, Providence, RI 02940; telephone: 401-455-4182. Any other inquiries about AMS meetings may be sent to meet@math.ams.org.

Should your university be interested in hosting an AMS meeting, see the January issue for details.
Meetings & Conferences

Boston,
Massachusetts
Northeastern University
October 7–8, 1995

Meeting #903
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: August 1995, p. 921
Program issue of Notices: October 1995
Issue of Abstracts: Fall 1995

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses
Kevin D. Corlette, University of Chicago, Harmonic maps, harmonic forms, and locally symmetric spaces.
Daniel S. Freed, University of Texas at Austin, Geometry and quantum field theory.
Freydoon Shahidi, Purdue University, Automorphic L-functions and representation theory.
Andrei V. Zelevinsky, Northeastern University, Totally positive factorizations of unipotent matrices.

Special Sessions
Harmonic maps, locally symmetric spaces, and related issues, Kevin D. Corlette, and Jonathan A. Poritz, University of Maryland at College Park.
Graph theory, Karen L. Collins, Wesleyan University, and Ruth Haas, Smith College.
Geometry of 3-manifolds, William D. Dunbar, Simon's Rock of Bard College, Robert Meyerhoff, Boston College, and Jeffrey Weeks, Canton, N.Y.
Ergodic theory, Stanley J. Eigen, Northeastern University, and Vidhu S. Prasad, University of Massachusetts, Lowell.
Representation theory and combinatorics, Sergey Fomin and Richard P. Stanley, Massachusetts Institute of Technology, and Andrei V. Zelevinsky.
Geometry, topology, and quantum field theory, Daniel S. Freed, and Ezra Getzler, Massachusetts Institute of Technology.
Discussions across boundaries in mathematics education, Maurice E. Gilmore, Northeastern University, Deborah Hughes Hallett, Harvard University, and Paul W. Davis, Worcester Polytechnic Institute.
Geometric and hyperbolic dynamics, Boris Hasselblatt, and Zbigniew H. Nitecki, Tufts University.

Kent, Ohio
Kent State University
November 3–4, 1995

Meeting #904
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: September 1995
Program issue of Notices: November 1995
Issue of Abstracts: Fall 1995

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses
Luchezar L. Avramov, Purdue University.
Alice Silverberg, Ohio State University.
Peter J. Sternberg, Indiana University.
Rodolfo H. Torres, University of Michigan, Ann Arbor.

Special Sessions
Functional analysis and operator theory, Richard M. Aron and Per Enflo, and Andrew M. Tonge, Kent State University.

Syzgies and geometry, Anthony A. Iarrobino, Jr., Alex Martenskovsky, and Jerzy Weyman, Northeastern University.
Cohomology of groups and geometric topology, Solomon M. Jekel, and Alexandru I. Suciu, Northeastern University.
Differential geometry and Lie groups, Chuu-Lian Terng, Northeastern University.
Partial differential equations in geometry and mathematical physics, Christopher K. King, Robert C. McOwen, and Mikhail A. Shubin, Northeastern University.
Automorphic forms and representation theory, Lawrence E. Morris, Clark University, and Freydoon Shahidi.
Discrete geometry, Egon Schulte, Northeastern University, and Marjorie Senechal, Smith College.

Accommodations Update
An additional room block has been made at the Best Western Boston, The Inn at Children's Hospital, 342 Longwood Avenue, Boston, MA 02115. Telephone: 617-731-4700; $108/single or double. Reservation deadline is September 8, 1995.
Toric varieties, intersection theory, and enumerative geometry, Chunsheng Ban, Lars J. Ernstrom, Gary P. Kennedy, and Lee J. McEwan, Ohio State University, Mansfield.

Groups and geometrics and related topics, Curtis D. Bennett, Bowling Green State University, and Daniel E. Frohardt, Wayne State University.

Representation theory of finite groups and related topics, Stephen M. Gagola and Donald L. White, Kent State University.

Harmonic analysis and applications, Steve C. Hofmann, University of Missouri, Columbia, and Rodolfo H. Torres.

Homological aspects of commutative ring theory, Andrew R. Kustin and Matthew Miller, University of South Carolina, Columbia.

Mathematical and computational chemistry and biology, Victor A. Nicholson, Kent State University.

Algebraic topology, John F. Oprea, Cleveland State University, and Paul Schick, John Carroll University.

Numerical linear algebra and scientific computing, Lothar Reichel, Arden Ruttan, and Richard S. Varga, Kent State University.

