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Alain Connes, André Lichnerowicz, and Marcel Paul Schützenberger

Our view of the world today is fundamentally influenced by twentieth century results in physics and mathematics. Here, three members of the French Academy of Sciences: Alain Connes, André Lichnerowicz, and Marcel Paul Schützenberger, discuss the relations among mathematics, physics, and philosophy, and other sciences. Written in the form of conversations among three brilliant scientists and deep thinkers, the conversations are sprinkled with stories and quotes from these outstanding scientists. The book will make you think again about things that you once thought were quite familiar.

Alain Connes is one of the founders of non-commutative geometry. He holds the Chair of Analysis and Geometry at the College de France. He was awarded the Fields Medal in 1982. In 2001, he was awarded the Crafoord Prize by The Royal Swedish Academy of Sciences.

André Lichnerowicz, mathematician, noted geometer, theoretical physicist, and specialist in general relativity, was a professor at the Collège de France.

Marcel Paul Schützenberger made brilliant contributions to combinatorics and graph theory. He was simultaneously a medical doctor, a biologist, a mathematician, a linguist, and an algebraist.

2001; 181 pages; Hardcover; ISBN 0-8218-2173-3; List $30; All AMS members $24; Order code TOTNT108

Recommended Text

Supplementary Reading

Arithmetic Algebraic Geometry
Brian Conrad, University of Michigan, Ann Arbor, MI, and Karl Rubin, Stanford University, CA, Editors

The articles in this volume are expanded versions of lectures delivered at the Graduate Summer School and at the Monitoring Program for Women in Mathematics held at the Institute for Advanced Study/Park City Mathematics Institute. The theme of the program was arithmetic algebraic geometry. The choice of lecture topics was heavily influenced by the recent spectacular work of Wiles on modular elliptic curves and Fermat's Last Theorem. The main emphasis of the articles in the volume is on elliptic curves, Galois representations, and modular forms. One lecture series offers an introduction to these objects. The others discuss selected recent results, current research, and open problems and conjectures. The book would be a suitable text for an advanced graduate course in arithmetic algebraic geometry.

IAS/Park City Mathematics Series, Volume 9; 2001; 569 pages; Hardcover; ISBN 0-8218-2079-3; List $70; All AMS members $56; Order code PCMS/9NT108

Recommended Text

Plane Algebraic Curves
Gerd Fischer, Heinrich-Heine-Universität, Düsseldorf, Germany

From a review for the German Edition:

The present book provides a completely self-contained introduction to plane complex curves from the traditional algebraic-analytic viewpoint. The arrangement of the material is of outstanding instructional skill, and the text is written in a very lucid, detailed and enlightening style. Compared to the many other textbooks on (plane) algebraic curves, the present new one comes closest in spirit and content, to the work of E. Brieskorn and H. Knorrer. One could say that the book under review is a beautiful, creative and justifiable abridged version of this work, which also stresses the analytic-topological point of view. The present book is a beautiful invitation to algebraic geometry, encouraging for beginners, and a welcome source for teachers of algebraic geometry, especially for those who want to give an introduction to the subject on the undergraduate-graduate level, to cover some not too difficult topics in substantial depth, but to do so in the shortest possible time.

Zentralblatt für Mathematik

This is an excellent introduction to algebraic geometry, which assumes only standard undergraduate mathematical topics: complex analysis, rings and fields, and topology. Reading this book will help the student establish the appropriate geometric intuition that lies behind the more advanced ideas and techniques used in the study of higher dimensional varieties.

This is the English translation of a German work originally published by Vieweg Verlag (Wiesbaden, Germany).

Student Mathematical Library, Volume 15; 2001; approximately 206 pages; Softcover; ISBN 0-8218-2122-3; List $35; All AMS members $28; Order code STML/15NT108

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Edmund Landau

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-Mathematical Gazette

After completing his famous Foundations of Analysis (See AMS Chelsea Publishing, Volume 78.H for the English Edition and AMS Chelsea Publishing, Volume 141 for the German Edition, Grundlagen der Analysis), Landau turned his attention to this book on calculus. The approach is that of an unrepentant analyst, with an emphasis on functions rather than on geometric or physical applications. The book is another example of Landau's formidable skill as an expositor. It is a masterpiece of rigor and clarity.

AMS Chelsea Publishing, 1965; 372 pages; Hardcover; ISBN 0-8218-280-4; List $35; All AMS members $28; Order code CHEU78NT108

Recommended Text

Principles of Functional Analysis
Second Edition
Martin Schechter, University of California, Irvine

From a review for the First Edition:

"Charming" is a word that seldom comes to the mind of a science reviewer, but if he is charmed by a treatise, why not say so? I am charmed by this book. Professor Schechter has written an elegant introduction to functional analysis including related parts of the theory of integral equations. It is easy to read and is full of important applications. He presupposes very little background beyond advanced calculus; in particular, the treatment is not burdened by topological refinements which nowadays have a tendency of dominating the picture.

The book can be warmly recommended to any reader who wants to learn about this subject without being deterred by less relevant introductory matter or scared away by heavy prerequisites.

-The American Scientist

The exposition in this book is inviting, following threads of ideas, describing each as fully as possible, before moving on to a new topic. Supporting material is introduced as appropriate, and only to the degree needed. Some topics are treated more than once, according to the different contexts in which they arise. This Second Edition incorporates many new developments while not overshadowing the book's original flavor. Areas in the book that demonstrate its unique character have been strengthened. In particular, new material concerning Fredholm and semi-Fredholm operators is introduced, requiring minimal effort as the necessary machinery was already in place. Several new topics are presented, but relate to only those concepts and methods emanating from other parts of the book. These topics include perturbation classes, measures of noncompactness, strictly singular operators, and operator constants.

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Graduate Studies in Mathematics, Volume 96; 2001; 393 pages; Hardcover; ISBN 0-8218-2895-9; List $69; All AMS members $55; Order code GSM/96NT108

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Riemannian Geometry of Contact and Symplectic Manifolds

D. E. Blair, Michigan State University, East Lansing, MI

This monograph deals with the Riemannian geometry of both symplectic and contact manifolds, with particular emphasis on the latter. The text is carefully presented. Topics unfold systematically from Chapter 1, which examines the general theory of symplectic manifolds. Principal circle bundles (Chapter 2) are then discussed as a prelude to the Boothby-Wang fibration of a compact regular contact manifold in Chapter 3, which deals with the general theory of contact manifolds. Chapter 4 focuses on the general setting of Riemannian metrics associated with both symplectic and contact structures, and Chapter 5 is devoted to integral submanifolds of the contact subbundle. Other topics treated include the class of Sasakian manifolds, other questions of structures on manifolds, the important study of curvature of contact metric manifolds, submanifold theory in both the Kähler and Sasakian settings, tangent sphere bundles, various curvature functionals, and complex contact manifolds.

The book will serve both as a general source for mathematicians requiring a reference to the basic properties of symplectic and contact manifolds and it will be an excellent resource for graduate students and those working in the Riemannian geometric arena. The prerequisite for understanding this text is a basic course in Riemannian geometry.

ISBN 0-8176-3904-7

Elements of Noncommutative Geometry

J. M. Gracia-Bondía, J. C. Várilly, & H. Figueroa, all, Universidad de Costa Rica, San José

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Mathematical Reviews
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M. Gromov, IHES, France with appendices by M. Katz, P. Pansu, and S. Semmes

English Translation by S. Bates, Columbia University, New York, NY

Based on Structures Métriques des Variétés Riemanniennes, edited by J. Lafontaine & P. Pansu

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Mathematical Reviews

PROGRESS IN MATHEMATICS, VOL. 152
1999, 219 PAGES / 9 ILLUSS. / HARDCOVER
ISBN 0-8176-3898-9 / $59.95

Geodesic Flows

G. P. Paternain, Centro de Matemática, Montevideo, Uruguay

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Mathematical Reviews

Geodesic flows are of considerable current interest since they are the most remarkable class of conservative dynamical systems. They provide a unified arena in which one can explore numerous interplays among smooth ergodic theory, symplectic and Riemannian geometry, and algebraic topology.

PROGRESS IN MATHEMATICS, VOL. 180
1999 / 160 PAGES / HARDCOVER
ISBN 0-8176-4144-0 / $59.95

New!
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A. Juhl, Universität Uppsala, Sweden

The periodic orbits of the geodesic flow of compact locally symmetric spaces of negative curvature give rise to meromorphic zeta functions (generalized Selberg zeta functions, Ruelle zeta functions). This book treats various aspects of the analytical properties of these functions on the basis of appropriate analogs of the Lefschetz fixedpoint formula in which the periodic orbits of the flow take the place of the fixed points. Included are many unsolved problems to promote further research.

PROGRESS IN MATHEMATICS, VOL. 194
2001 / 709 PP. / HARDCOVER
ISBN 3-7643-6405-X / $129.00

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W. Hugh Woodin

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Reviewed by Bryan Birch
F.A.M.S.

The Council of the Society, at its meeting in New Orleans this past January, approved a plan to increase the frequency and uniformity of AMS prizes and also introduced one new prize. The proposal originated in the Committee on the Profession and was endorsed by the Board of Trustees prior to approval by the Council, receiving enthusiastic support in all three fora: mathematicians in the Society's leadership were virtually unanimous in declaring that mathematics needs more prizes.

That prizes are a boost to an individual scientist's career is well established. In their now classic study of the physics community, Social Stratification in Science (University of Chicago Press, 1973), Jonathan and Stephen Cole looked at the role of prizes in a phenomenon they called "the accelerating accumulation of rewards", whereby slightly better scientists, because of the recognition effect, end up with vastly superior reputations and positions. Prizes, especially those that come early in a career, serve to mark the recipient as especially meritorious, which results in an increase in opportunities. The authors never reveal whether they view the phenomenon as benign or, for that matter, as an efficient way to allocate resources. Perhaps today we would wonder more about the effect on scientists from underrepresented groups or on those working in geographically disadvantaged venues.

As part of their study, the Coles investigated how important the prestige of the prize itself was in this process by asking a representative sample of physicists to rank prizes. As a control, they salted their survey with a few plausibly named but fictitious prizes. Sure enough, the phony prizes were deemed to carry prestige too! The real point is that had there been such prizes, they would have aided in recognition of the recipients as well.

One could debate whether mathematics has its own "accelerating accumulation of rewards" (or whether such a system would be desirable). But even if this system does exist in mathematics, prizes do not seem to play much of a role. In fact, one common theme in the discussions about the recent actions on AMS prizes was the view that mathematics is at a disadvantage compared to other sciences because of its paucity of prizes. Department heads were especially articulate on this point: they believed that many university honors that could justifiably have gone to mathematicians went instead to faculty in other disciplinary units simply because those disciplines have many more prizes than does mathematics.

Of course, there could never be enough prizes to honor all deserving mathematicians. But perhaps we could borrow another recognition device that many sciences employ: in my opinion, the AMS could have a special class of distinguished members identified as "Fellows of the American Mathematical Society". Based on the similar fellows programs of other societies, I would guess that we would name about 50 fellows a year, so that at steady state there would be about 1,500 to 2,000 Fellows of the AMS. Leave aside the problem of how to start (I assume there are at least 200 people who would be in the top 50 of current U.S. mathematicians), and leave aside the problems of formulating the criteria for fellowship and the mechanism for selecting fellows. Can we even conceive of a process that could identify 50 mathematicians a year for this honor?

In fact, we have a good model of that right now. The Society invites about 50 people a year to address its regional and national meetings. While the criteria for selecting fellows would be slightly different, my guess is that once steady state is achieved the set of people who have given an invited address and the set of fellows would be virtually identical. Indeed, we could use this observation to solve the start-up problem: we simply declare the former set to be grandmothered/grandfathered to fellowship status. We could even expand the charge to the existing program committees so that they name the new class of fellows each year as well.

Regardless of how a fellows program might be implemented by the Society, however, I think the benefits of the program are clear. In identifying mathematicians as fellows, the Society would be granting them recognition easily explained to deans and provosts, thereby enabling their universities to honor, reward, and compensate them on a par with their peers in the other sciences.

—Andy R. Magid
Associate Editor
Letters to the Editor

Comments on Tao’s Article
Terence Tao’s article “From Rotating Needles to Stability of Waves: Emerging Connections between Combinatorics, Analysis, and PDE” (March 2001 issue of the Notices) contains many historical inaccuracies. As an example, I will discuss here the origin and early history of Besicovitch sets. Further comments are posted on my Web page at http://www.math.ubc.ca/~ilaba/comments.html.

According to Tao, “In 1917 S. Kakeya posed the Kakeya needle problem: What is the smallest area ...? In 1927 the problem was solved by A. Besicovitch ...” (page 294). And further: “Historically, the first applications of the Kakeya problem to analysis arose in the study of Fourier summation in the 1970s” (page 298).

However, Besicovitch himself tells a very different story in Amer. Math. Monthly 70 (1963), 697–706. (See also K. J. Falconer, The Geometry of Fractal Sets, Chapter 7.) Namely, in 1917 Besicovitch was working on a problem in Riemann integration and was able to reduce it to the question of the existence of compact sets of measure zero in the plane which contain a unit line segment in each direction. He constructed such a set in 1919 and published his results in a Russian journal in 1920. About the same time (1917), Kakeya first mentioned the “needle problem”. The original question, in which the planar set was required to be convex, was promptly resolved by Pal (1921); the analogous question without the convexity assumption remained open.

There was hardly any communication between Russia and the rest of the world at the time, due to the civil war and the blockade. Hence Besicovitch’s work received little attention outside of Russia, and neither did Kakeya’s question reach him. Besicovitch was told of Kakeya’s problem shortly after he left Russia in 1924, and he resolved it in 1925 by modifying his original construction. His solution was published in Math. Zeitschrift in 1928.

It moreover follows that applications of “Kakeya sets” to analysis (the Riemann integration problem just mentioned) are as old as Besicovitch’s construction itself. See also Busemann and Feller, Fund. Math. 22 (1934), 226–256, where Kakeya sets are used in the context of differentiation of integrals. Furthermore, it is interesting to note that Stein and Weiss (Trans. Amer. Math. Soc. 140 (1969), 34–54) used a closely related construction due to Nikodym (1927) to disprove the unrestricted convergence of Poisson integrals.

—Izabella Laba
University of British Columbia

(Received April 11, 2001)

Editor’s Note: See also Terence Tao’s letter in the June/July 2001 issue.

History of the Woods Hole Fixed-Point Theorem

“In 1964 Michael and I were together again in Woods Hole, at an algebraic geometry conference.... During that conference we discovered our fixed point theorem, the Lefschetz fixed point theorem in this new context.”

I can certainly appreciate that they proved the theorem in the context of an elliptic complex, but I strongly disagree with him in his saying “we discovered,” as it suggests that they discovered it completely on their own. What he says contradicts what he and Atiyah said thirty-six years ago.

In fact, in the introduction of “Notes on the Lefschetz fixed point theorem for elliptic complexes”, Harvard University, Fall 1964, they wrote: “Our main formula also generalizes a result of Eichler on algebraic curves which was brought to our attention by Shimura during the recent conference at Woods Hole on algebraic geometry. In fact, this work resulted precisely from our attempt to prove Shimura’s conjectures in this direction.”

Also, their article in Bull. Amer. Math. Soc. 72 (1966), 245–250, contains the following sentence: “The first of these [which means Theorem 2 in that article] was conjectured to us by Shimura and was proved by Eichler for dimension one.”

I don’t remember whether there is a similar acknowledgment in their paper [42] (Ann. of Math. 86 (1967)); probably not in the introduction.

A large number of mathematicians participated in the conference, and I think many of them still remember that the theorem came into existence because of my conjecture. I wonder if they can accept the phrase “we discovered.”

The same paragraph ends with the following sentences: “The number theorists at first told us we must be wrong, but then we turned out to be right. So we enjoyed that!”

This is completely wrong. As far as I can remember, no number theorist said they must be wrong. After all, I conjectured it in the holomorphic case, and no number theorist was knowledgeable enough to be against its formulation for an elliptic complex. I may be excused to say that these sentences were added in order to say that they “discovered” it without help from the number theorists, of whom I am one.

—Goro Shimura
Princeton University

(Received April 13, 2001)

Response to Shimura’s Letter
Professor Shimura’s point is well taken, and I apologize for this gaffe in my interview. Had I the power to replace the two offending sentences, I would gladly replace them by:

At Woods Hole Atiyah and I discovered how to generalize Shimura’s conjectured fixed point formula to the elliptic context, and eventually we were able to establish this generalization by pseudo-differential techniques.

There remains the puzzle of how my original account came about. Unfortunately, an answer to this question involves me in precisely what I was trying to avoid at this late stage of the interview, namely, in relating yet another long story. But so be it, and
let that be my punishment for failing to censor my original impulsive account in the final draft.

First, however, this forewarning especially for our younger readers. In his wisdom the Good Lord has endowed all of us with very selective memories, designed to make life bearable even in old age. On the whole we tend to remember even the smallest of triumphs but forget all but our greatest blunders. Please keep this in mind during the following narrative.

For reasons which are now hidden from me, Michael Atiyah and I started our experimentation with a holomorphic fixed point theorem at the very start of the conference. I believe our experiments had to do with the Hecke correspondence in imaginary quadratic extensions. In any case, I have definite memories about my puzzlement that although fixed points were counted with complex numbers, they nevertheless added up to integers in the appropriate circumstances. Our computations dealt with correspondences on curves as well as maps. In any case we finally consulted some of our number-theoretic friends, and it was at this stage of our deliberations that our computations with the conjectured formula were at first declared to be wrong, but after more careful analysis were found to be correct. This is the incident referred to in my second sentence. A minor triumph, no doubt, but one that lifted our spirits and convinced us that we were on to something. This incident is confirmed by Michael, but not remembered by our consultants.

The next part of my account is even more murky, but I would be less than honest if I did not admit to it here. I seem to remember that we did these or similar computations before we interacted with Shimura! According to my memory, it was precisely during our search for the history of such formulas, and after we had been referred to Eichler’s work by several other people, that we were delighted to find an expert on these matters in Shimura, who set us straight and informed us that he had, in fact, conjectured the holomorphic fixed point formula in full generality for some time. Here my recollection is that we were not aware of the general formula before we talked with him. From that time on we of course, and quite properly, referred to the fixed point formula as Shimura’s conjecture, but subjectively I always remembered this encounter more as a confirmation than a revelation.

In any case, this interaction now made us all the more determined to find a proof. At this stage, I think, we also discovered how perfectly this Lefschetz formula fitted the Hermann Weyl character formula and found other interesting examples. Simultaneously we mercilessly consulted the large number of algebraic geometers at the conference in this regard, and eventually, in a special seminar devoted to this topic, a proof of the Lefschetz formula in the algebraic context was sketched out. In view of the large number of inputs to this result, it was named the “Woods Hole Fixed Point Theorem”. I believe that I served as a sort of master of ceremonies at the event. This proof was sheaf theoretic and used the internal Hom and derived functors but was not considered too difficult by the experts.

These techniques are not directly applicable in the holomorphic category, and so Michael and I, who had mainly been producers rather than actors in the developments so far, turned our attention to this case and eventually to the even more general elliptic version of the theorem. An especially memorable moment for us occurred during a walk in the gardens of the Whitney estate, when we discovered that the Dirac operator fitted into the picture. And, as I remarked earlier, we eventually produced a proof using essentially pseudo-differential techniques.

Finally, a comment on the quotes in Professor Shimura’s letter from the contemporary accounts of the Woods Hole story, both of them also written by me, I believe. Alas, here I must plead guilty once again to my penchant for cutting long stories short, for I have a distinct memory of debating with myself whether to include some of the above in those accounts, but at that time and in that context it seemed to me inappropriate.

This then is Bott’s long, long story. Is it true or a figment of my imagination? I am afraid that will be difficult to determine, given the universal nature of the “Anosov” evolution of our memory with time, which I alluded to earlier. But, true or not, let me end by expressing my sincere regret to Professor Shimura for having omitted his name altogether in my interview. In view of the foregoing, all I can do now is plead for his indulgence for my having committed this “Freudian” lapse.

—Raoul Bott
Harvard University

(Received May 14, 2001)

Mathematical Sciences Initiative

We write in response to the “Opinion” piece about the NSF Mathematical Sciences Initiative by Philippe Tondeur (March 2001, p. 293).

The mathematical research community has been skeptical about such matters in recent years, and it is easy to see why. Historically the backbone of NSF support of mathematical research has been support to Principal Investigators (PIs) on small grants. During two decades of various NSF initiatives, the number of proposals has risen by 50%, while the number of PIs supported dropped, reaching a twenty-year low in 2000. Moreover, the number would be lower still were it not for cuts in the level of support. Everyone who has been involved in the wrenching decisions process knows that the point at which cutoffs occur is well above the point at which work still merits support.

The funding of institutes, of conferences, and of educational initiatives, important as it is to mathematics, has nonetheless done little to alleviate this stark reality. Therefore, a skeptical reader of Director Tondeur’s article might expect limited impact for researchers—in particular, little or no additional support of PIs. Responses from the community could range from indifference to opposition.

What is important now is for the community to recognize that this time things really could be different. The writers of this letter were among the
members of the most recent triennial Committee of Visitors to the Division of Mathematical Sciences. We are persuaded that there is at present an understanding at the highest levels of NSF that the strength of the mathematical sciences is crucial to science as a whole, that the support for mathematical sciences must increase significantly, and that support of the research of individuals, as well as of groups, is a vital component.

If the current initiative is carried through as presented to us, the number of individuals supported on individual grants, the level of funding of individual grants, the support of research (and researchers) in other ways, and the support of graduate students and postdocs would all increase significantly. We would see a blossoming of opportunities for fostering the research efforts of mathematicians, both within mathematics and in collaboration with colleagues in other disciplines. This would be a major step forward in ensuring the health and the future of the mathematical sciences.

Whether this rosy picture can be realized within the current budget plans in Washington is not at all clear. Recent developments show that NSF and basic research do have some friends in Congress. We need to cultivate these friends by persuading our representatives, and the public in general, of the benefits to society of supporting basic mathematical research. What is clear is that divisiveness or indifference in the mathematical research community would make any change for the better even less likely. We urge our colleagues in the community to inform themselves about the potential impact and the exciting challenges in this initiative, to support the initiative wholeheartedly, and to make that support known vigorously.

—Sheldon Axler
San Francisco State University,
—Richard Beals
Yale University,
—Tony F. Chan
Institute for Pure and Applied Mathematics, and UCLA,
—Rick Durrett
Cornell University,
—C. Ward Henson
University of Illinois at Urbana-Champaign,
—Blaine Lawson
SUNY at Stony Brook,
—William W. Symes
Rice University,
—Carol Wood
Wesleyan University

(Received April 18, 2001)

The Boris Weisfeiler Legal Fund
Boris Weisfeiler, who was a professor of mathematics at Penn State University, disappeared in Chile during his hiking trip on January 5, 1985. Ten days later his backpack was found on the riverbank of the Nuble River. The official investigation of Boris's disappearance was closed shortly thereafter. In the Chilean press of those years there had been some speculation that Boris Weisfeiler was still alive and was being kept captive in the Colonia Dignidad, a German-speaking settlement with rumored Nazi connections.

During the next fifteen years Boris's family, colleagues, and friends tried unsuccessfully to find out what really happened to Boris, but no additional information was ever available. All the information received by the U.S. Embassy in Chile regarding Boris's whereabouts was classified and kept sealed in the embassy's files and the files of the U.S. Department of State. Nevertheless, the Chilean lawyer Hernan Fernandez, who has been working on the case on behalf of the Weisfeiler family for two and a half years, was able to reopen the case in the Chilean courts in January of 2000. On June 30, 2000, complying with the Chile Declassification Project, the U.S. Department of State declassified more than 250 official documents related to the disappearance of Boris Weisfeiler.

Since October of 2000 the Chilean Supreme Court and Judge Juan Guzman have been handling the case. In view of the current political climate in Chile, this investigation may become lengthy, and additional legal help will be needed to finally uncover what happened to Boris Weisfeiler. There remains some possibility that Boris Weisfeiler is still alive and is living as a prisoner within the Colonia Dignidad.

The Committee of Concerned Scientists, of which Boris was an active member, with particular concern and expertise on human rights abuses in Soviet mathematics, has set up The Boris Weisfeiler Legal Fund to provide financial support for ongoing investigation.

Tax-deductible contributions can be made by writing checks payable to the Committee of Concerned Scientists, with an indication on the check that it is for the Weisfeiler Fund. They should be mailed to:
Mrs. Dorothy Hirsch
Executive Director
Committee of Concerned Scientists
53-34 208th Street
Bayside, NY 11364


—V. Kac
Massachusetts Institute of Technology,
—D. Kazhdan
Harvard University,
—G. Margulis
Yale University,
—B. Mazur
Harvard University

(Received April 25, 2001)

Editor's Note: The AMS Council has endorsed the Boris Weisfeiler Legal Fund; see "Inside the AMS" in this issue of the Notices.
The Continuum Hypothesis, Part II

W. Hugh Woodin

Introduction

In the first part of this article, I identified the correct axioms for the structure \( (P(\mathbb{N}), \mathbb{N}, +, \cdot, \in) \), which is the standard structure for Second Order Number Theory. The axioms, collectively "Projective Determinacy", solve many of the otherwise unsolvable, classical problems of this structure.

Actually working from the axioms of set theory, ZFC, I identified a natural progression of structures increasing in complexity: \( (H(\omega), \in) \), \( (H(\omega_1), \in) \), and \( (H(\omega_2), \in) \), where for each cardinal \( K \), \( H(K) \) denotes the set of all sets whose transitive closure has cardinality less than \( K \). The first of these structures is logically equivalent to \( (\mathbb{N}, +, \cdot) \), the standard structure for number theory; the second is logically equivalent to the standard structure for Second Order Number Theory; and the third structure is where the answer to the Continuum Hypothesis, \( CH \), lies. The main topic of Part I was the structure \( (H(\omega_2), \in) \).

Are there analogs of these axioms, say, some generalization of Projective Determinacy, for the structure \( (H(\omega_2), \in) \)? Any reasonable generalization should settle the Continuum Hypothesis.

An immediate consequence of Cohen's method of forcing is that large cardinal axioms are not terribly useful in providing such a generalization. Indeed it was realized fairly soon after the discovery of forcing that essentially no large cardinal hypothesis can settle the Continuum Hypothesis. This was noted independently by Cohen and by Levy-Solovay.

So the resolution of the theory of the structure \( (H(\omega_2), \in) \) could well be a far more difficult challenge than was the resolution of the theory of the structure \( (H(\omega_1), \in) \).

One example of the potential subtle aspects of the structure \( (H(\omega_2), \in) \) is given in the following theorem from 1991, the conclusion of which is in essence a property of the structure \( (H(\omega_2), \in) \).

**Theorem (Woodin).** Suppose that the axiom Martin's Maximum holds. Then there exists a surjection \( \rho : \mathbb{R} \rightarrow \omega_2 \) such that \( \{ (x, y) \mid \rho(x) < \rho(y) \} \) is a projective set.

As we saw in Part I, assuming the forcing axiom, Martin's Maximum, \( CH \) holds projectively in that if \( X \subseteq \mathbb{R} \) is an uncountable projective set, then \( |X| = |\mathbb{R}| \). This is because Projective Determinacy must hold. However, the preceding theorem shows that assuming Martin's Maximum, \( CH \) fails projectively in that there exists a surjection

\[
\rho : \mathbb{R} \rightarrow \omega_2
\]

such that \( \{ (x, y) \mid \rho(x) < \rho(y) \} \) is a projective set. Such a function \( \rho \) is naturally viewed as a "projective counterexample" to \( CH \), for it is a counterexample to the following reformulation of \( CH \): Suppose that \( \pi : \mathbb{R} \rightarrow \alpha \) is a surjection of \( \mathbb{R} \) onto the ordinal \( \alpha \); then \( \alpha < \omega_2 \).

There is a curious asymmetry which follows from (the proofs of) these results. Assume there exist infinitely many Woodin cardinals. Then:

**Claim (1)** There can be no projective "proof" of \( CH \) (there can be no projective well-ordering of \( \mathbb{R} \) of length \( \omega_1 \)).

**Claim (2)** There can be a projective "proof" of \( \neg CH \) (there can be, in the sense just defined, a projective counterexample to \( CH \)).
Therefore, if there exist infinitely many Woodin cardinals and if the Continuum Hypothesis is to be decided on the basis of “simple” evidence (i.e., projective evidence), then the Continuum Hypothesis must be false. This is the point of the first claim.

But is this an argument against CH? If so, the playful adversary might suggest that a similar line of argument indicates that ZFC is inconsistent, for while we can have a finite proof that ZFC is inconsistent, we, by Gōdel’s Second Incompleteness Theorem, cannot have a finite proof that ZFC is consistent (unless ZFC is inconsistent). There is a key difference here, though, which is the point of the second claim. If there is more than one Woodin cardinal, then a projective “proof” that CH is false can always be created by passing to a Cohen extension. More precisely, if \((M, E)\) is a model of ZFC together with the statement “There exist 2 Woodin cardinals”, then is, if

\[(M, E) \models ZFC^+ \text{“There exist 2 Woodin cardinals,”}\]

then there is a Cohen extension, \((M^*, E^*)\), of \((M, E)\) such that \((M^*, E^*) \models ZFC + \phi\), where \(\phi\) is the sentence which asserts that there exists a surjection \(p: \mathbb{R} \rightarrow \omega_2\) such that \(\{(x, y) \mid \rho(x) < \rho(y)\}\) is a projective set. This theorem, which is the theorem behind the second claim above, shows that what might be called the Effective Continuum Hypothesis is as intractable as the Continuum Hypothesis itself.

These claims are weak evidence that CH is false, so perhaps large cardinal axioms are not quite so useless for resolving CH after all.

Of course there is no a priori reason that CH should be decided solely on the basis of projective evidence. Nevertheless, in the 1970s Martin conjectured that the existence of projective evidence against CH will eventually be seen to follow from reasonable axioms.

**Axioms for \(H(\omega_2)\)**

Encouraged by the success in Part I in finding the correct axioms for \(H(\omega_1)\), and refusing to be discouraged by the observation that large cardinal axioms cannot settle CH, we turn our attention to \(H(\omega_2)\). Here we have a problem if we regard large cardinal axioms as our sole source of inspiration: Even if there is an analog of Projective Determinacy for \(H(\omega_2)\), how can we find it or even recognize it if we do find it?

My point is simply that the axiom(s) we seek cannot possibly be implied by any (consistent) large cardinal hypothesis remotely related to those currently accepted as large cardinal hypotheses.

**Strong Logics**

The solution is to take an abstract approach. This we shall do by considering strengthenings of first order logic and analyzing the following question, which I shall make precise.

Can the theory of the structure \((H(\omega_2), \in)\) be finitely axiomatized (over ZFC) in a (reasonable) logic which extends first order logic?

The logics arising naturally in this analysis satisfy two important conditions, Generic Soundness and Generic Invariance. As a consequence, any axioms we find will yield theories for \((H(\omega_2), \in)\), whose “completeness” is immune to attack by applications of Cohen’s method of forcing, just as is the case for number theory.

How shall we define the relevant strong logics? There is a natural strategy motivated by the Gōdel Completeness Theorem. If \(\phi\) is a sentence in the language \(L(\in, \in)\) for set theory, then “ZFC \(\models \phi\)” indicates that there is a formal proof of \(\phi\) from ZFC. This is an arithmetic statement.

The Gōdel Completeness Theorem shows that if \(\phi\) is a sentence, then ZFC \(\models \phi\) if and only if \((M, E) \models \phi\) for every structure \((M, E)\) such that \((M, E) \models ZFC\).

Therefore a strong logic \(\Gamma_0\) can naturally be defined by first specifying a collection of test structures—these are structures of the form \(M = (M, E)\), where \(E \subseteq M \times M\)—and then defining “ZFC \(\Gamma_0\) \(\models \phi\)” if for every test structure \(M\), if \(M \models \phi\), then \(M \models \phi\).

Of course, we shall only be interested in the case that there actually exists a test structure \(M\) such that \(M \models ZFC\). In other words, we require that ZFC be consistent in our logic.

The smaller the collection of test structures, the stronger the logic, i.e., the larger the set of sentences \(\phi\) which are proved by ZFC. Note that if there were only one test structure, then for each sentence \(\phi\) either ZFC \(\Gamma_0\) \(\models \phi\) or ZFC \(\Gamma_0\) \(\models \neg \phi\). So in the logic \(\Gamma_0\) defined by this collection of test structures, no propositions are independent of the axioms ZFC.

By the Gōdel Completeness Theorem, first order logic is the weakest (nontrivial) logic.

To formulate the notion of Generic Soundness, I first define the cumulative hierarchy of sets: this is a class of sets indexed by the ordinals. The set with index \(\alpha\) is denoted \(V_\alpha\), and the definition is by induction on \(\alpha\) as follows: \(V_0 = \emptyset\); \(V_{\alpha+1} = P(V_\alpha)\); and if \(\beta\) is a limit ordinal, then \(V_\beta = \cup\{V_\alpha \mid \alpha < \beta\}\). It is easily verified that the sets \(V_\alpha\) are increasing, and it is a consequence of the axioms that every set is a member of \(V_\alpha\) for large enough \(\alpha\).

It follows from the definitions that \(V_\omega = H(\omega)\) and that \(V_{\omega+1} = H(\omega_1)\). However, \(V_{\omega+1} \neq H(\omega_1)\). Nevertheless, \(V_{\omega+1}\) and \(H(\omega_1)\) are logically equivalent in that each can be analyzed within the other. The relationship between \(V_{\omega+2}\) and \(H(\omega_2)\) is far more subtle. If the Continuum Hypothesis holds, then these structures are logically equivalent, but the assertion that these structures are logically
equivalent does not imply the Continuum Hypothesis.

Suppose that $M$ is a transitive set such that $(M, \in) \models \text{ZFC}$. The cumulative hierarchy in the sense of $M$ is simply the sequence $M \cap V_{\alpha}$ indexed by $M \cap \text{Ord}$. It is customary to denote $M \cap V_{\alpha}$ by $M_{\alpha}$. If $M$ is countable, then one can always reduce to considering Cohen extensions, $M^{*}$, which are transitive and for which the canonical embedding of $M$ into $M^{*}$ (given by Cohen's construction) is the identity. Thus, in this situation, $M \subseteq M^{*}$ and the ordinals of the Cohen extension coincide with those of the initial model.

The precise formulation of Generic Soundness involves notation from the Boolean Valued Model interpretation, due to Scott and Solovay, of Cohen's method of forcing. In the first part of this article I noted that Cohen extensions are parameterized by complete Boolean algebras (in the sense of the initial structure). Given a complete Boolean algebra $B$, one can analyze within our universe of sets the Cohen extension of our universe that $B$ could be used to define in some virtual larger universe where our universe, $V$, becomes, say, a countable transitive set. $V^{B}$ denotes this potential extension, and for each ordinal $\alpha$, $V^{B}_{\alpha}$ denotes the $\alpha$-th level of $V^{B}$. For each sentence $\phi$, the assertion $V^{B}_{\alpha} \models \phi$ is formally an assertion about the ordinal $\alpha$ and the Boolean algebra $B$; this calculation is the essence of Cohen's method.

**Definition.** Suppose that $\vdash_{\text{ZFC}}$ is a strong logic. The logic $\vdash_{\text{ZFC}}$ satisfies **Generic Soundness** if for each sentence $\phi$ such that $\text{ZFC} \vdash \phi$, the following holds. Suppose that $B$ is a complete Boolean algebra, $\alpha$ is an ordinal, and $V^{B}_{\alpha} \models \text{ZFC}$. Then $V^{B}_{\alpha} \models \phi$. □

Our context for considering strong logics will require at the very least that there exists a proper class of Woodin cardinals, and so the requirement of Generic Soundness is nontrivial. More precisely, assuming there exists a proper class of Woodin cardinals, for any complete Boolean algebra $B$ there exist unboundedly many ordinals $\alpha$ such that $V^{B}_{\alpha} \models \text{ZFC}$.

The motivation for requiring Generic Soundness is simply that if $\text{ZFC} \vdash \phi$, then the negation of $\phi$ should not (provably) realizable by passing to a Cohen extension. Of course, if $\vdash_{\text{ZFC}}$ is any strong logic which satisfies the condition of Generic Soundness, then it cannot be the case that either $\text{ZFC} \vdash_{\text{CH}}$ or $\text{ZFC} \vdash_{\text{CH}} \neg \text{CH}$; i.e., $\text{CH}$ remains unsolvable. This might suggest that an approach to resolving the theory of $H(\omega_{2})$ is based on strong logics is futile. But an important possibility arises through strong logics. This is the possibility that augmenting $\text{ZFC}$ with a single axiom yields a system of axioms powerful enough to resolve, through inference in the strong logic, all questions about $H(\omega_{2})$.

**Definition.** For a given strong logic $\vdash_{\text{ZFC}}$, the theory of the structure $(H(\omega_{2}), \in)$ is *finitely axiomatized over ZFC* if there exists a sentence $\Psi$ such that for some $\alpha$, $V_{\alpha} \models \text{ZFC} + \Psi$, and for each sentence $\phi$,

$$\text{ZFC} + \Psi \vdash \phi$$

if and only if $(H(\omega_{2}), \in) \models \phi$. □

**Universally Baire Sets**

There is a transfinite hierarchy which extends the hierarchy of the projective sets; this is the hierarchy of the universally Baire sets. Using these sets, I shall define a specific strong logic, $\Omega$-logic.

**Definition (Feng-Magidor-Woodin).** A set $A \subseteq \mathbb{R}^{n}$ is universally Baire if for every continuous function

$$f: \Omega \rightarrow \mathbb{R}^{n},$$

where $\Omega$ is a compact Hausdorff space, $f^{-1}[A]$ (the preimage of $A$ by $f$) has the property of Baire in $\Omega$; i.e., there exists an open set $O \subseteq \Omega$ such that the symmetric difference $f^{-1}[\Omega] \setminus O$ is meager. □

It is easily verified that every Borel set $A \subseteq \mathbb{R}^{n}$ is universally Baire. More generally, the universally Baire sets form a $\sigma$-algebra closed under preimages by Borel functions

$$f: \mathbb{R}^{n} \rightarrow \mathbb{R}^{m}.$$%

A little more subtle, and perhaps surprising, is that the universally Baire sets are Lebesgue measurable.

Every analytic set is universally Baire. The following theorem is proved using Jensen's Covering Lemma.

**Theorem (Feng-Magidor-Woodin).** Suppose that every projective set is universally Baire. Then every analytic subset of $[0, 1]$ is determined. □

The improvements of this theorem are quite subtle; the assumption that every projective set is universally Baire does not imply Projective Determinacy.

The following theorem of Neeman improves an earlier version of [Feng-Magidor-Woodin] which required the stronger hypothesis: There exist two Woodin cardinals.

**Theorem (Neeman).** Suppose that there is a Woodin cardinal. Then every universally Baire subset of $[0, 1]$ is determined. □

If there exists a proper class of Woodin cardinals, then the universally Baire sets are closed under continuous images (and so projections). Therefore:

**Theorem.** Suppose that there are arbitrarily large Woodin cardinals. Then every projective set is universally Baire. □
be the Cantor set, though any uncountable closed, nowhere dense subset of $[0,1]$ would suffice for what follows.

Suppose that $A \subseteq \mathbb{K}$ and that $B \subseteq \mathbb{K}$. The set $A$ is reducible to $B$ if there exists a continuous function

$$f : \mathbb{K} \to \mathbb{K}$$

such that $A = f^{-1}(B)$. The set $A$ is strongly reducible to $B$ if the function $f$ can be chosen such that for all $x, y \in \mathbb{K}$, $|f(x) - f(y)| \leq (1/2)|x - y|$. There is a remarkably useful lemma of Wadge which I state for the projective subsets of the Cantor set and with the reductions just defined. There is a version of this lemma for subsets of $[0,1]$, but the definitions of reducible and strongly reducible must be changed.

**Lemma (Wadge).** Suppose that the axiom Projective Determinacy holds and that $A_0$ and $A_1$ are projective subsets of $\mathbb{K}$. Then either $A_0$ is reducible to $A_1$ or $A_1$ is strongly reducible to $\mathbb{K} \setminus A_0$. □

The proof of Wadge's lemma simply requires the determinacy of a set $B \subseteq [0,1]$ which is the preimage of

$$(A_0 \times (\mathbb{K} \setminus A_1)) \cup ((\mathbb{K} \setminus A_0) \times A_1)$$

by a Borel function $F : [0,1] \to \mathbb{R}^2$. Such sets $B$ are necessarily universally Baire if both of the sets $A_0$ and $A_1$ are universally Baire. Therefore, by Neeman's theorem:

**Theorem.** Suppose that there is a Woodin cardinal. Suppose that $A_0$ and $A_1$ are universally Baire subsets of $\mathbb{K}$. Then either $A_0$ is reducible to $A_1$ or $A_1$ is strongly reducible to $\mathbb{K} \setminus A_0$. □

Suppose that $f : \mathbb{K} \to \mathbb{K}$ is such that for all $x, y \in \mathbb{K}$, $|f(x) - f(y)| \leq (1/2)|x - y|$. Then for some $x_0 \in \mathbb{K}$, $f(x_0) = x_0$. This implies that no set $A \subseteq \mathbb{K}$ can be strongly reducible to its complement $\mathbb{K} \setminus A$. Therefore, given two universally Baire subsets of $\mathbb{K}$, $A_0$ and $A_1$, and assuming there is a Woodin cardinal, exactly one of the following must hold. This is easily verified by applying the previous theorem to the relevant pairs of sets, sorting through the various possibilities, and eliminating those that lead to the situation that a set is strongly reducible to its complement.

1. Both $A_0$ and $\mathbb{K} \setminus A_0$ are strongly reducible to $A_1$, and $A_1$ is not reducible to $A_0$ (or to $\mathbb{K} \setminus A_0$).
2. Both $A_1$ and $\mathbb{K} \setminus A_1$ are strongly reducible to $A_0$, and $A_0$ is not reducible to $A_1$ (or to $\mathbb{K} \setminus A_1$).
3. $A_0$ and $A_1$ are reducible to each other, or $\mathbb{K} \setminus A_0$ and $A_1$ are reducible to each other.

Thus one can define an equivalence relation on the universally Baire subsets of the Cantor set by $A_0 \sim_w A_1$ if (3) holds, and one can totally order the induced equivalence classes by defining for universally Baire sets, $A_0$ and $A_1$, $A_0 <_w A_1$ if (1) holds.

Of course (1) can be used to define a partial order on all subsets of $\mathbb{K}$. In the context of determinacy assumptions, Martin proved that this partial order is well founded [Moschovakis 1980]. In the absence of any determinacy assumptions, Martin's theorem can be formulated as follows.