Arithmetic algebraic geometry, Alice Silverberg and Yuri G. Zarhin, Russian Academy of Sciences.

Ginzburg-Landau systems, Peter J. Sternberg.

Accommodations

Participants should make their own arrangements directly with the hotel of their choice and state that they will be attending the AMS meeting. All rooms will be on a space available basis after the deadline given. The AMS is not responsible for rate changes or the quality of the accommodations.


Food Service

The Student Center cafeteria will be open from 7:00 a.m. to 6:30 p.m. on Friday, and from 7:00 a.m. to 1:30 p.m. on Saturday. Formal dining is available on the third floor at Schwebel Garden Room (Friday 11:00 a.m.-2:00 p.m., 4:00 p.m.-9:00 p.m., and Saturday 4:00 p.m.-9:00 p.m.) In addition many fast food restaurants are located in the food court on the first floor.

Other Activities

AMS representatives will be on hand to demonstrate and discuss the newest AMS electronic products available on the World Wide Web, including MathSciNet, MR database on the Internet; electronic journals; the preprint server; and other products and member services available on e-MATH. Participants can also discuss membership opportunities, examine new titles, and order most AMS books at a special 50% discount offered only at meetings.

Joint Books, Journals, and Promotional Materials Exhibit: This exhibit will be open the same hours as the registration desk and will provide participants with the opportunity to order publications and other materials from various commercial publishers not represented at the meeting.

Parking

On Friday $2 will be charged for parking in the lot adjacent to the Student Center. There is no charge on Saturday. Stickers can be obtained at the meeting registration desk.

Registration and Meeting Information

All talks will take place in the Student Center with Invited Addresses in Kiva Auditorium (First Floor) and Special Sessions in various classrooms on the third floor. The registration desk will be located in Room 310AB of the Student Center. The hours of registration are 8:00 a.m. to 5:00 p.m. on Friday, November 3; and from 8:00 a.m. to 1:00 p.m. on Saturday, November 4. The registration fees (payable onsite only) are $30 for members of the AMS; $45 for nonmembers; and $10 for emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, MasterCard or Visa only.

Travel

USAir has been selected as the official airline for this meeting due to its generally convenient schedule to the Akron/Canton and Cleveland airports. The following benefits are available exclusively to mathematicians and their families attending the meeting: 5% discount off first class and any published USAir promotional round-trip fare, or 10% discount off unrestricted coach fares with seven-day advance reservations and ticketing required. These discounts are valid providing all rules and restrictions are met and are applicable for travel from the continental U.S., Bahamas, Canada, and San Juan, P.R. Discounts are not combinable with other discounts or promotions. Additional restrictions may apply on international travel. For reservations call (or have your travel agent call) 800-334-8644 between 8:00 a.m. and 9:00 p.m. Eastern Time. Refer to Gold File Number 4138007.

Travel from the airport: Kent State has made arrangements with Airport Limousine Service for Thursday night, departing Cleveland's Hopkins International Airport at 7:30 and 9:30 p.m. and Friday morning departing at 10:00 a.m. and noon, $11/person one-way. Reservations should be made by calling 800-543-9912 no later than October 27, 1995, giving arrival/departure times. Airport Limousine is
located at Exit 6 on the Baggage Level of the airport. Vans will be available to and from the hotels on Friday and Saturday. Transportation from Akron/Canton airport is readily available.

Kent State University is located in Kent, OH, along Ohio Route 59, approximately 10 miles east of Akron, 35 miles southeast of Cleveland, and 100 miles northeast of Pittsburgh, Pennsylvania.

Participants travelling by car from the east or west: Take the Ohio Turnpike (Rte. 80/90) towards Kent and then take exit 13 to Rte. 14 south to Rte. 43 south, take Rte. 59 exit (Kent State University), follow the signs.

From the north or south: Take Rte. 77 towards Akron, then take Rte. 76 east to Rte. 43 north, take Rte. 59 exit (Kent State University), follow signs.

Weather
Participants should prepare for seasonally cool temperatures in the low 30's in the evening to the mid 40's during the day.

Los Angeles,
California
University of Southern California
November 11-12, 1995
Meeting #905
Western Section
Associate secretary: Lance W. Small
Announcement issue of Notices: September 1995
Program issue of Notices: November 1995
Issue of Abstracts: Fall 1995

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses
Martin T. Barlow, University of British Columbia.
Paul Goerss, University of Washington.
Ellen E. Kirkman, Wake Forest University.
Luen-fai Tam, University of California, Irvine.