**Theorem (Martin).** Suppose that $(A_k : k \in \mathbb{N})$ is a sequence of subsets of $\mathbb{K}$ such that for all $k \in \mathbb{N}$, both $A_{k+1}$ and $\mathbb{K} \setminus A_{k+1}$ are strongly reducible to $A_k$. Then there exists a continuous function $g : \mathbb{K} \to \mathbb{K}$ such that $g^{-1}(A_1)$ does not have the property of Baire. □

As a corollary we obtain the well-foundedness of $<_w$, because the continuous preimages of a universally Baire set must have the property of Baire.

So (assuming large cardinals) the universally Baire subsets of the Cantor set form a well-ordered hierarchy under a suitable notion of complexity. The projective sets define an initial segment, since any set which is reducible to a projective set is necessarily a projective set. The hierarchy finely calibrates the universally Baire sets. For example, the initial segment of length $\omega_1$ is given by the Borel sets, and the corresponding ordinal rank of a Borel set is closely related to its classical Borel rank.

There is a natural generalization of first order logic which is defined from the universally Baire sets. This is $\Omega$-logic; the "proofs" in $\Omega$-logic are witnessed by universally Baire sets which can be assumed to be subsets of the Cantor set $\mathbb{K}$. The ordinal rank of the witness in the hierarchy of such sets I have just defined provides a quite reasonable notion of the length of a proof in $\Omega$-logic.

The definition of $\Omega$-logic involves the notion of an $A$-closed transitive set where $A$ is universally Baire.

**$A$-closed Sets**

Suppose that $M$ is a transitive set with the property that $(M, \in) \models ZFC$.

Suppose that $(\Omega, F, \tau) \in M$ and that

1. $(M, \in) \models \"\Omega is a compact Hausdorff space\"$.
2. $\tau$ is the topology on $\Omega$; i.e., $\tau$ is the set of $O \in M$ such that $(M, \in) \models \"O \subseteq \Omega and \ O is open\"$.
3. $(M, \in) \models \"F \in C(\Omega, \mathbb{R})\"$.

For example, if $M$ is countable and

$(M, \in) \models \"\Omega is the unit interval $[0,1]$\"$,

then $\Omega = [0,1] \cap M$. It is easily verified that $[0,1] \cap M$ is dense in $[0,1]$, and so in this case $\Omega$ is a countable dense subspace of $[0,1]$. Notice that the element $F$ of $M$ is necessarily a function, $F : \Omega \to \mathbb{R}$.

Trivially, $\tau$ is a base for a topology on $\Omega$ yielding a topological space which of course need not
be compact, as the preceding example illustrates. Nevertheless, this topological space is necessarily completely regular. The function $F$ is easily seen to be continuous on this space.

Let $\bar{\Omega}$ be the Stone-Cech compactification of this space, and for each set $O \in \tau$ let $\bar{O}$ be the open subset of $\bar{\Omega}$ defined by $O$. This is the complement of the closure, computed in $\bar{\Omega}$, of $O$.

The function $F$ has a unique continuous extension $\bar{F}: \bar{\Omega} \to \mathbb{R}$.

Suppose $A \subseteq \mathbb{R}$ is universally Baire. Then the preimage of $A$ under $\bar{F}$ has the property of Baire in $\bar{\Omega}$. Let

$$\tau_A = \{ O \in \tau \mid \bar{O} \setminus F^{-1}[A] \text{ is meager} \}.$$ 

**Definition.** Suppose that $A \subseteq \mathbb{R}$ is universally Baire and that $M$ is a transitive set with $(M, \in) \models \text{ZFC}$. The set $M$ is $A$-closed if for every $(\Omega, F, \tau) \in M$ as above, $\tau_A \in M$.

If $M$ is $A$-closed, then $A \cap M \in M$, but in general the converse fails.

Suppose that $A \subseteq \mathbb{R}$ is universally Baire. Then there exists a universally Baire set $A^* \subseteq \mathbb{R}$ such that for all transitive sets $M$ such that $(M, \in) \models \text{ZFC}$, $M$ is $A$-closed if and only if $M$ is $A^*$-closed. Thus, for our purposes, the distinction between universally Baire subsets of $\mathbb{R}$ versus universally Baire subsets of $\mathbb{K}$, the Cantor set, is not relevant.

**$\Omega$-logic**

Having defined $A$-closure, I can now define $\Omega$-logic. This logic can be defined without the large cardinal assumptions used here, but the definition becomes a bit more technical.

**Definition.** Suppose that there exists a proper class of Woodin cardinals and that $\phi$ is a sentence. Then

$$\text{ZFC} \vdash_{\Omega} \phi$$

if there exists a universally Baire set $A \subseteq \mathbb{R}$ such that $(M, \in) \models \phi$ for every countable transitive $A$-closed set $M$ such that $(M, \in) \models \text{ZFC}$. \hspace{1cm} \square

There are only countably many sentences in the language $L(\in, \bar{\in})$, and, further, the universally Baire sets are closed under countable unions and preimages by Borel functions. Therefore there must exist a single universally Baire set $A_0 \subseteq \mathbb{R}$ such that for all sentences $\phi$ of $L(\in, \bar{\in})$, $\text{ZFC} \vdash_{\Omega} \phi$ if and only if $(M, \in) \models \phi$ for every countable transitive set $M$ such that $M$ is $A_0$-closed and $(M, \in) \models \text{ZFC}$. Thus $\Omega$-logic is the strong logic defined by taking as the collection of test structures the countable transitive sets such that $(M, \in)$ is a model of $\text{ZFC}$ and $M$ is $A_0$-closed.

One can easily generalize the definition of $\Omega$-logic to define when $T \vdash_{\Omega} \phi$ where $T$ is an arbitrary theory containing $\text{ZFC}$. If $T$ is simply $\text{ZFC} + \forall \psi$

for some sentence $\psi$, then $T \vdash_{\Omega} \phi$ if and only if $\text{ZFC} \vdash_{\Omega} (\forall \psi \cdot \phi)$.

Suppose that $\phi$ is a sentence (of $L(\in, \bar{\in})$) and that $\text{ZFC} \vdash_{\Omega} \phi$. Suppose that $A \subseteq \mathbb{R}$ is a universally Baire set which witnesses this. Viewing $A$ as a "proof", one can naturally define the "length" of this proof to be the ordinal of $A$ in the hierarchy of the universally Baire subsets of the Cantor set, $\mathbb{K}$, given by the relation $\prec$.

Thus one can define the usual sorts of G"odel and Rosser sentences. These are "self-referential sentences", and Rosser's construction yields sentences with stronger undecidability properties than does G"odel's construction.

For example, one can construct a sentence $\phi_0$ (obviously false) which expresses:

"There is a proof $\text{ZFC}_+ \vdash_{\Omega} (\neg \phi_0)$ for which there is no shorter proof $\text{ZFC}_+ \vdash_{\Omega} \phi_0$", 

where $\text{ZFC}_+$ is $\text{ZFC}$ together with the axiom "There exists a proper class of Woodin cardinals". Such constructions illustrate that $\Omega$-logic is a reasonable generalization of first order logic.

Later in this article I shall make use of the notion of the length of a proof in $\Omega$-logic when I define abstractly the hierarchy of large cardinal axioms.

$\Omega$-logic is unaffected by passing to a Cohen extension. This is the property of Generic Invariance. The formal statement of this theorem involves some notation, which I discuss. It is customary in set theory to write for a given sentence $\phi$, "$V \models \phi$" to indicate that $\phi$ is true, i.e., true in $V$, the universe of sets. Similarly, if $B$ is a complete Boolean algebra, "$V_B \models \phi$" indicates that $\phi$ is true in the Cohen extensions of $V$ that $B$ could be used to define (again in some virtual universe where our universe becomes a countable transitive set, as briefly discussed when the notation $V_B \models \phi$ was introduced just before the definition of Generic Soundness).

**Theorem (Generic Invariance).** Suppose that there exists a proper class of Woodin cardinals and that $\phi$ is a sentence. Then for each complete Boolean algebra $B$, $\text{ZFC} \vdash_{\Omega} \phi$ if and only if $V_B \models \text{ZFC} \vdash_{\Omega} \phi$.

Similar arguments establish that if there exists a proper class of Woodin cardinals, then $\Omega$-logic satisfies Generic Soundness.

The following theorem is a corollary of results mentioned in the first part of this article.

**Theorem.** Suppose that there exists a proper class of Woodin cardinals. Then for each sentence $\phi$,

$$\text{ZFC} \vdash_{\Omega} "(H(\omega_1), \in) \models \phi"$$

if and only if $(H(\omega_1), \in) \models \phi$.

A straightforward corollary is that
which vividly illustrates that $\Omega$-logic is stronger than first order logic.

The question of whether there can exist analogs of determinacy for the structure $(H(\omega_2), \in)$ can now be given a precise formulation.

Can there exist a sentence $\Psi$ such that for all sentences $\phi$ either

$$ZFC + \Psi \vdash \langle H(\omega_2), \in \rangle \models \phi$$

or

$$ZFC + \Psi \vdash \langle H(\omega_2), \in \rangle \models \neg \phi$$

and such that $ZFC + \Psi$ is $\Omega$-consistent?

Such sentences $\Psi$ will be candidates for the generalization of Projective Determinacy to $H(\omega_2)$. Notice that I am not requiring that the sentence $\Psi$ be a proposition about $H(\omega_2)$; the sentence can refer to arbitrary sets.

Why seek such sentences?

Here is why. By adopting axioms which "settle" the theory of $(H(\omega_2), \in)$ in $\Omega$-logic, one recovers for the theory of this structure the empirical completeness currently enjoyed by number theory. This is because of the generic invariance of $\Omega$-logic.

More speculatively, such axioms might allow for the development of a truly rich theory for the structure $(H(\omega_2), \in)$, free to a large extent from the ubiquitous occurrence of unsolvable problems. Compare, for example, the theory of the projective sets as developed under the assumption of Projective Determinacy with the theory developed of the problems about the projective sets which are not solvable simply from ZFC.

The ideal $\mathcal{I}_{\text{NS}}$, which I now define, plays an essential and fundamental role in the usual formulation of Martin's Maximum.

**Definition.** $\mathcal{I}_{\text{NS}}$ is the $\sigma$-ideal of all sets $A \subseteq \omega_1$ such that $\omega_1 \setminus A$ contains a closed unbounded set. A set $S \subseteq \omega_1$ is *stationary* if for each closed, unbounded set $C \subseteq \omega_1$, $S \cap C \neq \emptyset$. A set $S \subseteq \omega_1$ is *co-stationary* if the complement of $S$ is stationary.

The countable additivity and the nonmaximality of the ideal $\mathcal{I}_{\text{NS}}$ are consequences of the Axiom of Choice.

In my view, the continuum problem is a direct consequence of assuming the Axiom of Choice. This is simply because by assuming the Axiom of Choice, the reals can be well ordered and so $|\mathbb{R}| = \kappa_\alpha$ for some ordinal $\alpha$. Which $\alpha$? This is the continuum problem.

Arguably, the stationary, co-stationary, subsets of $\omega_1$ constitute the simplest true manifestation of the Axiom of Choice. A metamathematical analysis shows that assuming Projective Determinacy, there is really no manifestation within $H(\omega_1)$ of the Axiom of Choice. More precisely, the analysis of the projective sets, assuming Projective Determinacy, does not require the Axiom of Choice.

These considerations support the claim that the structure $(H(\omega_2), \in)$ is indeed the next structure to consider after $(H(\omega_1), \in)$, being the simplest structure where the influence of the Axiom of Choice is manifest.

**The Axiom $(\star)$**

I now come to a central definition, which is that of the axiom $(\star)$. This axiom is a candidate for the generalization of Projective Determinacy to the structure $(H(\omega_2), \in)$. The definition of the axiom $(\star)$ involves some more notation from the syntax of formal logic. It is frequently important to monitor the complexity of a formal sentence. This is accomplished through the Levy hierarchy.

The collection of $\Sigma_0$ formulas of our language $L(\in, \in)$ is defined as the smallest set of formulas which contains all quantifier-free formulas and which is closed under the application of *bounded quantifiers*.

Thus, if $\psi$ is a $\Sigma_0$ formula, then so are the formulas $(\forall x)(\exists y)(x \in y)$ and $(\exists x)(\forall y)(x \in y)$. We shall be interested in formulas which are of the form $(\forall x)(\exists y)(\psi)$, where $\psi$ is a $\Sigma_0$ formula. These are the $\Pi_2$ formulas. Somewhat simpler are the $\Pi_1$ formulas and the $\Sigma_1$ formulas; these are the $\Pi_2$ formulas in which $\forall$ is replaced by $\exists$ and $\exists$ by $\forall$ respectively. $\psi$ is again a $\Sigma_0$ formula.

Informally, a $\Pi_2$ sentence requires two (nested) "bounded searches" to verify that the sentence is true, whereas for a $\Pi_1$ sentence only one unbounded search is required. Verifying that a $\Sigma_1$ sentence is true is even easier.

For example, consider the structure $(H(\omega), \in)$, which I have already noted is in essence the standard structure for number theory. Many of the famous conjectures of modern mathematics are expressible as $\Pi_1$ sentences in this structure. This includes both Goldbach's Conjecture and the Riemann Hypothesis.

However, the Twin Prime Conjecture is expressible by a $\Pi_2$ sentence, as is, for example, the assertion that $P \neq \text{NP}$, and neither is obviously expressible by a $\Pi_1$ sentence. This becomes interesting if, say, either of these latter problems were proved to be unsolvable from, for example, the natural axioms for $(H(\omega), \in)$. Unlike the unsolvability of a $\Pi_1$ sentence, from which one can infer its "truth", for $\Pi_2$ sentences the unsolvability does not immediately yield a resolution.

If $M$ is a transitive set and $P$ and $Q$ are subsets of $M$, then one may consider $(M, P, Q, \in)$ as a structure for the language $L(\in, P, Q, \in)$, obtained by adding two new symbols, $P$ and $Q$, to $L(\in, \in)$. One defines the $\Sigma_0$ formulas and the $\Pi_2$ formulas of this expanded language in the same way as above.

The structure I actually wish to consider is $(H(\omega_2), \mathcal{I}_{\text{NS}}, X, \in)$,
where $X \subseteq R$ is universally Baire. If $\phi$ is a sentence in the language $L(\in, \in, \emptyset, \emptyset)$ for this structure, then there is a natural interpretation of the assertion that

$$\text{ZFC} + "(H(\omega_2), \mathcal{N}_X, X, \in) \models \phi"$$

is $\Omega$-consistent. The only minor problem is how to deal with $X$. But $X$ is universally Baire. Thus I define

$$\text{ZFC} + "(H(\omega_2), \mathcal{N}_X, X, \in) \models \phi"$$
to be $\Omega$-consistent if for every universally Baire set $A$ there exists a countable transitive set $M$ such that

1. $M$ is $A$-closed and $M$ is $X$-closed;
2. $(M, \in) \models \text{ZFC}^+$;
3. $(H(\omega_2)^M, \mathcal{N}_X^M, X \cap M, \in) \models \phi$, where

$$H(\omega_2)^M = \{a \in M \mid (M, \in) \models "a \in H(\omega_2)"\},$$

and

$$(\mathcal{N}_X)^M = \{a \in M \mid (M, \in) \models "a \in \mathcal{N}_X"\}.$$\text{Theories of ZFC}.

These are the relevant sets as computed in $M$.

With these definitions in hand, I come to the definition of the axiom $(\ast)$. The version I give is anchored in the projective sets; stronger versions of the axiom are naturally obtained by allowing more universally Baire sets in the definition.

**Axiom $(\ast)$:** There is a proper class of Woodin cardinals, and for each projective set $X \subseteq R$, for each $\Pi_2$ sentence $\phi$, if the theory

$$\text{ZFC} + "(H(\omega_2), \mathcal{N}_X, X, \in) \models \phi"$$
is $\Omega$-consistent, then

$$(H(\omega_2), \mathcal{N}_X, X, \in) \models \phi.$$\text{Theories of ZFC}.

What kinds of assertions are there which can be formulated in the form $$(H(\omega_2), \mathcal{N}_X, X, \in) \models \phi$$ for some $\Pi_2$ sentence $\phi$? There are many examples. One example is Martin's Axiom $(\omega_1)$. Another, which identifies a consequence of the axiom $(\ast)$, is the assertion that if $A \subseteq R$ and $B \subseteq R$ are each nowhere countable and of cardinality $\aleph_1$, then $A$ and $B$ are order isomorphic. A set $X \subseteq R$ is nowhere countable if $X \cap O$ is uncountable for each (nonempty) open set $O \subseteq R$. Thus, assuming the axiom $(\ast)$, there is exactly one possible order type for nowhere countable subsets of $R$ which have cardinality $\aleph_1$.

I refer the reader to [Shelah 1998] for details, references, and other examples.

The axiom $(\ast)$ is really a maximality principle somewhat analogous to asserting algebraic closure for a field.

A cardinal $\kappa$ is an **inaccessible cardinal** if it is a limit cardinal with the additional property that any cofinal subset of $\kappa$ necessarily has cardinality $\kappa$. For example, $\omega$ is an inaccessible cardinal. The axiom which asserts the existence of an uncountable inaccessible cardinal is the weakest traditional large cardinal axiom.

**Theorem.** Suppose that there exists a proper class of Woodin cardinals and that there is an inaccessible cardinal which is a limit of Woodin cardinals. Then $\text{ZFC} + \text{axiom} (\ast)$ is $\Omega$-consistent. □

There is an elaborate machinery of iterated forcing; this is the technique of iterating Cohen's method of building extensions [Shelah 1998]. It is through application of this machinery that, for example, the consistency of

$$\text{ZFC} + "\text{Martin's Maximum}"$$
is established (assuming the consistency of ZFC together with a specific large cardinal axiom, much stronger than, for example, the axiom that there is a Woodin cardinal).

Iterated forcing can be used to show the consistency of statements of the form $(H(\omega_2), \mathcal{N}_X, X, \in) \models \phi$ for a rich variety of $\Pi_2$ sentences $\phi$.

The previous theorem, on the $\Omega$-consistency of the axiom $(\ast)$, is proved using the method of forcing but not using any machinery of iterated forcing. Further, the theorem is not proved as a corollary of some deep analysis of which $\Pi_2$ sentences can hold in $H(\omega_2)$.

The axiom $(\ast)$ settles in $\Omega$-logic the full theory of the structure $(H(\omega_2), \mathcal{N}_X)$. The stronger version of the following theorem, obtained by replacing $(H(\omega_2), \mathcal{N}_X)$ with $(H(\omega_2), X, \in)$ where $X$ is a projective set, is also true.

**Theorem.** Suppose that there exists a proper class of Woodin cardinals. Then for each sentence $\phi$, either

$$\text{ZFC} + \text{axiom} (\ast) \models \phi \text{ or } \text{ZFC} + \text{axiom} (\ast) \models \phi$$

Suppose that $\phi$ is a $\Pi_2$ sentence and that $X \subseteq R$ is a projective set such that

$$\text{ZFC} + "(H(\omega_2), \mathcal{N}_X, X, \in) \models \phi"$$
is not $\Omega$-consistent. Then the analysis behind the proof of the $\Omega$-consistency of the axiom $(\ast)$ yields a projective witness for the corresponding $\Omega$-proof.

Thus the axiom $(\ast)$ is in essence an axiom which can be localized to $H(\omega_2)$. More precisely, there is a (recursive) set of axioms, i.e., a recursive theory $\mathcal{T}$, such that, assuming the existence of a proper class of Woodin cardinals, the axiom $(\ast)$ holds if and only if

$$(H(\omega_2), \mathcal{N}_X, X, \in) \models \mathcal{T}.$$\text{Theories of ZFC}.

Finally, assuming there is a proper class of Woodin cardinals, the axiom $(\ast)$ is equivalent to a strong form of a bounded version of Martin's Maximum, so again seemingly disparate threads are woven into a single tapestry.
The Axiom (*) and $2^{{\aleph_0}}$

There is a $\Pi_2$ sentence $\psi_{AC}$, which if true in the structure $(H(\omega_2), \in)$ implies that $2^{{\aleph_0}} = \aleph_2$.

The statement "$(H(\omega_2), \in) \models \psi_{AC}$" is $\Omega$-consistent, and so as a corollary the axiom (*) implies $2^{{\aleph_0}} = \aleph_2$.

**Definition** $\psi_{AC}$: Suppose $S$ and $T$ are each stationary, co-stationary, subsets of $\omega_1$. Then there exist: a closed unbounded set $C \subseteq \omega_1$; a well-ordering $(L, \prec)$ of cardinality $\omega_1$; and a bijection $\pi: \omega_1 \rightarrow L$ such that for all $\alpha \in C$,

$$\alpha \in S \rightarrow \alpha^* \in T,$$

where $\alpha^*$ is the countable ordinal given by the order type of $(\pi(\beta) \mid \beta < \alpha)$ as a suborder of $(L, \prec)$.

By standard methods $\psi_{AC}$ can be shown to be expressible in the required form (as a $\Pi_2$ sentence).

**Lemma.** Suppose that $\psi_{AC}$ holds. Then $2^{{\aleph_0}} = \aleph_2$. □

There is a subtle aspect to this lemma. Suppose that CH holds and that $(\alpha_n : \alpha < \omega_1)$ is an enumeration of $\mathbb{R}$.

Thus $\psi_{AC}$ must fail. However, it is possible that there is no counterexample to $\psi_{AC}$ which is definable from the given enumeration $(\alpha_n : \alpha < \omega_1)$.

I note that Martin's Maximum can be shown to imply $\psi_{AC}$. This gives a completely different view of why the axiom Martin's Maximum implies that $2^{{\aleph_0}} = \aleph_2$.

**And What about CH?**

The basic question is the following. Is there an analog of the axiom (*) in the context of CH? Continuing the analogy with the theory of fields, one seeks to complete the similarity:

$$\frac{? + \text{CH}}{\text{real closed + ordered}} \rightarrow \frac{\text{axiom (*)}}{\text{algebraically closed}}.$$ 

More generally: Under what circumstances can the theory of the structure $(H(\omega_2), \in)$ be finitely axiomatized, over ZFC, in $\Omega$-logic?

Formally the sentences of our language, $L(\in, \in)$, are (certain) finite sequences of elements of the underlying alphabet, which in this case can be taken to be $\mathbb{N}$. There is a natural (recursive) bijection of $\mathbb{N}$ with the set of all finite sequences from $\mathbb{N}$. This associates to each sentence $\phi$ of $L(\in, \in)$ a positive integer $k_\phi$, which is the Gödel number of $\phi$.

To address the questions above, I require a definition generalizing the definition of $0'$ where $0'$ is the set

$$\{k_\phi \mid \phi \text{ is a } \Sigma_1 \text{ sentence and } (H(\omega), \in) \models \phi\}.$$ 

Assuming ZFC is consistent, then the set

$$\{k_\phi \mid \phi \text{ is a sentence and } \text{ZFC} \vdash \phi\}$$

is recursively equivalent to $0'$ (a simple, though somewhat subtle, claim). In fact, one could reasonably take this as the definition of $0'$. This suggests the definition of $0^{(\Omega)}$.

**Definition.** Suppose that there exists a proper class of Woodin cardinals. Then

$$0^{(\Omega)} = \{k_\phi \mid \text{ZFC } \vdash \Omega \phi\}.$$ 

Suppose that $M$ is a transitive set and $A \subseteq M$. Then the set $A$ is definable in the structure $(M, E)$ if there is a formula $\psi(x_1)$ of $L(\in, \in)$ such that

$$A = \{a \mid (M, E) \models \psi(a)\}.$$ 

The following theorem is one version of Tarski's theorem on the undefinability of truth.

**Theorem (Tarski).** Suppose that $M$ is a transitive set with $H(\omega) \subseteq M$. Then the set $\{k_\phi \mid (M, E) \models \phi\}$ is not definable in the structure $(M, E)$. □

For each sentence $\phi$, the set $\{k_\phi \mid \text{ZFC } + \phi \models \phi\}$ is definable in the structure $(H(\omega), E)$. Thus by Tarski's theorem, for each sentence $\phi$ the set

$$\{k_\phi \mid \text{ZFC } + \phi \models (H(\omega), E) \models \phi\}$$

is not equal to the set $\{k_\phi \mid (H(\omega), E) \models \phi\}$. This is a special case of Gödel's First Incompleteness Theorem.

Analogous considerations apply in our situation, and so our basic problem of determining when the theory of the structure $(H(\omega), \in)$ can be finitely axiomatized, over ZFC, in $\Omega$-logic naturally leads to the problem: How complicated is $0^{(\Omega)}$?

This set looks potentially extremely complicated, for it is in essence $\Omega$-logic. Note that since

$$\{k_\phi \mid \text{ZFC } \vdash (H(\omega_1), E) \models \phi\}$$

is equal to the set $\{k_\phi \mid (H(\omega_1), E) \models \phi\}$ by Tarski's theorem, $0^{(\Omega)}$ is not definable in the structure $(H(\omega_1), E)$.

The calculation of the complexity of $0^{(\Omega)}$ involves adapting the Inner Model Program to analyze models of Determinacy Axioms rather than models of Large Cardinal Axioms.

This analysis, which is a bit involved and technical, yields the following result where $c^*$ denotes the least cardinal greater than $c$. Suppose that there exists a proper class of Woodin cardinals. Then $0^{(\Omega)}$ is definable in the structure $(H(c^*), E)$.

Now if the Continuum Hypothesis holds, then $c = \omega_1$ and so $H(c^*) = H(\omega_2)$. Therefore, if the Continuum Hypothesis holds, then $0^{(\Omega)}$ is definable in the structure $(H(\omega_2), E)$.

Appealing to Tarski's theorem, we obtain as a corollary our main theorem.

**Theorem.** Suppose that there exists a proper class of Woodin cardinals, $\mathcal{V}_\kappa \models \text{ZFC } + \Psi$, and for each sentence $\phi$ of $L(\in, \in)$ either

$$\text{ZFC } + \Omega \phi \models (H(\omega_2), E) \models \phi$$

or

$$\text{ZFC } + \Omega \phi \text{ or } (H(\omega_2), E) \models \neg \phi.$$ 

Then CH is false. □
There are more precise calculations of the complexity of \( \Theta(\omega) \) than I have given. For the indicated application on \( \text{CH} \), one is actually interested in the complexity of sets \( X \subseteq \mathbb{N} \) which are \( \Omega \)-recursive. Ultimately, it is not really \( \text{CH} \) which is the critical issue, but effective versions of \( \text{CH} \).

**The \( \Omega \) Conjecture**

Perhaps \( \Omega \)-logic is not the strongest reasonable logic.

**Definition (\( \Omega^* \)-logic).** Suppose that there exists a proper class of Woodin cardinals and that \( \phi \) is a sentence. Then

\[
\text{ZFC} \vdash \Omega^* \phi
\]

if for all ordinals \( \alpha \) and for all complete Boolean algebras \( \mathcal{B} \), if \( \mathcal{B}_\alpha \models \text{ZFC} \), then \( \mathcal{B}_\alpha \models \phi \).

Generic Soundness is immediate for \( \Omega^* \)-logic, and evidently \( \Omega^* \)-logic is the strongest possible logic satisfying this requirement.

The property of generic invariance also holds for \( \Omega^* \)-logic.

**Theorem (Generic Invariance).** Suppose that there exists a proper class of Woodin cardinals and that \( \phi \) is a sentence. Then for each complete Boolean algebra \( \mathcal{B} \), \( \text{ZFC} \vdash \Omega^* \phi \) if and only if

\[
\mathcal{B} \models "\text{ZFC} \vdash \Omega^* \phi".
\]

Having defined \( \Omega^* \)-logic, a natural question arises: Is \( \Omega^* \)-logic the same as \( \Omega \)-logic (at least for \( \Pi_2 \)-sentences)? The restriction to \( \Pi_2 \) sentences is a necessary one.

**\( \Omega \) Conjecture:** Suppose that there exists a proper class of Woodin cardinals. Then for each \( \Pi_2 \) sentence \( \phi \), \( \text{ZFC} \vdash \Omega^* \phi \) if and only if \( \text{ZFC} \vdash \Omega \phi \).

If the \( \Omega \) Conjecture is true, then I find the argument against \( \text{CH} \), based on strong logics, to be a more persuasive one. One reason is that the \( \Omega \) Conjecture implies that if theory of the structure \( \langle H(\omega_2), \varepsilon \rangle \) is finitely axiomatized, over \( \text{ZFC} \), in \( \Omega^* \)-logic, then \( \text{CH} \) is false.

**Connections with the Logic of Large Cardinal Axioms**

\( \Omega \)-logic is intimately connected with an abstract notion of what a large cardinal axiom is. If the \( \Omega \) Conjecture is true, then the validities of \( \text{ZFC} \) in \( \Omega \)-logic—these are the sentences \( \phi \) such that \( \text{ZFC} \vdash \Omega \phi \)—calibrate the large cardinal hierarchy.

To illustrate this claim I make the following abstract definition of a large cardinal axiom, essentially identifying large cardinal axioms with one fundamental feature of such axioms. This is the feature of "generic stability". It is precisely this aspect of large cardinal axioms which underlies the fact that such axioms cannot settle the Continuum Hypothesis. A formula \( \phi \) is a \( \Sigma_2 \) formula if it is of the form \( (\exists \chi)(\forall x_j \psi) \) where \( \psi \) is a \( \Sigma_0 \) formula.

Suppose that \( \kappa \) is an ordinal and that \( \phi \) is a \( \Sigma_2 \) formula. Then \( "V \models \phi(\kappa)" \) indicates that \( \phi \) is true of \( \kappa \) in \( V \), the universe of sets. Similarly, if \( \mathcal{B} \) is a complete Boolean algebra, then \( "V^\mathcal{B} \models \phi(\kappa)" \) indicates that \( \phi \) is true of \( \kappa \) in the Cohen extensions of \( V \) that \( \mathcal{B} \) could be used to define.

An inaccessible cardinal \( \kappa \) is strongly inaccessible if for each cardinal \( \lambda < \kappa \), \( 2^\lambda < \kappa \).

**Definition.** \( (\exists x_1 \phi) \) is a large cardinal axiom if \( \phi(x_1) \) is a \( \Sigma_2 \)-formula; and, as a theorem of \( \text{ZFC} \), if \( \kappa \) is a cardinal such that \( V \models \phi(\kappa) \), then \( \kappa \) is uncountable, strongly inaccessible, and for all complete Boolean algebras \( \mathcal{B} \) of cardinality less than \( \kappa \), \( V^\mathcal{B} \models \phi(\kappa) \).

**Definition.** Suppose that \( (\exists x_1 \phi) \) is a large cardinal axiom. Then \( V \) is \( \phi \)-closed if for every set \( X \) there exist a transitive set \( M \) and \( \kappa \in M \cap \text{Ord} \) such that

\[
(M, \varepsilon) \models \text{ZFC},
\]

and evidently \( \phi \)-closed.

The connection between \( \Omega \)-logic and first order logic is now easily identified.

**Lemma.** Suppose that there exists a proper class of Woodin cardinals and that \( \Psi \) is a \( \Pi_2 \) sentence. Then \( \text{ZFC} \vdash \Omega \Psi \) if and only if there is a large cardinal axiom \( (\exists x_1 \phi) \) such that

\[
\text{ZFC} \vdash \Omega "V \models \phi" \text{ is } \phi \text{-closed}.
\]

and such that \( \text{ZFC} + "V \models \phi" \text{ is } \phi \text{-closed} \models \Psi \).

An immediate corollary of this lemma is that the \( \Omega \) Conjecture is equivalent to the following conjecture, which actually holds for all (conventional) large cardinal axioms currently within reach of the Inner Model Program.

**Conjecture:** Suppose that there exists a proper class of Woodin cardinals. Suppose that \( (\exists x_1 \phi) \) is a large cardinal axiom such that \( V \) is \( \phi \)-closed.

Then \( \text{ZFC} \vdash "V \models \phi" \text{-closed} \).

The equivalence of this conjecture with the \( \Omega \) Conjecture is essentially a triviality.

Nevertheless, reformulating the \( \Omega \) Conjecture in this fashion does suggest a route toward proving the \( \Omega \) Conjecture. Moreover, the reformulation, in conjunction with the preceding lemma, shows quite explicitly that if the \( \Omega \) Conjecture is true, then \( \Omega \)-logic is simply the natural logic associated to the set of large cardinal axioms \( (\exists x_1 \phi) \) for which \( V \) is \( \phi \)-closed.

**The \( \Omega \) Conjecture and the Hierarchy of Large Cardinals**

To the uninitiated the plethora of large cardinal axioms seems largely a chaotic collection founded on a wide variety of unrelated intuitions. An enduring
The mystery of large cardinals is that empirically they really do seem to form a well-ordered hierarchy. The search for an explanation leads to the following question.

Is it possible to formally arrange the large cardinal axioms \((\exists x \phi)\) into a well-ordered hierarchy incorporating the known comparisons of specific axioms?

If the \(\Omega\) Conjecture is true, then the answer is affirmative, at least for those axioms suitably realized within the universe of sets. More precisely, suppose there exists a proper class of Woodin cardinals. The large cardinal axioms \((\exists x \phi)\) such that

\[ \text{ZFC} \vdash \Omega \ 	ext{"V is } \phi \text{-closed"} \]

are naturally arranged in a well-ordered hierarchy by comparing the minimum possible lengths of the \(\Omega\)-proofs, \(\text{ZFC} \vdash \Omega \ 	ext{"V is } \phi \text{-closed"} \).

If the \(\Omega\) Conjecture holds in \(V\), then this hierarchy includes all large cardinal axioms \((\exists x \phi)\) such that the universe \(V\) is \(\phi\)-closed. This, arguably, accounts for the remarkable success of the view that all large cardinal axioms are comparable. Of course, it is not the large cardinals themselves \((\kappa\text{ such that } \phi(\kappa)\text{ holds})\) which are directly compared, but the auxiliary notion that the universe is \(\phi\)-closed. Nevertheless, restricted to those large cardinal axioms \((\exists x \phi)\) currently within reach of the Inner Model Program, this order coincides with the usual order which is (informally) defined in terms of consistency strength.

Finally, this hierarchy explains, albeit a posteriori, the intertwining of large cardinal axioms and determinacy axioms.

Resolving the \(\Omega\) Conjecture is essential if we are to advance our understanding of large cardinal axioms. If the \(\Omega\) Conjecture is true, we obtain, at last, a mathematically precise definition of this hierarchy. But, as one might expect, with this progress come problems (of comparing specific large cardinal axioms) which seem genuinely out of reach of current methods. If the \(\Omega\) Conjecture is refuted from some large cardinal axiom (which likely must transcend every determinacy axiom), then the explicit hierarchy of large cardinal axioms as calibrated by the validities of \(\Omega\)-logic is simply an initial segment of something beyond.

**Concluding Remarks**

So, is the Continuum Hypothesis solvable? Perhaps I am not completely confident the "solution" I have sketched is the solution, but it is for me convincing evidence that there is a solution. Thus, I now believe the Continuum Hypothesis is solvable, which is a fundamental change in my view of set theory. While most would agree that a clear resolution of the Continuum Hypothesis would be a remarkable event, it seems relatively few believe that such a resolution will ever happen.

Of course, for the dedicated skeptic there is always the "widget possibility". This is the future where it is discovered that instead of sets we should be studying widgets. Further, it is realized that the axioms for widgets are obvious and, moreover, that these axioms resolve the Continuum Hypothesis (and everything else). For the eternal skeptic, these widgets are the integers (and the Continuum Hypothesis is resolved as being meaningless).

Widgets aside, the incremental approach sketched in this article comes with a price. What about the general continuum problem; i.e. what about \(H(\omega_3), H(\omega_4), H(\omega(\omega_1+\omega_2))\), etc.?

The view that progress towards resolving the Continuum Hypothesis must come with progress on resolving all instances of the Generalized Continuum Hypothesis seems too strong. The understanding of \(H(\omega)\) did not come in concert with an understanding of \(H(\omega_1)\), and the understanding of \(H(\omega_1)\) failed to resolve even the basic mysteries of \(H(\omega_2)\). The universe of sets is a large place. We have just barely begun to understand it.

**References**


Arnold Ross, summer 1996.

Arnold Ross has been a major figure in American mathematics for the past several decades. He is best known for his program for mathematically talented high school students, which since its founding in 1957 has had various official names but is referred to, universally and fondly, as the Ross Program. Through this program Ross's love of mathematical exploration and his uncompromising standards have touched the lives of over 2,000 youngsters.

From his years as a student at the University of Chicago in the 1920s and 1930s, through his positions as chair of the mathematics departments of Notre Dame University and of the Ohio State University, Ross came into contact with some of the leading mathematicians of the twentieth century. While he has always taken an active interest in research, especially in number theory, his true calling is education. He seemed always to be one step ahead, organizing a program to improve teachers' mathematical knowledge before Sputnik woke the nation up to the inadequacy of mathematics and science instruction, and launching a program for inner-city minority students before the term "underrepresented groups" became a buzzword. In all his endeavors his aim is to kindle a passion for intellectual challenges.

Early Years in Odessa

Arnold Ephraim Ross was born Arnold Ephraim Chaimovich on August 24, 1906, in Chicago, an only child of Jewish emigrants from the Ukraine. In 1909 his father was not working, and his mother, a physical therapist, was the sole supporter of the family. She and Arnold then left the United States, bound for Odessa, where her extended family could provide help and security. The outbreak of the First World War in 1914 and the Russian Revolution in 1917 caused famine and economic deprivation. But young Arnold's education was not neglected.

Notices: From the beginning you had a strong love of learning. Where did that come from?
Ross: My mother. She knew that we were surrounded by proud people who wanted to talk Yiddish. But she wouldn't have it. She made me feel from the time I was small that the duty of everybody is to first master the language of the country they live in. The result was that I spoke very good Russian. The theater was very good in Odessa and also very much respected and liked by the intelligentsia. I loved the theater, I loved the language. I always had a deep feeling for the mystery of language as a tool for communication.

My mother's attitude toward study and learning was not rigid, but I was encouraged to read. We had very little money, and there were no public libraries, so she subscribed to a private library. We could not really afford it, but we had it. So I did an awful lot of reading. Among the things I absorbed was respect for people of learning and a love of exploration—first geographical exploration and then explorations of all kinds.
Ross 45th Reunion Conference

On July 27-29, 2001, a reunion conference celebrating the 45th year of the Ross Program will be held at the Ohio State University. The conference will be a time for friends of Arnold Ross and alumni of his program to gather in Columbus to renew contact and to celebrate the ongoing mission of the Ross Program.

In August 2000, at age 93, Ross suffered a stroke that left him unable to continue teaching in the program. But his mind and speech are unimpaired, and he plans to attend the reunion conference.

The conference will feature scientific lectures on a variety of topics. Many of the program alumni went into fields other than mathematics, so the talks will be accessible to nonspecialists, and some will be geared to current participants in the Ross Program. Capping the conference will be a banquet sponsored by the Clay Mathematics Institute, which has worked in partnership with the Ross Program for the past two years.

Information about the Ross Reunion Conference is available on the Web site http://www.math.ohio-state.edu/ross/rossconf2001.html. The Ross Program is also working to update its database of e-mail addresses of program alumni and friends. A recent version of that list is posted on the Web at http://www.math.ohio-state.edu/ross/alumni/. The program organizers would appreciate additions or updates to this information.

A.J.

My uncles were all medical people, and one of them, whom I especially loved and admired, was an X-ray diagnostian. This uncle was responsible for my opportunity to start studying mathematics. His own boy was very talented, so he hired the mathematician S.O. Shatunovsky as a tutor. There were lots of anecdotes about Shatunovsky. He was Jewish and had trouble getting a university position. Finally his colleagues got him a special permit to do so, and he had to pass an examination. When Shatunovsky came to be examined, it was not a friendly audience. One of the examiners asked about something he himself had discovered just that morning. Shatunovsky thought for a couple of minutes and came up with an answer. Whereupon the examiner said, "Where did you learn that? I thought I discovered it this morning!" So you see what I would take pride in from the time I was very young.

I loved mathematics, so when my uncle had Shatunovsky tutor his boy, I wanted to be a part of it. And of course my uncle said yes. What was Shatunovsky paid? Well, inflation was so pronounced that money didn't mean very much. His fee was a pound of French hard candy. So when Shatunovsky was employed by my uncle to tutor his boy, I was included in that pound of candy.

Notices: Did Shatunovsky teach his lessons in Russian?

Ross: Oh, yes. His Russian was perfect. He was also a charismatic lecturer.

This was the time of the famine, so many universities were closed. A group of university professors put together a Gymnasium [academic school]. They were all very able people mathematically. They did not teach us according to the prescription of a textbook. Our geometry teacher never lectured on proofs in geometry. What he did was say, "Now, let's take a look at this. What do you think is true?" We made guesses, some wrong, and we had to justify them. I loved to go to the blackboard in these sessions. That was really the beginning of my being cut off from the kind of strict education where you study to pass exams.

Later, when the University of Odessa reopened, Ross was among a small group of youngsters given special permission to attend courses there. Shatunovsky was one of the professors.

Ross: The students of course were crazy about Shatunovsky. Once we were on the veranda of the university, extolling Shatunovsky's remarkable personality and teaching. A biologist overheard us and said, "I don't know any mathematics, but nobody could be this good." So we said, "All right, come and listen to his lecture." "But I don't know any mathematics, and really I don't want to," he said. But we made him come and hide in the back of the room. When the lecture was over, we were all moving to the door; and there he was, his eyes shining, and he said, "I didn't understand a thing, but it was so wonderful!"

Notices: You left Odessa in 1922, when you were about 16 years old. How did you get out of Odessa?

Ross: I was born in Chicago, so I was an American citizen, according to the laws of that period, and because of that I was given my passport into the United States without any difficulty. But to get out of Russia, you had to have the permission of the secret police. So I went to the chief of the secret police to get permission. He questioned my being an American citizen. He said, "According to the laws of the Soviet Union, you are not an American." I said, "But I am an American!" It went on like that, back and forth. He had a gold pince-nez, which showed he had a sense of culture. He was getting a little angry; then all of a sudden he stopped, looked at me carefully, and realized that he was fighting a child. He signed my papers and said, "Get out of here before I change my mind!" I knew well enough to get out!

Then I had to take a ship to Constantinople [now Istanbul]. I'm here today because the police were not honest and my mother did not know how to discreetly bribe them. Fortunately, one of our relatives knew very well how to do it. By the time this relative left the money properly and I got permission to go, I had missed the ship. That ship was mined and also perhaps overloaded. Half a
dozen people were saved out of a couple hundred. So you see, that is fate.

Student Days in Chicago

Determined to get on the next ship, Ross went to see the ship’s captain. Although Ross had the necessary documents, the captain was wary of taking such a young passenger traveling alone. Ross sat on the captain’s doorstep every morning for two weeks until the captain relented. After arriving in the United States, Ross returned to Chicago, with the intention of studying at the University of Chicago with E. H. Moore, a pioneer in modern topology. Moore led the mathematics department at Chicago from 1892 until 1927, when Gilbert Ames Bliss was made chair. Moore built the department into an important center for research.

Notices: Did you know about E. H. Moore when you were in Odessa?