Special Sessions
Stochastic analysis, Kenneth S. Alexander, University of Southern California, and Ruth Williams, University of California, San Diego.
Flat surface and billiard dynamics, Eugene Gutkin, Nicolai Haydn, and Christopher M. Judge, University of Southern California.
Representations of classical orders and finite dimensional algebras, Lawrence S. Levy, University of Wisconsin, Madison, and Birge K. Zimmermann-Huisgen, University of California, Santa Barbara.
Harmonic maps, Andrejs E. Treibergs, University of Utah, and Luen-fai Tam.
Spectral dynamics and conformal geometry, Paul Yang and Xianghe Dai, University of Southern California.

Accommodations
Participants should make their own arrangements directly with the hotel of their choice and state that they will be attending the AMS meeting. All rooms will be on a space available basis after the deadline given. The AMS is not responsible for rate changes or the quality of the accommodations.

- Crowne Plaza (adjacent to campus), 3540 S. Figueroa St., Los Angeles, CA 90015. Telephone: 213-748-4141 or 800-872-1104; $70/single or $75/double. Deadline for reservations: October 9, 1995.
- Holiday Inn LA City Center (1.5 miles), 1020 S. Figueroa St., Los Angeles, CA 90015. Telephone: 213-748-1291; $60/single, double, triple or quad. Deadline for reservations: October 23, 1995.
- Hyatt Regency, 711 South Hope St., Los Angeles, CA 90015. Telephone: 213-683-1234 or 800-233-1234; $95/single or double. Deadline for reservations is October 13, 1995.
All prices listed are subject to a 14% City of Los Angeles occupancy tax.

Food Service
The University Commons dining service will be open on Saturday and Sunday (hours to be announced). This facility includes both fast-food and informal sit-down dining. In
addition many restaurants are located off campus, in the surrounding downtown area, and in the hotels.

Other Activities
An AMS representative will be on hand (location to be announced) so that participants can discuss membership opportunities, examine new titles, and order most AMS books at a special 50% discount offered only at meetings.

Joint Books, Journals, and Promotional Materials Exhibit: This exhibit will be open the same hours as the registration desk and will provide participants with the opportunity to order publications and other materials from various commercial publishers not represented at the meeting.

Parking
On-campus parking will cost $6 per day. Space has been reserved in Parking Structure A, which is the first parking structure on the right as you enter the campus through Gate #6.

Registration and Meeting Information
Invited addresses will be held in Kaprelian Hall (KAP) and Special Sessions will be held in Grace Ford Salvatori (GFS). The registration desk will be located in the lobby of the Denny Research Building (DRB). The hours of registration will be from 8:00 a.m. to 5:00 p.m. on Saturday, November 11, and from 8:00 a.m. to 1:00 p.m. on Sunday, November 12. The registration fees (payable onsite only) are $30 for members of the AMS; $45 for nonmembers; and $10 for emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, MasterCard or Visa only.

Travel
USAir has been selected the official airline of this meeting for its convenient schedule to the Los Angeles International (LAX) airport. The following benefits are available exclusively to mathematicians and their families attending the meeting: 5% discount off first class and any published USAir promotional round-trip fare, or 10% discount off unrestricted coach fares with seven-day advance reservations and ticketing required. These discounts are valid providing all rules and restrictions are met and are applicable for travel from the continental U.S., Bahamas, Canada, and San Juan, P.R. Discounts are not combinable with other discounts or promotions. Additional restrictions may apply on international travel. For reservations call (or have your travel agent call) 800-334-8644 between 8:00 a.m. and 9:00 p.m. Eastern Time. Refer to Gold File Number 4138007.

Travel from the airport: Public transportation from the airport is conveniently accessible outside all terminal baggage areas. One of the shuttle services available is Super Shuttle, with service to and from the airport. Advance reservations can be made by calling 213-775-6600 or 310-782-6600, or at the airport at the Blue Van Stop area on the airport lower level. Super Shuttle has agreed to a discount rate for our group; mention you are attending the AMS meeting to the driver. The rate will be $12 for the first person and $10 for each accompanying person with the same destination.

Weather
Participants should prepare for fall temperatures in the mid 60's during the day to the mid 40's during the evening, with conditions being from very windy and dry to heavy rain. Temperature and weather can be checked via the WWW at www.usc.edu; and a view of the center of campus can be found at www.usc.edu/dept/TommyCam/.

Greensboro, North Carolina
University of North Carolina at Greensboro
November 17-18, 1995
Meeting #906
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: September 1995
Program issue of Notices: November 1995
Issue of Abstracts: Fall 1995

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses
H. Thomas Banks, North Carolina State University, Modeling, estimation and control in smart material systems.
Mladen Bestvina, University of Utah, R-trees in geometry, topology, and group theory.
Bodil Branner, Technical University, Denmark, Iteration of complex polynomials
Meetings & Conferences

Curtis Greene, Haverford College, Partially ordered sets and tableaux.

Special Sessions
Complex dynamics, Bodil Branner.
Algebraic combinatorics of posets and tableaux, Lynne M. Butler, Haverford College, and Curtis Greene.
Geometric topology, Alexander Chigogidze, University of Saskatchewan, and Richard B. Sher, University of North Carolina at Greensboro.
Geometric group theory, Mark E. Feighn, Rutgers University, and Michael Handel, Lehman College (CUNY).
Theory of ordered sets, Bernd W. Schroder, Hampton University.
Control and optimization design arising in industrial processes, H. T. Tran, North Carolina State University.
Set-theoretic topology, Jerry E. Vaughan, University of North Carolina at Greensboro.
Number theory and related topics, Theresa P. Vaughan, University of North Carolina at Greensboro.
Complexity theory, Jie Wang, University of North Carolina at Greensboro.

Accommodations
Participants should make their own arrangements directly with the Sheraton Hotel and state that they will be attending the AMS meeting. All rooms will be on a space available basis after the deadline given. The AMS is not responsible for rate changes or the quality of the accommodations.


Food Service
The Sheraton Greensboro offers a restaurant and small sandwich shop with bakery on the premises for the convenience of all participants. Guest Services, located in the hotel lobby, can assist participants seeking other restaurants.

Other Activities
AMS representatives will be on hand to demonstrate and discuss the newest AMS electronic products available on the World Wide Web, including MathSciNet, MR database on the Internet; electronic journals; the preprint server; and other products and member services available on e-MATH. Participants can also discuss membership opportunities, examine new titles, and order most AMS books at a special 50% discount offered only at meetings.

Joint Books, Journals, and Promotional Materials Exhibit: This exhibit will be open the same hours as the registration desk and will provide participants with the opportunity to order publications and other materials from various commercial publishers not represented at the meeting.

Parking
Parking is complimentary for guests staying at the Sheraton Hotel and there is a reduced rate available to those attending the sectional meeting with validated passes.

Registration and Meeting Information
Invited Addresses will be held in the Governor's Ballroom located on the lobby level of the Sheraton Greensboro. Special Sessions will be held in various meeting rooms of the hotel, further details will be available onsite. The registration desk will be located in the SC Foyer. The hours of registration will be from 8:00 a.m. to 5:00 p.m. on Friday, November 17, and from 8:00 a.m. to 1:00 p.m. on Saturday, November 18. The registration fees (payable onsite only) are $30 for members of the AMS; $45 for nonmembers; and $10 for emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, MasterCard or Visa only.

Travel
Delta has been selected as the official airline for this meeting. The following benefits are available exclusively to mathematicians and their families attending the meeting: a savings of 5% off promotional fares and 10% off full coach fares based on published round-trip fares between Greensboro and other cities in the U.S. and Canada, Bermuda, Nassau, San Juan, St. Thomas and St. Croix. Call 800-241-6760 between 7:30 a.m. and 11:00 p.m. EDT Monday through Friday, or 8:30 a.m. and 11:00 p.m. EDT Saturday and Sunday to contact Delta directly. Or call any licensed travel agent. Instruct the ticket agent to refer to file #X60351 in order to apply for the applicable discount.
The Sheraton Greensboro Hotel & Conference Center is located minutes from I-85 and I-40 in the middle of the business district and downtown. It is 12 miles from the Piedmont Triad International Airport (Greensboro). Coming from the airport take Highway 68 to I-40 east, taking a right onto Wendover Avenue East to the Market Street exit and bear right, then left on Eugene St., right on Smith St. then right on Greene St. The hotel entrance will be on the left just past the intersection of Greene and Lindsay Sts.
Participants travelling by car from the North or South: take US 29 to the Cone Blvd. exit heading west, turn left on Elm St. (towards downtown), turn onto Lindsay St., then left onto Greene and the hotel entrance is on the left.
East or West: take either I-85 or I-40 towards Greensboro and then take the South Elm exit. Follow South Elm-Eugene St. into the downtown area, take a right off Eugene St. onto Smith St. (go one block), turn right on Greene St., hotel entrance is on the left.
Weather
The average high temperature during mid-November is 60°F, the average low is 38°F, there is a chance of light rain or even snow.