Ross: Yes. My Gymnasium teachers told me, “If you can go to the University of Chicago, study with E. H. Moore.” I had that in my mind. When I got to Chicago I got a job in a bookbinding shop. The owner was a friend of the family. He thought I should not try to get into the university. He wanted me to learn linotyping. He said, “That’s the place where there’s money.” He was very opinionated, but I didn’t think he was learned enough to really understand.

Notices: Did you speak English then?

Ross: I would not say I could speak English, but I could understand some, because I had studied English during the year before I left for America. I also studied English when I got to Chicago, at the Lewis Institute [now the Illinois Institute of Technology].

Notices: Did you live with your father in Chicago?

Ross: Only for about a week or so, until I got my first job. We never got along. I got a room in a house owned by friends of the family. But the environment was very unintellectual.

Notices: What did your father do?

Ross: He was a mechanical engineer. He had gotten his degree in Germany. But he was not very ambitious and was never successful as an engineer. By that time it was obvious I wanted to be a mathematician. My father said, “If you study engineering, I’ll help you. If you want to be a mathematician, you can starve on your own!” Interesting, isn’t it?

To understand. And the first one shook his head and said, “No alcohol.” So the other laborer asked me, “What happened to you? Are you ill?” “Oh, no,” I said, “I am not ill. But I am very, very tired. I just got off my shift.” I was only 17 years old. The two of them babyed me until I got off. You see, mathematics was not formally imbedded in me, but there were many positive influences in my life that were indestructible. That’s what I have been trying to give to others.

After working a year at the bookbinding shop, Ross had saved enough for tuition for one term at the University of Chicago. He then enrolled in a course taught by E. H. Moore.

Ross: E. H. Moore was head of the department at the University of Chicago. When he was made head, he was young and untired. But he had worked in Germany and had a very good mathematical background, and he was also very talented. He hired two distinguished German mathematicians [Oskar Bolza and Heinrich Maschke]. Moore held his own, and they respected him even though they considered him an upstart.

Moore knew that I did not have traditional schooling, so he gave me special attention and encouraged me. He knew how young I was. The university made a special concession for the fact that I had no diploma of any kind and let me take Moore’s course in topology. I was the only undergraduate in that course.

Moore’s teaching was even stronger than that of our teachers in the Gymnasium. He taught us the beginnings of topology. He never lectured. He would tell us what he conjectured, and we were to prove it. If we had suggestions as to what may be true, we would give them; then we would defend them. It was incredibly exciting. He never paid much attention to the school bell. His lessons might last half an hour or one hour or two hours. So it was best for us not to plan our lunches.

Calculus was taught in a traditional way. But E. H. Moore taught...
Arnold Ross, summer 1996, Ohio State.

Dickson was responsible for most of that.

Gilbert Bliss was also at Chicago then. He worked in the calculus of variations. He certainly was not a trivial mathematician, but he had strange prejudices in education, and he was very narrow-minded in many ways. Individuals sometimes become instruments in slowing down progress. Bliss was one of those people. When I got my Ph.D. with Dickson, Bliss gave me a lecture on discretion. What did that lecture consist of? He said: "Now remember, you learned many things from Dickson, and in a sense you have to always credit him with that and never forget it. Some of my pupils sometimes use my ideas to advance themselves without giving me proper credit." Dickson would never have said anything like that, because he was a most generous man and to him progress was important, not credit-giving. But Bliss was very different.

As one of Dickson's 64 doctoral students, Ross finished his degree in 1931, with a dissertation entitled "On representation of integers by indefinite ternary quadratic forms". That same year he married Bertha (Bee) Halley Horecker, a talented singer and musician who was the daughter of some neighbors of Ross in Chicago. After a two-year fellowship at Caltech, Ross and his wife returned to Chicago.

 Notices: You went back to Chicago around 1933, during the Depression, and you taught at the People's Junior College. What was the People's Junior College?

 Ross: That was a fantastic thing. During the Depression many community colleges closed. A group of very talented, socially minded people decided that all those youngsters who were out of school because there was no place for them to go should have a place. So we started the People's Junior College in a Jewish community center. I was teaching mathematics and physics. We had on the faculty a young economist from the University of Chicago. Chicago was very strong in economics and has always been. He was so accomplished that even as he was teaching in the People's Junior College, he was employed as an advisor by many governments.

 The People's Junior College had to be approved by a state education board. Everybody told us, "That board is very strict and doesn't encourage new enterprises. Don't hope to get approval within a reasonable time." A member of the board visited the college, and he came to my classroom. I was very unorthodox, and I made my students participate in discussion in the classroom and do a little exploration. The board member was at first very stiff, but as he participated in what the class was doing, he visibly warmed up. The result was that we were approved right away. In retrospect, everybody was surprised.

 Notices: How long did you teach there?

 Ross: I think almost a year.

 Notices: And then what happened to the college?

 Ross: We tried to keep it alive, but it didn't work, because there were very few people who were prepared to give it so much of themselves.

 In 1935 Ross joined the faculty of St. Louis University, which is a Jesuit institution. Heightened awareness of racial inequality led the university to start admitting black students in 1944, a bold and progressive move at the time. Another decade had to pass before the landmark court decision Brown v. the Board of Education of Topeka mandated desegregation of the nation's public schools.

 Ross: One of my students at St. Louis University was the first black woman to receive an M.S. in mathematics in the South. She was handicapped because she had had polio when she was young, and she was paralyzed in the left leg. The students and the young priests were with me in saying she should be accepted to the university, and that's actually what made it possible for the university to make an exception and to start...
accepting black students when it was a very unpopular thing to do.

Usually upon graduation the students would form a marching arrangement and would walk around the block downtown, not far from the building in which the university was holding classes. It was obvious that the marching tempo of healthy students was a little too fast for this student of mine. So I asked one of the youngsters who was directing things if he had noticed she could not keep up. He said, "I didn't. We'll take care of it." They did. The tempo of the whole procession came down to the tempo that could be maintained by my student. Well, it makes you feel good about your young people. I so wanted her to get a higher degree. She was capable, but money was the constraining feature. She was the sole supporter of her aging mother.

**Notre Dame Years**

Many distinguished mathematicians fled Europe during World War II and came to the United States. One of these was the Hungarian mathematician Gabor Szegö, who spent a few years at Washington University in St. Louis before taking a position at Stanford University. In St. Louis the Szegö and Ross families became good friends. On Szegö’s recommendation Ross was accepted to a summer school at Brown University designed to sharpen the skills of young scientists and mathematicians so that they could help with the war effort. Ross went to Brown in the summer of 1941 and came into contact with two more refugee mathematicians, Jacob Tamarkin and Antoni Zygmund. Between 1941 and 1945 Ross periodically spent time doing war-related research in the laboratory of Stromberg-Carlson, an electronics and communications firm in Rochester, New York. He worked on proximity fuses, which are bomb fuses that cause detonation when the bomb comes within a certain proximity of its target. In 1946 Ross accepted an offer to succeed Karl Menger as chair of the mathematics department at the University of Notre Dame. Ross worked hard to improve the research climate there, inviting such visitors as A. Adrian Albert, Max Dehn, Kazimierz Kuratowski, Louis J. Mordell, Marston Morse, Wacław Sierpiński, Thoralf Skolem—and the inimitable Paul Erdős.

**Notices:** What do you remember about Paul Erdős’s visits to Notre Dame?

**Ross:** Paul Erdős was a friend. He would come, lecture, and get everybody excited, with lots of discussion.

**Notices:** Did he teach at Notre Dame?

**Ross:** That’s an interesting story. Paul Erdős was never given an academic job, because the administrators in American colleges thought he didn’t know how to teach. What a shocking lack of wisdom! Well, that is so common in academic life. When I invited Paul to come to Notre Dame, he accepted right away. At our first meeting in my office, Paul said, "What will be my duties? You know I have not had a background of regular academic positions." I said, "Paul, you are a distinguished mathematician, so you must have a position that matches your distinction. You are going to be a full professor of mathematics, with all the duties and responsibilities thereto appertaining." So you see, we cut across this idea of his inability to teach. Full professor, with everything—the hard work and the pleasure. For his course in set theory I chose among the graduate students those who could appreciate him. And those students had the most exciting time of their lives. It was a remarkable course—difficult, yes, but not unduly difficult, just real mathematics. People thought Paul might be a bad teacher because of his emphasis on research and on asking new questions. Somehow, in the eyes of many near-sighted people, research and teaching are not related. We still have some people like that. If you knew Paul, you would understand that he would be an excellent teacher because his ideas of how to do mathematics were right.

I knew Erdős’s mother—a remarkable woman. Everybody used to ask her to help if they wanted to reach Paul. Paul traveled so much that the only way to find out where he was, was to call his mother. Whenever I had to write to Paul about something urgent, I would write to her to find out where he was traveling, and then on the basis of that information I would choose five places and write to each one of them. Paul entered into the spirit of this. He answered every one of my letters.

**Notices:** Did he answer them all the same way?

**Ross:** No, but usually my letters were about different things. I would not write Paul five letters that were very much alike. As I said, Paul traveled a lot, so very often he would come unannounced, and usually he would be a welcome guest. One time a friend, a mathematician whose name...
“Think Deeply of Simple Things”

Each summer fifty or sixty students, ranging in age from 14 to 19, spend eight weeks on the campus of the Ohio State University as participants in the Ross Summer Mathematics Program. With only a modicum of advertising and mostly through word-of-mouth, the program attracts some of the most talented students from all over the country. The aim is not to turn them all into mathematicians, but rather to give them, in the words of Arnold Ross, “a vivid apprenticeship to a life of exploration.” Most of the students are profoundly changed by the experience.

Funding has waxed and waned over the years, but the Ross Program has always managed to stay afloat. The most consistent support has come from the Ohio State University. The National Science Foundation has over the years provided varying levels of funding. Recently, substantial support has come through a partnership with the Clay Mathematics Institute. The program has also received grants from the AMS Epsilon Fund (see “AMS Epsilon Fund Makes Awards”, Notices, May 2001, page 515) and the Oracle Corporate Giving Program.

The Ross Program has inspired the creation of similar programs at other institutions. Those most closely resembling the Ross Program include PROMYS at Boston University, run by Glenn Stevens, and the Honors Math Camp, run by Max Warshauer at Southwest Texas State University. Others whose educational programs were influenced by Ross include Paul Sally of the University of Chicago and Manuel Berroizabal of the University of Texas at San Antonio.

There are several key elements in the success of the Ross Program. One is the focus on number theory, which allows students with relatively little mathematical background to grapple with deep ideas. Another is the daily problem sets, which Ross has honed carefully over the years. These are not the usual school math problems; many of them simply present a statement together with the instruction “Prove or disprove and salvage if possible.” Starting with relatively simple questions, the problem sets lead students on explorations of increasing depth as their ability to handle abstraction grows. This notion is captured in the program’s motto “Think deeply of simple things”.

Another key element is the role of the counselors. Carefully chosen from the ranks of program alumni, the counselors read the solutions to the daily problem sets and provide extensive, individualized feedback. Because they live in the same dorms as the students, the counselors act as the eyes and ears of the program, alerting the directors to potential problems among the students. The counselors also take special advanced mathematics courses during the program. Becoming a counselor is a point of honor for Ross Program participants, and the continual handing down of traditions helps insure the vitality of the program.

And then there is Ross himself. With his trademark string tie, his Old World manners, and a slight Russian lilt in his voice, he seems an unlikely figure to appeal to a bunch of American kids. How does he relate to them? “That’s the magic of mathematics,” says Ross’s longtime Ohio State colleague, Dijen Ray-Chaudhuri, who has taught in the program for years and whose three children are program alumni. Through the abstraction of mathematics Ross bypasses the usual barriers to communication and introduces the students to a world of ideas.

—A.J.
of National Guardsmen with bayonets confronted a couple of thousand students demonstrating in front of the university administration building; this occurred just days before the fatal shootings on the Kent State University campus. Ross and other Ohio State faculty, wearing red armbands to signify their neutrality, formed a line between the guardsmen and the students, attempting to calm the situation. H. Marks Richard, a professor of mathematics at Norfolk State University, who was a graduate student at the time, witnessed the scene. As he explains it, "Dr. Ross put his own life on the line to protect the students."

**Notices:** In 1970 students were rioting on the campus. What do you remember of that time?

**Ross:** I tried to keep things quiet by walking around the campus. I felt that the students were right in everything except rioting. I gave them a great deal of sympathy, because I felt that they should get better treatment but that rioting was not the way. Walking on the campus at that time was not a very safe thing to do, because rioting could break out anywhere. But whenever I would find myself close to the rioting, I saw some black faces right near me, forming a protective cordon, which meant I had been able to make them see how little sympathy I had for the feelings of racial prejudice.

Around that time I had a student, a young lady, who was very ambitious with regard to learning, and I tried to encourage her. Once when we were sitting talking about our studies, she said, "Professor Ross, I want to ask you something. I hope you won’t mind and you’ll be candid. Doesn’t it make any difference to you that I am black?" Of course, I started laughing. I said, "Not a bit. It just doesn’t affect me at all." She looked relieved, because she didn’t want to hurt my feelings. We continued discussion of our studies, and I didn’t come back to the topic. To discuss that sort of thing would be to honor it with our attention.

In 1976, at age 70, Ross took mandatory retirement from Ohio State. Felix Browder, then at the University of Chicago, encouraged Ross to bring his summer program for high school students to Chicago, and it was held there for two years. Another Chicago faculty member, Paul Sally, was inspired by the program.

**Notices:** You met Paul Sally when the program moved to Chicago for two years.

**Ross:** Yes. At first Paul was not such an enthusiastic supporter of the program, since at that time he was the chair and finances had to be considered. But now he is very supportive. He also started his own program for gifted students, and he spends considerable time with undergraduates at Chicago, which is very good. He also gave his own money for the Arnold Ross Lecture Series. That is something that could do much good, provided that quality is always held uppermost. For a while it looked as if there would be no support for the

Madeleine and Arnold Ross in 1996 with Ohio State colleague Dijen Ray-Chaudhuri (far right) and his wife, Joya.

series, but Paul Sally gave the money. He has been an immense supporter of that sort of thing.

In 1983 Ross's wife, Bee, died after a protracted illness. Her death affected Ross deeply. Friends and colleagues say that during this dark period Ross lived only for his summer program. He would come to life as he taught in the program, eventually abandoning the cane he used during the rest of the year. He was rejuvenated when he met Madeleine Green, a widow and a native of France, who as the wife of a diplomat had traveled and lived all over the world. The two married in 1990.

In the summer of 2000, at age 93, Ross taught for the last time in his summer program. Later that year he suffered a stroke, and although his mind is unimpaired, the physical debilitation meant he could no longer teach. The Ross Program will continue under the leadership of Ohio State faculty member Daniel Shapiro.

**Inspiring Students to Excel**

Those who have seen Arnold Ross at the front of a class speak of his masterly ability to marshal the group's energy and enthusiasm. At the same time, he never loses touch with individual needs and personalities. His aim is to spark each individual intellectual experiences that enrich and ennoble.

**Notices:** In your summer program the students are extremely competitive. How do you handle that?

**Ross:** You encourage it. Except that being competitive doesn't mean being mean, and it doesn't mean that you don't help other people who may

The Arnold Ross Lecture Series is a program run by the AMS in which outstanding mathematicians present lectures to groups of high school students. The lectures are presented once a year in different cities in the U.S. For further information, see "Inside the AMS" in this issue of the Notices.
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become competitors. We didn’t talk much about these things because that doesn’t bring good results. We created an atmosphere where not to help somebody who needed help was undesirable.

Notices: But did the competition get out of hand sometimes?
Ross: Ah, but we watched carefully. You see, things get out of hand if you keep hands off. Otherwise, how can they get out of hand? So you have to watch very carefully.

Those kids are phenomenal. If anybody tells me that our children don’t have the ability, don’t have the interest, don’t have this or that—all that is very empty. That is believed by people who keep their hands off the very essential parts of education. They talk about education, but many of them have never experienced good education.

Notices: The Ross Program has always attracted more boys than girls. Do you think it’s true that girls have less mathematical ability?
Ross: I think that some girls have exceptional talents. No, I think that what happens is grotesque. There are teachers who tell students, “You’d better not try because you won’t succeed.” Some teachers are not prejudiced against women, but if they think a student is not able, they tell the student so. And that of course is very wrong. I know many cases where there was no exceptional talent, but once there was strong desire to excel, there were no mental hazards, other than the original prejudice, that would stand in the person’s way. This business of generalizing about ability is an empty enterprise.

A strong desire to achieve something is terribly important. You may be very much interested in your students and guide them well, but if you don’t give them an opportunity to suffer a little on their own with some problems, as a rule nothing happens afterwards. But if you get them excited about doing something, they will fight through.
Women Becoming Mathematicians: Creating a Professional Identity in Post-World War II America

Reviewed by Judy Green

In *Women Becoming Mathematicians: Creating a Professional Identity in Post-World War II America*, Margaret A. M. Murray gives a fascinating picture of thirty-six women who earned Ph.D.’s in mathematics in the United States during the twenty years between 1940 and 1959. Her careful examination of the lives and careers of these women is based on the extensive interviews she conducted with them. Murray succeeds in providing a coherent collective picture of her interviewees, and in this respect her book is unique among books that examine the lives and careers of women mathematicians.

The group of women Murray interviewed includes some whose names are well known in the mathematical community, although most of the names will not command general recognition, even among mathematicians. Among the best known women Murray interviewed are Evelyn B. Granville (Yale University, 1949), the first African American woman to receive a Ph.D. in mathematics;1 Cathleen S. Morawetz (New York University, 1951), the first woman elected to the applied mathematics section of the National Academy of Sciences and the second woman president of the AMS;2 Lida K. Barrett (University of Pennsylvania, 1954), the second woman president of the Mathematical Association of America;3 and Alice T. Schafer (University of Chicago, 1942), the second president of the Association for Women in Mathematics.4 Murray’s interviewees are self-selected, first by either maintaining membership in a mathematical organization or by staying in contact with those who did, and then by responding to a solicitation for an interview. They are drawn from the approximately two hundred women she identified as having received Ph.D.’s during the middle fifth of the twentieth century. These two hundred women represent 6 percent of the total number of Ph.D.’s in mathematics granted by American institutions during those two decades. For comparison, during the rest of the twentieth

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1The only other African American woman to receive a Ph.D. in mathematics between 1940 and 1959 was Marjorie Lee Browne (Michigan, 1950).

2The first woman president of the AMS was Julia Robinson (Berkeley, 1948).

3The first woman president of the MAA was Dorothy Bernstein (Brown, 1939).

4The first president of the AWM was Mary Gray (Kansas, 1964).
century the representation of women among all Ph.D.'s in mathematics awarded by American institutions was 13 percent (1900-19), 14 percent (1920-39), 8 percent (1960-79), and 20 percent (1980-99).

Murray builds her book on a conceptual framework that she calls the myth of the mathematical life course. According to Murray the myth supposes that "the process of becoming a mathematician is one of single-minded, lifelong dedication to the ideal of research excellence" (p. 199). Murray uses masculine pronouns in her lengthy description of the myth, since she will show that it is not consistent with the mathematical life course of the women she interviewed. The myth, as Murray articulates it, includes the following elements:

- "[M]athematical talent and creative potential emerge very early in childhood. . . ."
- "In college, that the major will be mathematics is a foregone conclusion, and the student proceeds from college to an elite graduate school."
- "In graduate school, the student comes under the tutelage of a powerful mentor, under whose direction he writes a doctoral dissertation that makes a significant contribution to his area of study. . . ."
- "His mentor assists him in landing a postdoctoral research position at a similarly elite doctorate-granting department of mathematics, and afterward he goes on to one or more positions at comparably distinguished universities, where his creative achievements are rewarded with tenure."
- "The mathematician is extraordinarily productive in research from his late teens until his early forties and during this period does his best work. . . ."
- "It is very helpful if the mathematician has a spouse who will take care of domestic and family concerns and provide him with a peaceful home environment that supports his creative work."
- "In the later years, research productivity continues, albeit at a somewhat lesser rate. . . ."
- "It is perhaps possible, later in life, for the mathematician to enjoy some hobbies and diversions, but his primary concern is and continues to be mathematics." (p. 16)

Although we all are aware of male mathematicians who do not closely fit the mathematician of this myth, I have heard enough mathematicians espouse various parts of it to know that there are many in the mathematical community whose expectations of themselves and others reflect much, if not all, of the myth as Murray describes it. Murray makes the point that, although in many respects the myth dates back to the nineteenth century, it gained power in the post-World War II period, particularly through personal accounts written by and about male research mathematicians. Using the recollections of women mathematicians whose lives do not conform to the myth, she provides a counterbalance to the impressions left by these biographies and memoirs.

Women Becoming Mathematicians starts with a short historical introduction that includes a description of the growth of participation of American women in mathematics from the late nineteenth century until just before World War II. Murray also describes the division of the mathematical community into teachers and researchers that occurred around the time of World War I as well as the participation of women in mathematics during World War II and afterwards. She then gives us an introduction to the women Ph.D.'s of the 1940s and 1950s in the context of American society at the time. Although Murray notes that biographical information on many of these women exists in standard reference sources, she does not provide sufficient data to substantiate her assertion that her interviewees constitute "a representative sampling of the professionally active women mathematicians of this generation" (Murray's italics, p. 22). This is the only lapse in the book's otherwise excellent documentation.