Guanajuato, Mexico
November 29–December 2, 1995

Meeting #907
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: August 1995, p. 924
Program issue of Notices: November 1995
Issue of Abstracts: None

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired
Second joint meeting of the AMS and the Sociedad Matematica Mexicana (SMM).

Invited Addresses
David Gabai, California Institute of Technology.
Luis Gorostiza, CINVESTAV-IPN.
David W. McLaughlin, Courant Institute of Mathematical Sciences, New York University.
Victor Neumann, IMATE-UNAM.
Jose Antonio de la Peña, IMATE-UNAM.
Dennis Sullivan, Graduate School & University Center, City University of New York.

Special Sessions
Stochastic processes, Rodrigo Banuelos, Purdue University, and Luis Gorostiza, CINVESTAV.
Differential geometry, Charles Boyer, University of New Mexico, and Adolfo Sanchez Valenzuela, CIMAT.
Complex analysis and operator theory, Enrique Ramirez de Arellano, CINVESTAV, and Norberto Salinas, University of Kansas.
Hamiltonian systems with few degrees of freedom, Rafael de la Llave, University of Texas at Austin, and Arturo Olvera, IIMAS-UNAM.

Low dimensional topology, Mario Eudave and Max Neumann, IMATE-UNAM, and John E. Luecke, University of Texas at Austin.
Convexity and combinatorial geometry, Paul R. Goodey, University of Oklahoma, and Luis Montejano, IMATE-UNAM.
Representations of finite dimensional algebras and applications, Edward L. Green, Virginia Polytechnic Institute and State University, and Roberto Martinez Villa, IMATE-UNAM.
General topology and continuum theory, Alejandro Illanes, IMATE-UNAM, and Leonard R. Rubin, University of Oklahoma.
Applied nonlinear analysis, William Kath, ESAM-McCormick School of Engineering, Northwestern University, Anton maria Minzoni, IIMAS-UNAM, and Jean Taylor, Rutgers University.
Associative rings, Sergio Lopez-Permouth, Ohio University, Athens, and Francisco Raggi, IMATE-UNAM
Graph theory and combinatorics, Victor Neumann, IMATE-UNAM, and Michael D. Plummer, Vanderbilt University.
Complex algebraic geometry, singularities, and foliations, Sevin Recillas, Unidad Morelia del Instituto de Matemáticas, and Le Dung Trang, Paris.
Smooth dynamical systems, José Seade, IMATE-UNAM, and John Smille, Cornell University.
Commutative algebra and algebraic coding theory, Horacio Tapia, UAM Iztapalapa, Wolmer V. Vasconcelos, Rutgers University, and Rafael Villareal, ESFM-IPN.

Orlando, Florida
January 10–13, 1996

Meeting #908
Joint Mathematics Meetings including the 102nd Annual Meeting of the AMS, 79th 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).
Associate secretary: Lance W. Small
Announcement issue of Notices: October 1995
Program issue of Notices: January 1996
Issue of Abstracts: Winter 1996

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: September 10, 1995
For abstracts: October 2, 1995

Invited Addresses
Irving Kaplansky, Mathematical Sciences Research Institute, Rings and things (Retiring Presidential Address).
Janos Pach, Hungarian Academy of Science.
Peter W. Shor, AT&T Bell Laboratories.
Steven Weinberg, University of Texas, Austin, Is field theory the answer? Is string theory the answer? What was the question? (Gibbs Lecture).
Andrew J. Wiles, Princeton University (Colloquium Lectures).

Special Sessions

History of mathematics, Thomas Archibald, Acadia University, and Victor J. Katz, University of the District of Columbia.

Mathematics and education reform, William H. Barker, Bowdoin College; Naomi Fisher, University of Illinois at Chicago; Kenneth C. Millett, University of California, Santa Barbara; Hugo Rossi, University of Utah; and Philip D. Wagreich, University of Illinois at Chicago. (AMS-MAA)

Quantum information and computation, Charles Bennett and Peter W. Shor, IBM, Yorktown Heights.