Besides a set of norms against which the careers of her interviewees can be assessed, the myth provides a chronology on which the book is organized and on which Murray's questions to her interviewees were based. Chapters 3 through 8 are entitled: Family Background and Early Influences; High School and College; Graduate School and the Pursuit of the Ph.D.; Interweaving a Career and a Life; Teaching, Research, and the Question of Identity; and Dimension of Personal and Professional Success. In each chapter Murray provides the relevant information concerning the lives of some of her interviewees and shows how they do and do not correspond to the norms of the myth. She also shows how her interviewees overcame obstacles, some of which were obvious artifacts of the myth. As Murray points out, these are the stories of women who succeeded in becoming mathematicians, women who "had the patience, the stamina, the financial and moral support of families who helped them to overcome the obstacles" (p. 99). From these success stories, which are rich in detail, we learn that not only do these women not follow the model of the myth of the mathematical life course, they do not follow any single model. In addition to presenting the recollections of these women, Murray conveys their feelings towards various incidents in their lives, such as pride, acceptance, anger, and bitterness.

Murray’s interviewees come from all types of backgrounds. Some were raised in cities and others on farms, some had parents without high school degrees and others had parents with doctorates, some had no siblings and others had many siblings,
some were educated in public schools and others were educated at home. In very few cases did mathematical talent become evident in childhood.

A significant portion of Women Becoming Mathematicians centers on college and graduate school training. Again the interviewees had vastly different experiences. They attended women's colleges, women's coordinate colleges of men's schools, and public and private coeducational colleges and universities. Most lived at home for all or most of their college experience, and more than one-third had graduated from college by the time they were twenty. Almost all the interviewees spoke of at least one teacher who could be considered a mentor, and their most encouraged encouragement from male teachers. Most did not see a mathematics major as a foregone conclusion; many found in college an explicit message that women do not become mathematicians.

Most of the interviewees did not proceed quickly from the undergraduate degree to the doctorate. Some taught; some raised families. Although more than one-third of the interviewees were very young when they received their undergraduate degrees, very few of them proceeded to a doctorate by the age of twenty-five. Only twenty schools appear on the list of institutions that granted Ph.D.'s to the thirty-six interviewees. New York University and the University of Chicago granted the most, six and five respectively. While NYU and Chicago were clearly hospitable to women graduate students, they were not as encouraging as the numbers might imply. NYU assigned its women graduate students editorial and clerical tasks early in their graduate student careers, although they usually were given more explicitly mathematical work later. Furthermore, while NYU often offered employment to its new Ph.D.'s in applied mathematics, typically the males were hired into tenure-track positions while the females were offered research associateships. On the other hand, NYU prepared its women Ph.D.'s in pure mathematics to enter the larger mathematical community. Chicago did not; instead it trained women to be college teachers rather than researchers.

The longest chapter in Women Becoming Mathematicians looks at the interviewees' lives and careers subsequent to graduate school. Murray describes two models for an academic career: “the women's college model, which entailed nearly selfless devotion to the college and emphasized teaching generally to the exclusion of research, and the emerging model of the research career provided by the myth of the mathematical life course” (p. 159). She notes that the latter model was not generally available to women, since the universities that saw themselves as research institutions were not hiring women onto their faculties. Nonetheless, of the three-quarters of the women who had academic careers, Murray identifies about one-third as researchers, another one-third as teachers, and the final third as scholar-teachers. She describes this last category as “a creative synthesis of the 'female' role of teacher and the 'male' role of research mathematician” (p. 45).

A pervasive theme throughout the book is the effect of marriage and children on the education and careers of the interviewees. Although most of the 1940s Ph.D.'s expected to marry and have children, only ten of the seventeen, less than 60 percent, married; all of the marriages occurred after receipt of the doctorate. On the other hand, seventeen of the nineteen 1950s Ph.D.'s married, fifteen before receipt of the Ph.D. This may account, at least in part, for a longer average time between

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Interviewees for Women Becoming Mathematicians

In the following list of the thirty-six women who were interviewed for the book, a surname in italics denotes the name under which the Ph.D. was granted; if a name appears in parentheses, it was later dropped. The women and the school and year of their Ph.D.'s are:

- Anne Lewis Anderson (Chicago, 1943)
- Winifred Asprey (Iowa, 1945)
- Lida Barrett (Pennsylvania, 1954)
- Grace Bates (Illinois, 1946)
- Barbara Beechler (Iowa, 1955)
- Janie Lapsley Bell (Illinois, 1943)
- Anne Whitney Calloway (Pennsylvania, 1949)
- Mary Dean Clement (Chicago, 1943)
- Jane Cronin Scanlon (Michigan, 1949)
- Patricia (Wells) Eberlein (Michigan State, 1955)
- Herta Freitag (Columbia, 1953)
- Betty Jane Gasser (NYU, 1957)
- Evelyn Boyd Granville (Yale, 1949)
- Susan Hahn (NYU, 1957)
- Violet Hachmeister Lame (Wisconsin, 1950)
- Anneli Lax (NYU, 1955)
- Edith Luchins (Oregon, 1957)
- Dorothy Maharam Stone (Bryn Mawr, 1940)
- Margaret Owchar Marchand (Minnesota, 1950)
- Margaret Martin (Minnesota, 1944)
- Catherine Morawetz (NYU, 1951)
- Vivienne Morley (Chicago, 1956)
- Vera Pless (Northwestern, 1957)
- Joan Rosenblatt (North Carolina, 1956)
- Jean Rubin (Stanford, 1955)
- Mary Ellen Estill Rudin (Texas, 1949)
- Alice Turner Schafer (Chicago, 1942)
- Augusta Schurter (Wisconsin, 1952)
- Domina Spencer (MIT, 1942)
- Maria Weber Steinberg (Cornell, 1949)
- Ruth Rebbeka Strunk (NYU, 1955)
- Jean Walton (Pennsylvania, 1948)
- Tilla (Klotz) Weintraub (NYU, 1959)
- Margaret Willerding (St. Louis, 1947)
- Joyce Williams (Illinois, 1954)
- Marie Wurster (Chicago, 1946)
STOCHASTICS AND DYNAMICS (SD)
EDITOR-IN-CHIEF: LUDWIG ARNOLD
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GEOMETRIC MODULAR FORMS AND ELLIPTIC CURVES
by Haruzo Hida (UCLA)
This book provides a comprehensive account of the theory of moduli spaces of elliptic curves (over integer rings) and its application to modular forms. The construction of Galois representations, which play a fundamental role in Wiles' proof of the Shimura-Taniyama conjecture, is given.

Readership: Graduate students and researchers in number theory.
376pp / Sept 2000 / 981-02-4337-5 @ USD86

LECTURE NOTES ON CHERN-SIMONS-WITTEN THEORY
by Sen Hu (Princeton)
This invaluable monograph has arisen in part from E. Witten's lectures on topological quantum field theory in the spring of 1989 at Princeton University. At that time Witten unified several important mathematical works in terms of quantum field theory, most notably the Donaldson polynomial, the Chern-Simons-Trilinear homology, and the Jones polynomial.

In this book, Sen Hu has added material to provide some of the details left out of Witten's lectures and to update some new developments. In addition, some highly relevant material by S S Chern and E Witten has been included as appendices for the convenience of readers.

Readership: Senior undergraduates, postgraduates and researchers in mathematics and physics.
200pp (cl) / Scheduled Summer 2001 / 981-02-3909-2 @ USD55
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SCISSORS CONGRUENCES, GROUP HOMOLOGY AND CHARACTERISTIC CLASSES
by Johan L Dupont (Univ. of Aarhus, Denmark)
These lecture notes are based on a series of lectures given at the Nankai Institute of Mathematics in the fall of 1998. They provide an overview of the work of the author and the late Chi-Han Sah on various aspects of Hilbert's Third Problem. Are two Euclidean polyhedra with the same volume "scissors-congruent", i.e. can they be divided into finitely many pairwise congruent pieces?

Readership: Graduate students and researchers in geometry and topology.
176pp / Feb 2001 / 981-02-4506-7 @ USD40 / 981-02-4508-4 (pbk) @ USD28

DYNAMICS AND MISSION DESIGN NEAR LIBRATION POINTS
by G Gomez (Universitat Politecnica de Catalunya, Spain), L Llibre, R Martinez (Universitat Autonoma de Barcelona, Spain), C Simo (Universitat de Barcelona, Spain) & J Masdemont (Universitat Politecnica de Catalunya, Spain)
Most of the materials of the four volumes are based on author's many years work for European Space Center which are only available in public recently. Prof. Simo's recent work on stable configurations of three-body problem suggests new possible ways of motion in astronomy.

Readership: Applied mathematicians, computational physicists and aerospace engineers.
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272pp / Feb 2001 / 981-02-4210-7 @ USD69


receipt of the bachelor's degree and the doctorate for the 1950s Ph.D.'s. Since half of the interviewees were married to academics, anti-nepotism rules and practices at colleges and universities significantly limited the choice of jobs during the early careers of the married women. These prohibitions against the employment of a husband and wife at the same institution, which for the most part remained in effect through the end of the 1960s, were applied mainly to exclude women. An extreme case noted by Murray concerned the termination of the contract of a tenured associate professor when she married an untenured assistant professor. Even without such explicit rules, most women who married academics were expected to put their husbands' careers ahead of their own.

On the other hand, the unmarried women, although employed, did not always fare well. As Murray describes this group: "[T]hey frequently felt greater freedom to travel and to exploit career opportunities, [but] their professional lives were complicated by the fact that their colleagues, and society as a whole, tended to view them as carefree (even irresponsible) individuals who had much more time to take on more work and at the same time required less pay" (p. 152).

Half of the interviewees had children. Many had children at an early age, some before receiving their Ph.D.'s. The decade of the 1950s was one that celebrated the domestic role of women; it was a time when mothers were supposed to stay home, and pregnant women lost their jobs. One of the interviewees was even told that attending class as a student while pregnant would violate state laws. Some of the women were able to return to mathematics after raising children and did so in the 1960s and 1970s when the women's movement opened doors to opportunities that probably did not exist for them at the beginning of their careers simply because of their gender. Others had research careers that were both continuous and productive, although they did not achieve tenure status as early in their careers as comparably situated men would probably have done. Among these are several of the best-known women in the study.

Women Becoming Mathematicians ends with two appendices. The first is a note on oral history; the second is a list of the interviewees, their Ph.D. dates, and some personal information about them. In the first appendix Murray describes the methodology she used to obtain the stories that she has woven into a picture of a group of women who received Ph.D.'s in mathematics in the 1940s and 1950s. However, it is the stories themselves and the insight they give us into the lives of these remarkable women that form the heart of this well-conceived and well-written book and make it a particularly valuable contribution to the growing literature on women in mathematics.
Number: From Ahmes to Cantor

Reviewed by Bryan Birch

Number: From Ahmes to Cantor
Midhat Gazalé
Princeton University Press, 2000
Hardcover, $29.95, 272 pages

Midhat Gazalé has always been fascinated by numbers, and in this book he sets out to transmit his fascination to the common reader by giving an account of the development of numbers from the early systems of ancient Mesopotamia to the transfinite ordinals of Cantor. The author's intended audience is a person with some mathematical knowledge but without mathematical sophistication, and he speaks as an engineer rather than as a mathematician. In his very first chapter he stresses Plato's distinction between ἀριθμητική, nowadays usually translated as mathematics, in which proof is paramount, and λογιστική, the art of calculation, which the Greeks were less good at and which is what most of the world (but not the reviewer) usually means by arithmetic nowadays. His book is about λογιστική, not about ἀριθμητική in Plato's sense!

The author's first chapter is a delight to read; he speaks of the genesis of number systems, from early Mesopotamia and Egypt to the Indo-Arabic decimal system adopted by the modern world. His style is to give an overview of what happened, garnished liberally with literary references and anecdotes. He does not try to give a formal history; the chapter starts with the Sumerians and ends with Simon Stevin, and, in between, time jumps back and forth as he leaps from continent to continent. He picks out various highlights (there are more details in Georges Ifrah's Universal History of Numbers) to illuminate his story; and though there are many developments that he omits, his choice is for the most part excellent. The story of how a positional number system was developed by the Babylonians (albeit in the scale of 60) and then deliberately discarded by the Greeks in favour of an inferior alphabetical notation is particularly fascinating, as it involves quite recently discovered history. Tacked on to the end of the chapter is a section of "marginalia"; this seems less carefully prepared and contains various bits and pieces, the biggest of which is a version of the early history of the development of computers.

This first chapter is a very natural preparation for the next two, which form the centre-piece of the book. The author develops the arithmetic of positional number systems in great detail. He starts off by setting out the division algorithm and then dives in to show how to expand a positive integer y in terms of a given mixed basis b = (m₀, m₁, m₂, ...), where the mᵢ are positive integers greater than or equal to 2: there is a unique expansion

\[ y = \sum_{i=0}^{N} \delta_i m_i, \]

where \( \delta_i \) are integers in the range \( 0 \leq \delta_i < m_i \), and \( N \) is the least integer with \( \pi_N > y \). (So if every \( m_i \) is 10, we get the ordinary decimals.) He goes on to show how to convert from one such basis to another, how to add and multiply, and how to express fractions: if \( 0 < \alpha < 1 \) and \( (m'_1, m'_2, ...) \) is a mixed basis, we may express \( \alpha \) uniquely as

\[ \sum_{i \geq 1} a_i / \pi'_i, \]

where this time

\[ \pi'_i = \prod_{j=1}^{i} m'_j \]

and \( 0 \leq a_i < m'_i \), and we may write

\[ \alpha = a_1 a_2 a_3 \ldots \]

with respect to this basis. Though utterly elementary, the arithmetic of these mixed systems is decidedly complicated, not to say
tiresome, though some of the fractions are nice; the "exponential" basis with \( m^2_j = i + 1 \), with respect to which the exponential has the expansion \( e^{-2} = \cdots \), is really very pretty. (This is very typical of the sort of example that Gazale's book is full of; indeed, he goes on to show that given any positive irrational \( \alpha \) less than 1, we may find a mixed basis with respect to which the expansion of \( \alpha \) is \( \cdots \).) Considering the inconvenience of the arithmetic involved, it is surprising how many such systems have been used. The Babylonian system to base 60 was really a mixed-base system, with \( b = (10, 6, 10, 6, 10, 6, \ldots) \); the Mayan system was another. More recently, the avoidupois system of weights and measures is possibly the most complicated of all widely used mixed-base systems; very oddly, the author does not refer to it as an example of a mixed basis, though it is in the marginalia of Chapter 1 as an example of Anglo-Saxon foolishness.

In Chapter 3 he goes more deeply into the properties of expansions of rational numbers with respect to periodic bases. He starts off with various fundamental theorems, like the fundamental theorem of arithmetic, Euler's theorem (and a mild extension thereof), and the primitive root theorem. He shows that the expansion of a rational number with respect to a periodic basis is periodic and shows how to find the period. He warns that this is a more difficult chapter, because it contains proofs. I fear that it is more difficult than it need have been, since sometimes he includes proofs, sometimes he omits them, and sometimes he indicates why something is true without really proving it, and it may not be clear to the reader which he is doing.

Chapter 4 is entitled "Real Numbers" and starts off with a nice essay on Kronecker's theme that "God made the integers, all the rest is the work of man"; Gazale shows some sympathy (appropriate in the context) with Poincaré's dictum that "later mathematicians will regard set theory as a disease from which one has recovered." He gives the standard construction of the rationals from the integers and reasonable indications, with references to Dedekind and Eudoxus, as to how one might go on to define the real numbers, but he does not complete a definition. A really nice part of the chapter is about Pythagorean triangles. He gives a discussion, more detailed than the one in Georges Ifrah's book, of the Plimpton tablet, which contains several Pythagorean triples known to the Babylonians. (So Pythagoras's theorem was believed before the time of Pythagoras, but was there a proof?) The chapter also contains a couple of neat proofs that \( \sqrt{2} \) and \( e \) are both irrational.

Chapter 5 is about continued fractions, a beautiful subject; sadly, he does not allow himself enough space to do them justice. In particular, it is surprising that he did not say more about their approximation properties at this stage, since they have fundamental relevance for his cleavages in the next chapter (so that some of these properties of continued fractions have to be developed piecemeal in Chapter 6). He gives some pretty examples—Euler's continued fraction for \( e \) and the periodic continued fractions of quadratic surds—but he proves very little; he very rightly refers the reader who wants to know more to H. Davenport's \textit{Higher Arithmetic}.

In Chapter 6 he introduces the idea of cleavages: if \( \mu \) is a positive number, then the line \( y = \mu x \) cleaves the positive integer points of the positive quadrant into two sets, an upper set \( U \) consisting of integer points \( (x, y) \) for which \( y \geq \mu x \) and a lower set \( L \) consisting of those \( (x, y) \) for which \( y < \mu x \). So the cleavage is very much like a Dedekind cut, with \( \left( \frac{y}{x} \right) < \mu \) if \( (x, y) \) is in the lower set of the cleavage. It is arguable that cleavages will give some amateurs a better idea of what is involved in Dedekind's cuts than does Dedekind's original definition: a picture separating the integers in the first quadrant into two sets is easier to look at than a picture of the rationals.

In his final chapter Gazale treats infinity. Despite certain felicities (for instance, a clear proof that a set may not be put into 1-1 correspondence with its set of subsets; a reasonable picture of the Cantor set; and Woody Allen's remark that eternity is very boring, particularly near the end) it is inadequate; there are real difficulties in the subject matter which the author has not faced up to. There are also real errors: it is wrong to assert that one cannot order the rationals; there are models of set theory in which the Continuum Hypothesis is false; and at the very end of the book, his explanation of why the sky is black is inadequate, since stars are not points.

To sum up: Many ordinary people will thoroughly enjoy this book, even if they give up before the end. The author says clearly that he is not writing for professional mathematicians; if, nonetheless, mathematicians try it, they will begin like ordinary people by thoroughly enjoying it and will become more and more dissatisfied.
NSF Fiscal Year 2002 Budget Request

In early April 2001, President Bush sent to Congress his fiscal year 2002 budget request. For the scientific community the request was deeply disappointing. Apart from the National Institutes of Health, whose budget is slated to rise 13.5%, science funding in nearly all federal agencies would remain flat or decline under the request. In particular, the National Science Foundation (NSF) would get just a 1.3% increase—effectively a cut, given the inflation rate of 3.4% (as measured by the Consumer Price Index). Over the last few years, the scientific community helped to build a bipartisan consensus among members of Congress and the Clinton administration about the need to increase funding for science overall and also to achieve the right balance between funding for biomedical research and funding for the rest of science. As a result, increases for the NSF in recent years have been strong. But this year, said AMS Washington Office director Samuel M. Rankin III, "we're going backwards."

For mathematics the situation is especially frustrating. Over the past year or so momentum has built at the NSF for a big increase for mathematics. Last October the policymaking body of the NSF approved a major new initiative in the mathematical sciences.1 No dollar amounts were formally stated, but NSF director Rita Colwell said she hoped to bring spending on the mathematical sciences to $400-500 million per year over the coming five years, which is around four or five times the current amount. Such a rise would depend on the NSF obtaining healthy increases—which it would not, under the terms of the fiscal year 2002 request. Still, the requested increase of $20 million, or 16.5%, for the NSF's Division of Mathematical Sciences (DMS) is clearly a positive sign when seen in the context of the flat or negative budgets for other divisions across the foundation. As DMS director Philippe Tondeur put it, "The mathematical sciences are disappointed about the low increase for the NSF, but we still appreciate the allocation to the DMS. This increase singles out the mathematical sciences for their fundamental role in science and their importance to society."

Low Funding for Science Criticized
Since releasing its budget request, the Bush administration has heard from many quarters that its plans for funding science are wrongheaded. In an Op-Ed piece in the New York Times, former presidential science adviser D. Allan Bromley took the administration to task for pursuing a "self-defeating policy" with regard to science. Members of both houses of Congress have also voiced concerns about such a small increase for science, especially for the NSF. It seems the Bush administration is starting to listen. "I think they've begun to realize they made a mistake," Rankin observed. "The administration understands it has to do something about the balance of funding in science." It is not a matter of overcoming any opposition to the NSF—indeed there is none—but rather of how budget priorities will be worked out as the government finds ways to pay for the president's tax

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cut and as the national economic slowdown begins to affect tax revenues.

Over the next several months Congress will go through the process of negotiating and writing the bills that actually appropriate money for government spending. This process could end up increasing the NSF's fiscal year 2002 budget above the level of the president's request, for the foundation has strong support among some influential members of Congress. One is Christopher Bond (R-MO), who, until the Democrats gained the majority in the Senate this spring, chaired the Senate Appropriations Subcommittee for Veterans' Affairs, Housing and Urban Development, and Independent Agencies. The NSF appropriation falls under this subcommittee. Earlier this year Bond wrote an amendment to the Senate budget resolution to increase the 2002 budget for the NSF. The resolution passed, and while it is not binding, it does express the sense of the Senate. One of the co-sponsors of the resolution was Barbara Mikulski (D-MD), who succeeded Bond as chair of the VA-HUD-Independent Agencies Appropriations Subcommittee. Mikulski has long argued for increased funding for the NSF and has called the 2002 request "unacceptable." Similar support for the NSF has been shown by some members of the House of Representatives. Visitors at the April 2001 meeting of the AMS Committee on Science Policy suggested that an increase of 7% might be a realistic outcome for the NSF. "If the NSF gets more money" through congressional action, said Rankin, "then we have to figure out how to encourage them to increase the amount in the mathematical sciences initiative."

**Highlights of the NSF Request**

One of the highlights in the NSF fiscal year 2002 budget request is a new activity called Math and Science Partnerships, to be launched in the foundation's Education and Human Resources (EHR) directorate. Mandated by the Bush administration, this activity is part of the president's "leave no child behind" theme. One hundred twenty million dollars of the activity's $200 million budget would come from reallocations within EHR, and the rest would be a combination of new funds and reallocations from other directorates. According to the NSF budget request document, "The Partnership initiative will provide funds for states and local school districts to join with institutions of higher education, particularly with their departments of mathematics, science, and engineering, to strengthen K-12 math and science education." There will be two kinds of partnerships, Infrastructure Partnerships and Action Partnerships. The former would work at the state level on broad-based activities such as teacher certification or aligning assessments to standards, while the latter would operate mostly at the local level, pursuing such projects as adapting curricular models to local needs.

The request includes an increase of nearly $8 million, or 8.8%, for graduate student support, including the NSF Graduate Research Fellowships. The additional funds will go toward increasing the fellowships from $18,000 to $20,500 per year. "Currently, the average stipend level for graduate students in science and engineering disciplines is less than half the average wage for bachelor's degree recipients," the budget document states. The hope is that the increase in the fellowship amount will help to stem a decline in the number of graduate enrollments in science. This decline has been felt in mathematics: According to the AMS-IMS-MAA Annual Survey, the number of first-year graduate students enrolled in doctoral programs in mathematics in the U.S. declined about 13% between 1991 and 1999. Mathematics is usually underrepresented among the NSF Graduate Fellows because a smaller proportion of mathematics students apply than in other areas of science and engineering.

The NSF is continuing its emphasis on a number of "priority areas": Biocomplexity in the Environment, Information Technology Research, Nanoscale Science and Engineering, and Learning for the 21st Century. These initiatives, some carried out in partnership with other federal agencies, take an interdisciplinary approach to major challenges in science and engineering. Thus they provide some opportunities for participation by mathematicians.

Another opportunity is offered by the NSF's Science and Technology Centers (STCs) program. This year's phase-out of twelve STCs will free up more than $25 million for a new competition to launch an estimated six to eight new STCs. This competition will take place during fiscal year 2002. The NSF funded two STCs in the mathematical sciences: the Geometry Center at the University of Minnesota (for which NSF funding ended in fiscal year 1999), and DIMACS, the Center for Discrete Mathematics and Theoretical Computer Science (for which NSF funding ended in fiscal year 2000).

**Mathematical Sciences, "A Centerpiece"**

In the description of the NSF's "core investments", the budget request document says that "Interdisciplinary Mathematics" is "a centerpiece" and will receive a $20 million increase—exactly the amount of the increase for the DMS. "This emphasis on the mathematical sciences recognizes its increasingly critical role in advancing interdisciplinary science," the request states. "In FY 2002, NSF will focus on management of large data sets, the modeling of uncertainty, and the modeling and prediction of complex nonlinear systems." Tondeur said he does not wish to make a sharp distinction between
“fundamental” mathematics, meaning internal developments within the field itself, and “interdisciplinary” mathematics, which might involve interactions between different areas of mathematics or between mathematics and other areas of science and engineering. “Fundamental and interdisciplinary mathematics are inseparable agendas,” he said. “The emphasis at NSF is to advance the mathematical sciences as a discipline as well as to invigorate its strong connections with science and engineering. The goal is to explore partnerships that will advance both the mathematical sciences and these other areas.”

Among the main funding priorities for the DMS is the establishment of new institutes in the mathematical sciences. A competition is currently under way; the deadline was in January 2001, and the division received between ten and twenty proposals. The budget request says, “increased funding of $7.0 million for the Mathematical Sciences Research Institutes will provide support for up to four new Institutes in interdisciplinary mathematical sciences.” Tondeur confirmed that the DMS has not yet decided how many institute proposals will be funded. He noted that the time at which the decisions in the current institute competition must be made “dovetails nicely” with the time at which Congress will make the NSF appropriation—around the beginning of fiscal year 2002 on October 1, 2001. When Congress acts, the DMS will have a clearer idea of exactly what it can spend on new institutes.

Tondeur said that the other main funding priority for the DMS is the Focused Research Groups activity, through which small groups of researchers can apply for funds for collaborative research. The DMS has emphasized the VIGRE activity in recent years, but Tondeur indicated that, under the terms of the budget request, the DMS would not be able to significantly increase funding for VIGRE in the

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Table 1: National Science Foundation (Millions of Dollars)

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</thead>
<tbody>
<tr>
<td>(1) Mathematical Sciences Research Support</td>
<td>$93.6</td>
<td>$100.7</td>
<td>$106.0</td>
<td>$121.5</td>
<td>$141.5</td>
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<tr>
<td>(2) Other Research Support (Note a)</td>
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<td>$2777.6</td>
<td>$2978.9</td>
<td>$3342.5</td>
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<td>(3) Education and Human Resources (Note b)</td>
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<td>$683.6</td>
<td>$785.6</td>
<td>$872.4</td>
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<td>(4) Salaries and Expenses (Note c)</td>
<td>$141.7</td>
<td>$149.5</td>
<td>$154.9</td>
<td>$166.8</td>
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<tr>
<td>(5) Totals</td>
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<td>$3690.3</td>
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<td>(6) (1) as a % of the sum of (1) and (2)</td>
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<td>3.5%</td>
<td>3.44%</td>
<td>3.51%</td>
<td>4.13%</td>
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<tr>
<td>(7) (1) as a % of (5)</td>
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<td>2.73%</td>
<td>2.70%</td>
<td>2.75%</td>
<td>3.16%</td>
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</table>

Note: a: Support for research and related activities in areas other than the mathematical sciences. Includes scientific research facilities and instrumentation, and the Antarctic program. Note b: Support for education in all fields, including the mathematical sciences. Does not include funds collected through H-1B Nonimmigrant Petitioner receipts. Note c: Administrative expenses of operating the NSF, including the Office of the Inspector General.

Table 2: Directorate for Mathematical and Physical Sciences (Millions of Dollars)

<table>
<thead>
<tr>
<th></th>
<th>1998 Actual</th>
<th>1999 Actual</th>
<th>2000 Actual</th>
<th>2001 Plan</th>
<th>2002 Request</th>
<th>% of Total</th>
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<tr>
<td>(1) Mathematical Sciences</td>
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<td>$100.7</td>
<td>$106.0</td>
<td>$121.5</td>
<td>$141.5</td>
<td>16.4%</td>
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<td>(2) Astronomical Sciences</td>
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<td>$122.5</td>
<td>$148.6</td>
<td>$156.3</td>
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<td>(3) Physics</td>
<td>$142.7</td>
<td>$162.7</td>
<td>$168.3</td>
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<tr>
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<td>$130.1</td>
<td>$135.3</td>
<td>$138.6</td>
<td>$153.5</td>
<td>$153.5</td>
<td>17.8%</td>
</tr>
<tr>
<td>(5) Materials Research</td>
<td>$178.9</td>
<td>$186.4</td>
<td>$190.5</td>
<td>$209.7</td>
<td>$205.4</td>
<td>23.8%</td>
</tr>
<tr>
<td>(6) Office of Multidisciplinary Activities</td>
<td>$28.3</td>
<td>$29.9</td>
<td>$29.9</td>
<td>$29.9</td>
<td>$23.4</td>
<td>2.7%</td>
</tr>
<tr>
<td>(7) Totals</td>
<td>$687.2</td>
<td>$733.6</td>
<td>$755.9</td>
<td>$850.8</td>
<td>$863.6</td>
<td>100%</td>
</tr>
</tbody>
</table>
coming fiscal year. VIGRE, which stands for Grants for Vertical Integration of Research and Education in the Mathematical Sciences, supports innovative educational programs in which research and education are integrated and in which undergraduates, graduate students, postdoctoral fellows, and faculty work together. VIGRE is in its third year of funding, with around thirty grants active. It is not yet known how many more VIGRE grants will be funded in the next competition, the deadline for which is July 30, 2001.

Many are looking to Congress to improve the budget outlook for the NSF for the next fiscal year. Asked what his hopes are for the DMS budget, Tondeur did not specify a monetary figure. "My dreams are big, but they are not the determining factor," he said. "All I can say is that I leave no stone unturned to get our budget increased." The talk of a big boost for mathematics funding raised the expectations of many in the mathematical community, and Tondeur said he received some "irate" letters from mathematicians saying that a $20 million increase is not enough. But "it's not a good moment to complain," he pointed out, given that the foundation overall has such a small requested increase. It seems clear that, had the request been larger, the DMS would have done even better. That it got a reasonably good increase in a very lean request is perhaps the most encouraging sign of all.

—Allyn Jackson

Table 3: Compilation of NSF Budget, 1996–2002 (Millions of Dollars)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
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</tr>
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<tbody>
<tr>
<td>(1) Mathematical Sciences</td>
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<tr>
<td>Research Support</td>
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<td>$92.9</td>
<td>$93.6</td>
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<td>$106.0</td>
<td>$121.5</td>
<td>$141.5</td>
<td>20.9%</td>
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</tr>
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<td></td>
<td></td>
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<tr>
<td>(2) Other Research Support</td>
<td>2381.0</td>
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<td>2777.6</td>
<td>2978.9</td>
<td>3342.5</td>
<td>3281.8</td>
<td>25.1%</td>
<td>37.8%</td>
</tr>
<tr>
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<td>1568.8</td>
<td>1667.2</td>
<td>1729.9</td>
<td></td>
<td></td>
<td>14.0%</td>
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<tr>
<td>(3) Education and Human</td>
<td>601.2</td>
<td>619.1</td>
<td>633.2</td>
<td>662.5</td>
<td>683.6</td>
<td>785.6</td>
<td>872.4</td>
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<tr>
<td>Resources (Note b)</td>
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<td>139.6</td>
<td>141.7</td>
<td>149.5</td>
<td>154.9</td>
<td>166.8</td>
<td>176.8</td>
<td>13.5%</td>
<td>28.5%</td>
</tr>
<tr>
<td>(4) Salaries and Expenses</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant Dollars</td>
<td>87.0</td>
<td>87.0</td>
<td>86.9</td>
<td>89.7</td>
<td>89.9</td>
<td></td>
<td></td>
<td>3.3%</td>
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</tr>
<tr>
<td>(5) Totals</td>
<td>$3206.3</td>
<td>$3298.8</td>
<td>$3425.7</td>
<td>$3690.3</td>
<td>$3923.4</td>
<td>$4416.4</td>
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<td>39.5%</td>
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<tr>
<td>Constant Dollars</td>
<td>2043.5</td>
<td>2055.3</td>
<td>2101.7</td>
<td>2215.1</td>
<td>2278.4</td>
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<td>11.5%</td>
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</tbody>
</table>

Current dollars are converted to constant dollars using the Consumer Price Index (based on prices during 1982-1984).

For Notes a, b, and c, see Table 1.
Update on the 2000 New Doctoral Recipients

Introduction

The Annual Survey of the Mathematical Sciences collects information each year about departments, faculties, and students in the mathematical sciences at four-year colleges and universities in the United States. Definitions of the various groups surveyed in the Annual Survey can be found in the box on page 719 of this report. For the second year, departments in Group Vb (operations research and management science) are no longer being surveyed. More discussion of this can be found in the 2000 First Report in the February 2001 Notices of the AMS, pages 195-208.

This Second Report includes data from two parts of the 2000 Annual Survey. First, we update information about new doctoral recipients reported earlier in the February 2001 issue. Second, we present the starting salaries of the new doctoral recipients who responded to a follow-up survey. In past years this report would contain a third part presenting information about the faculties and instructional programs at the undergraduate and graduate levels in these departments for the 2000-2001 academic year. Starting with the 2000 survey, we have chosen to present this data in a separate report which is expected to be published in the September issue of the Notices of the AMS.


Information about recipients of doctoral degrees awarded between July 1, 1999, and June 30, 2000, was collected from doctorate-granting departments beginning in late spring 2000 and from a follow-up census of individual degree recipients beginning in October. The "2000 Annual Survey of the Mathematical Sciences (Second Report)" is under the direction of the Annual Survey Data Committee, a joint committee of the American Mathematical Society, the American Statistical Association, the Institute of Mathematical Statistics, and the Mathematical Association of America. The current members of this committee are Lorraine Denby, J. Douglas Faires, Mary W. Gray, Alfred W. Hales, Peter E. Haskell, Ellen E. Kirkman, James M. Kister, James Lewis, Don O. Loftsgaarden (chair), James W. Maxwell (ex officio), and Yashaswini Mittal. The committee is assisted by AMS survey analyst Kinda Remick Priestley and survey coordinator Colleen Rose. Comments or suggestions regarding this Survey Report may be directed to the committee.
Highlights

There were 1,127 new doctoral recipients from U.S. institutions for 1999-2000, down 8 from the previous year.

The final 1999-2000 unemployment rate for new doctoral recipients was 3.3%, down from 3.8% last year and the lowest rate in the past ten years.

Females totaled 304 of the new doctoral recipients, down from 318 last year, but still the second highest number ever recorded. The number of males was 823, up six from last year.

There were 566 U.S. citizen new doctoral recipients, which was 50.2% of the total and the highest percentage since 1986-87. There were 164 female U.S. citizen doctoral recipients, down from a record high of 188 last year, but again the second-highest number ever recorded. The number of male U.S. citizen new doctoral recipients was 402, an increase of 30 from last year.

Of the 957 new doctoral recipients known to have employment in October 2000, 89.4% found jobs in the U.S. Among the 856 new doctoral recipients taking employment in the U.S., 31.1% took nonacademic positions (government or business and industry), compared to 26.9% last year. Thirty-eight more new doctoral recipients accepted jobs in business and industry than last year.

The number of new doctoral recipients finding academic employment (including research institutes and other nonprofits) in the U.S. was $90, a drop of 20 from last year.

Median salaries for new doctoral recipients taking 9-10-month positions in U.S. academic institutions increased from $39,000 to $40,300 for females, while males increased from $40,000 to $41,500 overall.

The median age for new doctoral recipients is 30.0, and the average age is 31.7. These are nearly identical to last year’s figures.


Table 1A shows the fall and final counts of new doctoral recipients in the mathematical sciences awarded by U.S. institutions from 1992 through 2000. Final counts include those new doctoral recipients reported from departments who missed the deadline for inclusion in the First Report. Numbers in this table have been revised from previous reports to exclude new doctorates data from Group Vb departments, which are no longer surveyed.

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Final</th>
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</thead>
<tbody>
<tr>
<td>1992-93</td>
<td>1104</td>
<td>1116</td>
</tr>
<tr>
<td>1993-94</td>
<td>1025</td>
<td>1034</td>
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<tr>
<td>1994-95</td>
<td>1148</td>
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<td>1995-96</td>
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<td>1999-00</td>
<td>1119</td>
<td>1127</td>
</tr>
</tbody>
</table>

Table 1B gives a breakdown of the 1,127 doctoral degrees awarded in the mathematical sciences between July 1, 1999, and June 30, 2000, by type of degree-granting department.

<table>
<thead>
<tr>
<th>Number</th>
<th>I (Pu)</th>
<th>I (Pr)</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>Va</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>22.8</td>
<td>13.9</td>
<td>19.7</td>
<td>11.9</td>
<td>25.7</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Tables 2A, 2B, and 2C display updates of employment data, found in these same tables in the First Report, for the fall count of 1999-2000 doctoral recipients plus eight additional doctoral recipients reported late. These tables are partitioned by field of thesis research and by the survey group of their degree department. At the time of this Second Report, the fall 2000 employment status of 1,000 of the 1,127 doctoral recipients was known.

The fall 2000 unemployment rate for new doctoral recipients, based on information gathered by the time of the Second Report, was 3.3%. The unemployment rate rose steadily in the early 1990s and reached its all-time high of 10.7% in 1994 and held that rate through 1995. It began to decrease in 1996, reaching 3.3% for 2000, the lowest it has been in the past ten years. Figure 3 presents the fall 1978 through fall 2000 trend in the final unemployment rate of new doctoral recipients. The counts on which these rates are

Don O. Loftsgaarden is professor emeritus of mathematics, University of Montana. James W. Maxwell is AMS associate executive director for Professional Services. Kinda Remick Priestley is AMS survey analyst.

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<table>
<thead>
<tr>
<th>TYPE OF EMPLOYER</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (Public)</td>
<td>38</td>
<td>21</td>
<td>59</td>
</tr>
<tr>
<td>Group I (Private)</td>
<td>24</td>
<td>27</td>
<td>51</td>
</tr>
<tr>
<td>Group II</td>
<td>21</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>Group III</td>
<td>8</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Group IV</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Group Va</td>
<td>9</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Master's</td>
<td>9</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Bachelor's</td>
<td>26</td>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td>Two-Year College</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Other Academic Dep.</td>
<td>5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Research Institute/Other Nonprofit</td>
<td>4</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Government</td>
<td>33</td>
<td>28</td>
<td>61</td>
</tr>
<tr>
<td>Business and Industry</td>
<td>35</td>
<td>16</td>
<td>51</td>
</tr>
<tr>
<td>Non-U.S. Academic</td>
<td>11</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Non-U.S. Nonacademic</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>6</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Unknown (non-U.S.)</td>
<td>4</td>
<td>6</td>
<td>10</td>
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<tr>
<td><strong>COLUMNTOTAL</strong></td>
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<td>95</td>
<td>273</td>
</tr>
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<td><strong>COLUMNSUBTOTALS</strong></td>
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<td>Female</td>
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<td>75</td>
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<td><strong>GROUP I (PRIVATE)</strong></td>
<td></td>
<td></td>
<td>57</td>
</tr>
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<td><strong>GROUP II</strong></td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td><strong>GROUP III</strong></td>
<td></td>
<td></td>
<td>34</td>
</tr>
<tr>
<td><strong>GROUP IV</strong></td>
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<td></td>
<td>51</td>
</tr>
<tr>
<td><strong>GROUP VA</strong></td>
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<td></td>
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<td><strong>MASTER'S</strong></td>
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<td></td>
<td>60</td>
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<tr>
<td><strong>BACHELOR'S</strong></td>
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<td></td>
<td>79</td>
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<td><strong>BUSINESS AND INDUSTRY</strong></td>
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</table>

Table 2B: Fall 2000 Employment Status of 1999-2000 U.S. Doctoral Recipients by Type of Degree-Granting Department, Updated April 2001

<table>
<thead>
<tr>
<th>TYPE OF DOCTORAL DEGREE-GRANTING DEPARTMENT</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (Public) Math</td>
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<td>21</td>
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<tr>
<td>Group I (Private) Math</td>
<td>24</td>
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<td>51</td>
</tr>
<tr>
<td>Group II Math</td>
<td>21</td>
<td>9</td>
<td>30</td>
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<tr>
<td>Group III Math</td>
<td>8</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Group IV Math</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Group Va Math</td>
<td>9</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Master's Math</td>
<td>9</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Bachelor's Math</td>
<td>26</td>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td>Two-Year College Math</td>
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<td>5</td>
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<td>Other Academic Dept. Math</td>
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<td>8</td>
</tr>
<tr>
<td>Research Institute/Other Nonprofit Math</td>
<td>4</td>
<td>7</td>
<td>11</td>
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<tr>
<td>Government Math</td>
<td>33</td>
<td>28</td>
<td>61</td>
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<td>Business and Industry Math</td>
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<td>16</td>
<td>51</td>
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<tr>
<td>Unknown (non-U.S.) Math</td>
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<td>414</td>
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<tr>
<td><strong>GROUP I (PUBLIC)</strong></td>
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<td><strong>GROUP I (PRIVATE)</strong></td>
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<tr>
<td><strong>GROUP VA</strong></td>
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<td><strong>MASTER'S</strong></td>
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<td><strong>BUSINESS AND INDUSTRY</strong></td>
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<td><strong>NON-U.S. ACADEMIC</strong></td>
<td></td>
<td></td>
<td>92</td>
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<td><strong>NON-U.S. NONACADEMIC</strong></td>
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<td></td>
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<tr>
<td><strong>NOT SEEKING EMPLOYMENT</strong></td>
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<td></td>
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<tr>
<td><strong>STILL SEEKING EMPLOYMENT</strong></td>
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<td></td>
<td>33</td>
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<tr>
<td><strong>UNKNOWN (U.S.)</strong></td>
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<td>67</td>
</tr>
<tr>
<td><strong>UNKNOWN (NON-U.S.)</strong></td>
<td></td>
<td></td>
<td>58</td>
</tr>
</tbody>
</table>

**1** Includes those whose status is reported as "unknown" or "still seeking employment".
Table 2C: 1999-2000 New Doctoral Recipients: Field of Thesis by Type of Degree-Granting Department, Updated April 2001

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (Public)</td>
<td></td>
<td>74</td>
<td>32</td>
<td>46</td>
<td>26</td>
<td>9</td>
<td>4</td>
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<td>16</td>
<td>5</td>
<td>31</td>
<td>9</td>
<td>14</td>
<td>0</td>
<td>2</td>
<td>257</td>
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<tr>
<td>Group I (Private)</td>
<td></td>
<td>42</td>
<td>18</td>
<td>33</td>
<td>16</td>
<td>9</td>
<td>2</td>
<td>14</td>
<td>9</td>
<td>0</td>
<td>18</td>
<td>7</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>157</td>
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<td>Group II</td>
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<td>32</td>
<td>20</td>
<td>20</td>
<td>7</td>
<td>4</td>
<td>31</td>
<td>18</td>
<td>7</td>
<td>31</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>222</td>
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<td>Group III</td>
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<td>10</td>
<td>17</td>
<td>4</td>
<td>24</td>
<td>11</td>
<td>10</td>
<td>1</td>
<td>19</td>
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<td>0</td>
<td>134</td>
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<td>Group IV</td>
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<td>0</td>
<td>0</td>
<td>9</td>
<td>272</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>290</td>
</tr>
<tr>
<td>Group Va</td>
<td></td>
<td>0</td>
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<td>4</td>
<td>5</td>
<td>25</td>
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<td>13</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>67</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>178</td>
<td>95</td>
<td>110</td>
<td>87</td>
<td>42</td>
<td>311</td>
<td>105</td>
<td>59</td>
<td>27</td>
<td>94</td>
<td>16</td>
<td>3</td>
<td>1127</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

determined do not include those new doctoral recipients whose fall employment status was unknown at the time of the Second Report. Note that prior to 1999 the new doctoral recipients from Group Vb are included in the total unemployment rate for each year.