Recursive and feasible mathematics, Douglas Cenzer, University of Florida, Gainesville, and Jeffrey B. Remmel, University of California, San Diego.

Analytic methods in several complex variables, F. Michael Christ, UCLA.

Knot theory, Tim D. Cochran, Rice University.


Number theory and diophantine questions, Henri R. Darmon, McGill University, and Andrew J. Granville, University of Georgia.

Algebraic groups and invariant theory, Amassa C. Fauntleroy and Aloyisius Helminck, North Carolina State University.

Differential geometry and mathematical relativity, Gregory J. Galloway, University of Miami, Coral Gables.

Geometry, topology, and analysis on noncompact manifolds, Peter E. Haskell, Virginia Polytechnic Institute & State University.

Multi-dimensional complex dynamics, John H. Hubbard, Cornell University, and Ralph W. Oberste-Vorth, University of South Florida.

Non-selfadjoint operator algebras and their applications, Timothy D. Hudson and Elias G. Katsoulis, East Carolina University.

Commutative algebra, Craig L. Huneke, Purdue University and University of Michigan, Ann Arbor, Gennady Lyubeznik, University of Minnesota, Minneapolis.

Representation theory and harmonic analysis of topological groups, Carolyn E. Johnston, Florida Atlantic University, and Gail D. L. Ratcliff, University of Missouri, St. Louis.

Mathematical physics, Michael P. Loss, Georgia Institute of Technology.

Algebra, algebra cohomology, and polynomial identities, Andy R. Magid, University of Oklahoma, and Lance W. Small, University of California, San Diego.

Research in undergraduate mathematics education, Annie Selden, Tennessee Technical University, and John Selden, MERC. (AMS-MAA)

Computational harmonic analysis and approximation theory, Richard A. Zalik, Auburn University.

Iowa City, Iowa

University of Iowa, Iowa City

March 22–23, 1996

Central Section

Associate secretary: Andy R. Magid

Announcement issue of Notices: To be announced

Program issue of Notices: To be announced

Issue of Abstracts: Spring 1996

Deadlines

For organizers: June 22, 1995

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Invited Address

Franc Forstneric, University of Wisconsin, Madison.

Michal Misiurewicz, Indiana University-Purdue University at Indianapolis.

Daniel I. Tataru, Northwestern University.

Ruth J. Lawrence, University of Michigan, Ann Arbor.

Special Sessions

Commutative ring theory, Daniel D. Anderson, University of Iowa, Iowa City.

Current issues in nonlinear conservation laws, Suncica Canic, Iowa State University.

Research in mathematics by undergraduates, Carl C. Cowen, Purdue University.

Moments and operators, Raúl E. Curto, Palle E. T. Jorgensen, and Paul S. Muhly, University of Iowa, Iowa City.

Arrangements of hyperplanes, Michael Falk, University of Iowa, Iowa City, and Richard C. Randell, Northern Arizona University.

Topology of 3-manifolds, Charles Frohman and Ying-Qing Wu, University of Iowa, Iowa City.

Theta Correspondences and Automorphic Forms, David C. Manderscheid, University of Iowa.

Mostly finite geometries, Norman Johnson, University of Iowa, Iowa City.

Derivatives and financial mathematics, John F. Price, Maharishi International University.
Geometry and cohomology, Walter I. Seaman, University of Iowa, Iowa City.

Physical knot theory, Jonathan K. Simon, University of Iowa, Iowa City.

Nonlinear partial differential equations, Gerhard O. Strohmer and Lihe Wang, University of Iowa.

Group representations and mathematical physics, Tuong Ton-That, University of Iowa, Iowa City.

New York, New York
Courant Institute of Mathematical Sciences, New York University

April 13–14, 1996
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1996

Deadlines
For organizers: July 13, 1995
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses
Claude R. Lebrun, SUNY at Stony Brook.
Ze'ev Rudnick, Princeton University.
Jose Scheinkman, University of Chicago, Department of Economics.
Michael F. Singer, North Carolina State University.

Special Sessions
Partial differential equations, Patricia E. Bauman, Purdue University, West Lafayette, Fang-Hua Lin, Courant Institute, and Peter Sternberg, Indiana University.
Global Riemannian geometry, Tobias H. Colding, Courant Institute, Claude R. LeBrun, and Santiago R. Simanca, Polytechnic University.
Number theory, William Duke, Rutgers University, and Ze'ev Rudnick.
Hyperbolic geometry and discrete groups, Jane P. Gilman, Rutgers University.
Gauge field theory, Janet C. Talvacchia, Swarthmore College, and Yisong Yang, Polytechnic University.
Topological methods, Charles R. Traina, Lawrence Narisi, and Edward Beckenstein, St. John's University.
Stochastic models in mathematical finance, Thaleia Zariphopoulou, University of Wisconsin, Madison.

Baton Rouge, Louisiana
Louisiana State University

April 19–21, 1996
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1996

Deadlines
For organizers: July 19, 1995
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses
Ronald A. Fintushel, Michigan State University.
Fritz Gesztesy, University of Missouri, Columbia.
Edward L. Green, Virginia Polytechnic Institute and State University.
William A. Morris, AT&T Bell Laboratories.

Special Sessions
Geometric group theory, Stephen G. Brick, University of South Alabama, and Jon M. Corson, University of Alabama.
Real algebraic geometry and ordered algebraic structures, Charles N. Delzell and James J. Madden, Louisiana State University, and Scott Woodward, Southern University.
Nonlinear partial differential equations, J. Robert Dorroh and Gisele Ruiz Goldstein, Louisiana State University.
Asymptotic behavior of difference equations with applications, Saber N. Elaydi, Trinity University (San Antonio), and Vlajko L. Kocic, Xavier University of Louisiana.
Control theory, Guillermo Ferreyra and Peter R. Wolenski, Louisiana State University.
Low–dimensional topology, Patrick M. Gilmer, Rick Lithuania, and Neal W. Stoltzfus, Louisiana State University.
Fluid dynamics, Jerome A. Goldstein and Michael M. Tom, Louisiana State University.
Representations of finite groups, algebraic groups, and Lie algebras, Randall Reed Holmes, Auburn University, and Cornelius Pillen, University of South Alabama.
Number theory and quadratic forms, Jurgen Hurrelbrink, Jorge F. Morales, Robert V. Perlis, and Paul B. van Wamezen, Louisiana State University.
Fixed point theory and dynamical systems, Michael R. Kelly, Loyola University.
Rings and modules, Ellen E. Kirkman, Wake Forest University, and Dan Zacharia, Syracuse University.
Stochastic analysis and its applications, Hui-Hsiung Kuo and Ambar N. Sengupta, Louisiana State University.

Real analytic geometry and o-minimal structures, Christopher L. Miller, University of Illinois at Chicago, and Lou van den Dries, University of Illinois.

Transform theory and evolution equations, Frank Neubrander and Lutz Weis, Louisiana State University.

Antwerp, Belgium
May 22–24, 1996
First joint meeting of the AMS and the mathematical societies of the BENELUX countries (Belgium, the Netherlands, and Luxembourg).

Associate secretary: Robert J. Daverman
Announcement issue of Notices: January 1996
Program issue of 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

Lawrenceville, New Jersey
Rider University
October 5–6, 1996

Graduate school in geometry and topology, Lawrenceville, New Jersey.

Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1996

Deadlines
For organizers: January 5, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses
Louis J. Billera, Cornell University.
Fred I. Diamond, University of Cambridge.
Karen E. Smith, Massachusetts Institute of Technology.
Nicole Tomczak-Jaegermann, University of Alberta.

Special Sessions

Homotopy theory, Martin Bendersky, Hunter College, and Donald M. Davis, Lehigh University.

Moduli spaces of vector bundles over curves with or without additional structure, Hans Ulysses Boden, Max Planck Institute for Mathematics.

Mirror symmetry and toric varieties, Ciprian S. Borcea, Rider University, and Sylvain E. Cappell, Courant Institute, New York University.

Partial differential equations in geometry, Thomas P. Branson, University of Iowa, Iowa City, and Robert C. McOwen, Northeastern University.

Operads, Hopf algebras, and categories, Arthur M. DuPré, Rutgers University, and James D. Stasheff, University of North Carolina, Chapel Hill.

Elliptic surfaces, William L. Hoyt, Rutgers University, and Charles F. Schwartz, Rider University.

Geometric topology, Norman Levitt, Rutgers University, and Georgia Triantafillou, Temple University.

Automorphic forms, J. S. Li, University of Maryland, and P. Sarnak, Princeton University.

Radon transforms and tomography, Andrew G. Markoe, Rider University, and Eric Todd Quinto, Tufts University.

Invariants of smooth 4-manifolds, John Morgan, Columbia University, and Frank S. Quinn, Virginia Polytechnic Institute and State University.

Combinatorial and computational geometry, William Steiger, Rutgers University, and Ileana Streinu, Smith College.

Algebraic K-theory, Charles A. Weibel, Rutgers University.
Chattanooga, Tennessee
University of Tennessee, Chattanooga
October 11-12, 1996
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1996

Deadlines
For organizers: January 10, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses
Christopher J. Bishop, SUNY at Stony Brook.
David Harbater, University of Pennsylvania.
Joyce R. McLaughlin, Rensselaer Polytechnic Institute.

Special Sessions
Commutative ring theory, David F. Anderson and David E. Dobbs, University of Tennessee, Knoxville.
Galois theory, Kevin R. Coombes, University of Maryland, College Park, and Helmut Voelklein, University of Florida.

Columbia, Missouri
University of Missouri, Columbia
November 1-3, 1996
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1996

Deadlines
For organizers: February 1, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses
Alejandro Adem, University of Wisconsin, Madison.
David Barrett, University of Michigan, Ann Arbor.
Patricia E. Bauman, Purdue University.
Yan Soibelman, Kansas State University.

Special Sessions
Partial differential equations and mathematical physics, Mark S. Ashbaugh, University of Missouri, Columbia.
Harmonic analysis and probability, Nakhle Habib Asmar and Stephen J. Montgomery-Smith, University of Missouri, Columbia.
Differential geometry, John K. Beem and Adam D. Helfer, University of Missouri, Columbia.
Differential equations and dynamical systems, Carmen C. Chicone and Yuri Latushkin, University of Missouri, Columbia.
Commutative algebra, Steven Dale Cutkosky and Hema Srinivasan, University of Missouri, Columbia.
Gauge theory and its interaction with holomorphic and symplectic geometry, Stamatis A. Dostoglou, University of California at Santa Barbara, Jan Segert and Shuguang Wang, University of Missouri, Columbia.
Spectral theory and completely integrable systems, Fritz Gesztesy, University of Missouri, Columbia.

San Diego, California
January 8-11, 1997
Joint Mathematics Meetings including the 103rd Annual Meeting of the AMS, 80th 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).
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: January 1997
Issue of Abstracts: Winter 1997

Deadlines
For organizers: April 8, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Memphis, Tennessee
University of Memphis
March 21-22, 1997
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1997

Deadlines
For organizers: June 21, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions
Approximation in mathematics, George A. Anastassiou, University of Memphis.
Meetings & Conferences

College Park, Maryland

*University of Maryland in College Park*

**April 12-13, 1997**

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Spring 1997

**Deadlines**
- For organizers: July 12, 1996
- For consideration of contributed papers in Special Sessions: To be announced
- For abstracts: To be announced

Milwaukee, Wisconsin

*University of Wisconsin, Milwaukee*

**October 24-26, 1997**

Central Section
Associate secretary: Andy R. Magid
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Fall 1997

**Deadlines**
- For organizers: January 4, 1997
- For consideration of contributed papers in Special Sessions: To be announced
- For abstracts: To be announced

**Special Sessions**
*Computability theory*, Steffen Lempp, University of Wisconsin, Madison, and Robert I. Soare, University of Chicago.

Detroit, Michigan

*Wayne State University*

**May 2-4, 1997**

Central Section
Associate secretary: Andy R. Magid
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Spring 1997

**Deadlines**
- For organizers: August 2, 1996
- For consideration of contributed papers in Special Sessions: To be announced
- For abstracts: To be announced

Baltimore, Maryland

**January 7-10, 1998**

*Joint Mathematics Meetings including the 104th Annual Meeting of the AMS, 81st Annual Meeting of the Mathematical Association of America (MAA), and annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).*

Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: January 1998
Issue of *Abstracts*: Winter 1998

**Deadlines**
- For organizers: April 10, 1997
- For consideration of contributed papers in Special Sessions: To be announced
- For abstracts: To be announced

Atlanta, Georgia

*Georgia Institute of Technology*

**October 10-12, 1997**

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Fall 1997

**Deadlines**
- For organizers: January 4, 1997
- For consideration of contributed papers in Special Sessions: To be announced
- For abstracts: To be announced

Manhattan, Kansas

*Kansas State University*

**March 27-28, 1998**

Central Section
Associate secretary: Andy R. Magid
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Spring 1998

**Deadlines**
- For organizers: June 26, 1997
- For consideration of contributed papers in Special Sessions: To be announced
- For abstracts: To be announced

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