Of the 1,000 new doctoral recipients whose employment is known, 856 were employed in the U.S., 101 were employed outside the U.S., 33 were still seeking employment, and 10 were not seeking employment.

Table 2D presents the trend in the percentage of employed new doctoral recipients by general employment sector for the last three years. Academic employment includes those employed by research institutes and other nonprofits. The total number of new doctoral recipients known to be employed at the time of the Second Report was 965,955, and 957, for 1998, 1999, and 2000 respectively.

Among new doctoral recipients who are employed, the percentage taking nonacademic employment (U.S. government, U.S. business and industry, and non-U.S. nonacademic) varied significantly by field of thesis. For those whose field of thesis is in the first three columns in Table 2A, this percentage is the lowest at 13.9%, while the percentage for those with theses in probability or statistics is the highest at 43.5%.

Figure 3: Percentage of New Doctoral Recipients Unemployed, As Reported in the Respective Annual Survey Second Reports, 1978-2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>0.7</td>
</tr>
<tr>
<td>1979</td>
<td>1.5</td>
</tr>
<tr>
<td>1980</td>
<td>0.9</td>
</tr>
<tr>
<td>1981</td>
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<tr>
<td>1982</td>
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<td>2.2</td>
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<td>2.1</td>
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<td>1985</td>
<td>0.8</td>
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<td>2.3</td>
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<td>4.9</td>
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<td>1999</td>
<td>4.7</td>
</tr>
<tr>
<td>2000</td>
<td>3.3</td>
</tr>
</tbody>
</table>
Tables 4A through 4E first appeared in the First Report for 1999–2000, although they do not have the same table numbers in that report. They have all been updated with information obtained from the individual new doctoral recipients who responded to a follow-up questionnaire. The next few paragraphs give a few things we can glean from these tables.

Table 4A shows that 38 more new doctoral recipients accepted jobs in business and industry compared to last year, an increase of 20.5%.

Table 4B shows that 20 fewer new doctoral recipients were hired in U.S. academic institutions than last year, a decrease of 3.3%.

Table 4C shows that Group I, II, and III departments combined hired 17 fewer new doctoral recipients this year than they did last year, a decrease of 7.3%, while the number of new doctoral recipients hired by Group M and B departments is down by 13 (6.7%) compared to last year.

Table 4D gives information about the production and hiring of female new doctoral recipients in the doctoral-granting departments of this survey.

Table 4E shows that the new doctoral recipients from Group Va departments have the highest unemployment rate this year at 5.5%, while those from Group III departments have the lowest unemployment rate at 1.8%.

Updated Information about New Doctoral Recipients by Sex and Citizenship

Tables 4F and 4G show the sex and citizenship of the 1,127 new doctoral recipients and the fact that 856 new doctoral recipients found jobs in the U.S. this year. This is 89.4% of the 957 new doctoral recipients known to have jobs in October 2000.

Sex and citizenship is known for all of the 1,127 new doctoral recipients. The final count of new doctoral recipients who are U.S. citizens is 566. At 50.2%, up slightly from 49.3% last year, this is the largest percentage reported by the Annual Survey since 1986–87. The final count of new doctoral recipients who are non-U.S. citizens decreased from 575 last year to 561 this year and remains well below the record high of 679 reported in the final count for 1992–93. Pages 200–202 of the First Report present further information related to the citizenship of the 1999–2000 new doctoral recipients.

Of the 566 U.S. citizen new doctoral recipients, 164 are female and 402 are male. The 164 female new doctoral recipients comprise 29.0% of the U.S. citizen total for 1999–2000, a decrease from last year's count of 188, which was 33.6% of the U.S. citizen new doctoral recipients. The number of U.S. citizen males, 402, increased by 30 (8.1%) from 372 last year.

Table 4H shows that while U.S. academic doctoral departments, Groups I through Va, hired 51.1% U.S. citizens, U.S. academic positions other than in the doctoral departments hired 69.2% U.S. citizens.
Table 4F: Employment Status of 1999-2000 Male U.S. New Doctoral Recipients by Type of Citizenship

<table>
<thead>
<tr>
<th>TYPE OF EMPLOYER</th>
<th>U.S. CITIZENS</th>
<th>NON-U.S. CITIZENS</th>
<th>MALE DOCTORAL RECIPIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Permanent Visa</td>
<td>Temporary Visa</td>
<td>Unknown Visa</td>
</tr>
<tr>
<td>U.S. Employer</td>
<td>344</td>
<td>48</td>
<td>210</td>
</tr>
<tr>
<td>U.S. Academic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groups I, II, III, and Va</td>
<td>247</td>
<td>29</td>
<td>123</td>
</tr>
<tr>
<td>Group IV</td>
<td>17</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Non-Ph.D. Department</td>
<td>125</td>
<td>11</td>
<td>39</td>
</tr>
<tr>
<td>Research Institute/Other Nonprofit</td>
<td>10</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>U.S. Nonacademic</td>
<td>97</td>
<td>19</td>
<td>87</td>
</tr>
<tr>
<td>Non-U.S. Employer</td>
<td>21</td>
<td>1</td>
<td>47</td>
</tr>
<tr>
<td>Non-U.S. Academic</td>
<td>20</td>
<td>1</td>
<td>44</td>
</tr>
<tr>
<td>Non-U.S. Nonacademic</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td>8</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>375</td>
<td>53</td>
<td>270</td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>27</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Unknown (non-U.S.)</td>
<td>0</td>
<td>2</td>
<td>35</td>
</tr>
<tr>
<td>TOTAL</td>
<td>402</td>
<td>63</td>
<td>316</td>
</tr>
</tbody>
</table>

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

Table 4G: Employment Status of 1999-2000 Female U.S. New Doctoral Recipients by Type of Citizenship

<table>
<thead>
<tr>
<th>TYPE OF EMPLOYER</th>
<th>U.S. CITIZENS</th>
<th>NON-U.S. CITIZENS</th>
<th>FEMALE DOCTORAL RECIPIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Permanent Visa</td>
<td>Temporary Visa</td>
<td>Unknown Visa</td>
</tr>
<tr>
<td>U.S. Employer</td>
<td>137</td>
<td>24</td>
<td>65</td>
</tr>
<tr>
<td>U.S. Academic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groups I, II, III, and Va</td>
<td>111</td>
<td>13</td>
<td>47</td>
</tr>
<tr>
<td>Group IV</td>
<td>19</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Non-Ph.D. Department</td>
<td>11</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Research Institute/Other Nonprofit</td>
<td>71</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>U.S. Nonacademic</td>
<td>26</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Non-U.S. Employer</td>
<td>4</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Non-U.S. Academic</td>
<td>4</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Non-U.S. Nonacademic</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td>3</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>149</td>
<td>26</td>
<td>86</td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>14</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Unknown (non-U.S.)</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>164</td>
<td>31</td>
<td>97</td>
</tr>
</tbody>
</table>

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

citizens. The percentage of U.S. citizens hired for nonacademic positions in the U.S. was 46.2%. Among those 856 1999-2000 doctoral recipients taking employment in the U.S., 31.1% took nonacademic employment (government or business and industry). This is up from 26.9% in 1998-99.

New Information from the EENDR Survey

Of the 1,127 new doctoral recipients reported in the First Report, the 1,046 whose addresses were known were sent the Employment Experiences of New Doctoral Recipients (EENDR) survey in October 2000, and 603 (57.6%) responded. The response rates varied considerably among the various subgroups of new doctoral recipients defined by their employment status as reported by departments. Among those who were employed, the highest response rate, 69.0%, was from those in academia in the U.S., while the lowest, 50.0%, was from those in foreign academia.

The EENDR gathered details on employment experiences not available through departments. The rest of this section presents the additional
information available on this subset of the 1999-2000 doctoral recipients.

Table 5 shows the citizenship of the 603 new doctoral recipients who responded to the EENDR.

Of the 603 total respondents to the EENDR, 536 were employed in the U.S., 49 were employed outside the U.S., 9 were still seeking employment, 5 were not seeking employment, and 4 were unknown (non-U.S.) as of the week of October 10, 2000. The unemployment rate for those responding to the EENDR is 1.5%. Among those employed in the U.S., 519 were employed full-time and 16 were employed part-time (one individual did not answer this question). Of the 16 reporting part-time employment, 6 reported that they were working part-time because a suitable full-time job was not available, while 9 also reported they were working part-time while they pursued additional education.

Among the 536 employed in the U.S., 317 reported obtaining a permanent position and 218 a temporary position (one individual did not answer this question). Of the 218 in temporary positions, 92 (42.2%) reported taking temporary employment because a suitable permanent position was not available and 157 (72.0%) classified their position as postdoctoral. Furthermore, among those in postdoctoral positions, 35.0% reported that they took the position because a suitable permanent position was not available.

Among the 317 who reported obtaining a permanent position in the U.S., 59.3% were employed in academia (including 8.3% in research institutes and other nonprofits), 36.3% in business or industry, and 2.3% in government.

Among the 49 individuals employed outside the U.S., 87.8% were employed in academia (including 12.2% in research institutes and other nonprofits) and the other 12.2% were in business or industry. None were employed in government. Twenty-one of those employed outside the U.S. were U.S. citizens, 15 of which were in temporary positions, while none were U.S. permanent residents.

Figure 6 gives the age distribution of the 595 new doctoral recipients who responded to this question. The median age of new doctoral recipients was 30.0, while the mean age was 31.7. The first and third quartiles were 28 and 34 respectively. These figures are almost identical to those reported last year.

| Table 5: Employment Status of 1999-2000 EENDR Respondents by Type of Citizenship |
|---------------------------------|---------------------------------|-----------------|-----------------|
| **TYPE OF EMPLOYER**            | **U.S. CITIZENS**               | **NON-U.S. CITIZENS** | **TOTAL EENDR RESPONDENTS** |
|                                 | **U.S.** | **PERMANENT VISI** | **TEMPORARY VISI** | **UNKNOWN VISI** | **536** |
| **U.S. Academic**               | 337      | 267              | 80               | 0                | 397    |
| Groups I, II, III, and Va       | 0        | 22               | 7                | 0                | 29    |
| Group IV                        | 24       | 103              | 2                | 0                | 58    |
| Non-Ph.D. Department            | 148      | 15               | 12               | 0                | 165   |
| Research Institute/Other Nonprofit | 15 | 52               | 0                | 0                | 0     |
| **U.S. Nonacademic**            | 70       | 15               | 1                | 0                | 22    |
| **Non-U.S. Employer**           | 21       | 1                | 0                | 0                | 7     |
| Non-U.S. Academic               | 20       | 1                | 0                | 0                | 18    |
| Non-U.S. Nonacademic            | 1        | 0                | 0                | 0                | 1     |
| **Not Seeking Employment**      | 2        | 0                | 0                | 0                | 5     |
| **Still Seeking Employment**    | 4        | 2                | 2                | 0                | 9     |
| **SUBTOTAL**                    | 364      | 39               | 182              | 14               | 603   |
| **Unknown (U.S.)**              | 0        | 0                | 0                | 0                | 0     |
| **Unknown (non-U.S.)**          | 1        | 0                | 0                | 0                | 4     |
| **TOTAL**                       | 365      | 39               | 185              | 14               | 603   |

1 includes those whose status is reported as "unknown" or "still seeking employment".
Acknowledgments
The Annual Survey of the Mathematical Sciences attempts to provide an accurate appraisal and analysis of various aspects of the academic mathematical sciences scene for the use and benefit of the community and for filling the information needs of the professional organizations. Every year, college and university departments in the United States are invited to respond. The Annual Survey relies heavily on the conscientious efforts of the dedicated staff members of these departments for the quality of its information. On behalf of the Annual Survey Data Committee and the Annual Survey staff, we thank the many secretarial and administrative staff members in the mathematical sciences departments for their cooperation and assistance in responding to the survey questionnaires.

Starting Salary Survey of New Doctoral Recipients
The starting salary figures for 2000 were compiled from information gathered on the EENDR questionnaires sent to individuals who received doctoral degrees in the mathematical sciences during the 1999–2000 academic year from universities in the United States (see previous section for more details).

The questionnaires were distributed to 1,046 recipients of degrees using addresses provided by the departments granting the degrees; 603 individuals responded between late October and April. Responses with insufficient data or from individuals who indicated they had part-time employment were considered unusable. Numbers of usable responses for each salary category are reported in the following tables.

Readers should be warned that the data in this report are obtained from a self-selected sample, and inferences from them may not be representative of the population.

Key to Tables. Salaries are listed in hundreds of dollars. Nine-month salaries are based on 9–10 months’ teaching and/or research, not adding extra stipends for summer grants or summer teaching or the equivalent. Years listed are the academic year in which the doctorate was received. M and F are male and female respectively. Some persons receiving a doctoral degree had been employed in their present position for several years. Quartile figures are given only in cases where the number of responses is large enough to make them meaningful. All categories of “Teaching or Teaching and Research” and “Research” contain only those recipients employed at academic institutions. The “Research, 9-10-Month Salaries” table was dropped as of 1998 because so few recipients respond in this category that the data was not considered meaningful. Starting salaries for those reporting a postdoctoral position are available for a fourth year. These salaries are also included within the academic tables and box plots on pages 717-718.


For each boxplot the box shows the first quartile (Q1), the median (M), and the third quartile (Q3). The interquartile range (IQR) is defined as Q3−Q1. Think of constructing invisible fences 1.5×IQR below Q1 and 1.5×IQR above Q3. Whiskers are drawn from Q3 to the largest observation that falls below the upper invisible fence and from Q1 to the smallest observation that falls above the lower invisible fence. Think of constructing two more invisible fences, each falling 1.5×IQR above or below the existing invisible fences. Any observation that falls between the fences on each end of the boxplots is called an outlier and is plotted as * in the boxplots. Any observation that falls outside of both fences either above or below the box in the boxplot is called an extreme outlier and is marked as * in the boxplot.
### Academic Teaching/Teaching and Research

#### 9-10-Month Salaries (in hundreds of dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>Min</th>
<th>Q₁</th>
<th>Median</th>
<th>Q₃</th>
<th>Max</th>
</tr>
</thead>
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<td>80</td>
<td>105</td>
<td>360</td>
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</tr>
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<td>2000</td>
<td>250</td>
<td>380</td>
<td>415</td>
<td>450</td>
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</tbody>
</table>

**Ph.D. Year**

- 1965
- 1970
- 1975
- 1980
- 1985
- 1990
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000

#### Ph.D. Year

- Total (183 male/72 female)
- 2000M 250 380 415 450 650
- 2000F 321 380 413 450 620

#### One year or less experience (149 male/57 female)

- 2000M 250 380 415 450 650
- 2000F 321 380 413 450 620

### Academic Teaching/Teaching and Research

#### 11-12-Month Salaries (in hundreds of dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>Min</th>
<th>Q₁</th>
<th>Median</th>
<th>Q₃</th>
<th>Max</th>
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<td>374</td>
<td>420</td>
<td>469</td>
<td>650</td>
</tr>
</tbody>
</table>

**Ph.D. Year**

- Total (45 male/13 female)
- 2000M 300 390 460 650 1170
- 2000F 395 465 500 570 750

#### One year or less experience (34 male/10 female)

- 2000M 300 390 460 650 1170
- 2000F 395 474 510 560 750

### Figure

- **1994** to **2000**
- **Salary (in hundreds of 2000 dollars)**
- **Estimated 3-year moving averages**
- **Median estimates**
- **Minimum and maximum observations**

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**2000 Annual Survey of the Mathematical Sciences**
### Academic Research Only

**11-12-Month Salaries**

<table>
<thead>
<tr>
<th>Ph.D. Year</th>
<th>Min</th>
<th>Q₁</th>
<th>Median</th>
<th>Q₃</th>
<th>Max</th>
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<td>384</td>
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<td>555</td>
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</tbody>
</table>

**Reported Median in 2000$**

- **Total (23 male/17 female)**
  - 2000M: 4400
  - 2000F: 4500

**One year or less experience (23 male/14 female)**

- 2000M: 3000
- 2000F: 3000

### Government

**11-12-Month Salaries**

<table>
<thead>
<tr>
<th>Ph.D. Year</th>
<th>Min</th>
<th>Q₁</th>
<th>Median</th>
<th>Q₃</th>
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<td>440</td>
<td>540</td>
<td>640</td>
<td>830</td>
<td>600</td>
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</table>

**Reported Median in 2000$**

- **Total (11 male/6 female)**
  - 2000M: 4400
  - 2000F: 4500

**One year or less experience (9 male/4 female)**

- 2000M: 3000
- 2000F: 3000
### Definitions of the Groups

As has been the case for a number of years, much of the data in these reports is presented for departments divided into groups according to several characteristics, the principal one being the highest degree offered in the mathematical sciences. Doctoral-granting departments of mathematics are further subdivided according to their ranking of "scholarly quality of program faculty" as reported in the 1995 publication *Research-Doctorate Programs in the United States: Continuity and Change*. These rankings update those reported in a previous study published in 1982. Consequently, the departments which now comprise Groups I, II, and III differ significantly from those used prior to the 1996 survey.

The subdivision of the Group I institutions into Group I Public and Group I Private was new for the 1996 survey. With the increase in number of the Group I departments from 39 to 48, the Annual Survey Data Committee judged that a further subdivision of public and private would provide more meaningful reporting of the data for these departments.

Brief descriptions of the groupings are as follows:

- **Group I** is composed of 48 departments with scores in the 3.00-5.00 range. Group I Public and Group I Private are Department at public institutions and private institutions respectively.
- **Group II** is composed of 56 departments with scores in the 2.00-2.99 range.
- **Group III** contains the remaining U.S. departments reporting a doctoral program, including a number of departments not included in the 1995 ranking of program faculty.
- **Group IV** contains U.S. departments (or programs) of statistics, biostatistics, and biometrics reporting a doctoral program.
- **Group V** contains U.S. departments (or programs) in applied mathematics/applied science, operations research, and management science which report a doctoral program.
- **Group Va** is applied mathematics/applied science; **Group Vb**, which is no longer surveyed as of 1998-99, was operations research and management science.
- **Group M** contains U.S. departments granting a master's degree as the highest graduate degree.
- **Group B** contains U.S. departments granting a baccalaureate degree only.

*Listings of the actual departments which comprise these groups are available on the AMS Website at [www.ams.org/employment/].*

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2These findings were published in *An Assessment of Research-Doctorate Programs in the United States: Mathematical and Physical Sciences*, edited by Lyle V. Jones, Gardner Lindzey, and Porter E. Coggeshall, National Academy Press, Washington, DC, 1982. The information on mathematics, statistics, and computer science was presented in digest form in the April 1983 issue of the Notices, pages 237-267, and an analysis of the classifications was given in the June 1983 Notices, pages 392-393.
Other Data Sources

Supplemental Listing of New Doctoral Recipients, 1999–2000

CALIFORNIA

University of California, Los Angeles (6)

Statistics
Bentov, Stanley, A Markov chain Monte Carlo method for approximating 2-way contingency tables with applications in the stability analysis of ecological ordination.

Brauer, Amy, A rate-disorientation approach to massive data set analysis.

Bond, Jason, A robust approach to SIR estimation.

Hua, Ming-Yi, Model checking for incomplete high dimensional categorical data.

Piersol, Laura, Fitting nonlinear mixed effect models by Laplace approximation.

Xie, Jun, Entropy filtering method and insertion/deletion robust algorithm for multiple local sequence alignment.

NEW HAMPSHIRE

University of New Hampshire (2)

Mathematics
Parker, Andy, Topics in chaotic secure communication.

Pendharkar, Hemant, Central sequences and C*-algebras.
Lieb Awarded Schock Prize

The Royal Swedish Academy of Sciences has announced the names of recipients of the Rolf Schock Prizes. These international prizes honor contributions to mathematics, logic and philosophy, visual arts, and music. The prizes, awarded every two years, amount to 400,000 Swedish crowns (approximately US$40,000).

ELLIOTT H. LIEB of Princeton University has been awarded the 2001 Schock Prize in mathematics "for his outstanding work in mathematical physics, particularly for his contribution to the mathematical understanding of the quantum-mechanical many-body theory and for his work on exact solutions of models in statistical mechanics and quantum mechanics."

Lieb has made pioneering contributions in many areas of mathematics, particularly mathematical analysis and mathematical physics. He has contributed to the understanding of many of the fundamental theories of quantum mechanics, statistical mechanics, and thermodynamics. Of particular importance is his work on exactly solvable models in statistical mechanics and quantum mechanics, as well as his contribution to understanding of the quantum-mechanical many-body problem. By studying the distribution of energy within quantum-mechanical systems, Lieb and his coworkers have achieved very precise results regarding fundamental questions of the stability of matter.

Elliot H. Lieb was born in Boston in 1932. He studied at the Massachusetts Institute of Technology and at the University of Birmingham, England, from which he received his Ph.D. in mathematical physics in 1956. He was professor of applied mathematics between 1968 and 1973 and of mathematics and mathematical physics between 1973 and 1975, both at MIT. Since 1975 he has been professor of mathematics and physics at Princeton University.

About Rolf Schock

Rolf Schock was born in France on April 5, 1933. His family had emigrated from Germany in 1931; they later settled in the United States. He studied geology, psychology, and mathematics at the University of New Mexico and then pursued postdoctoral studies in philosophy, first at the University of California, Berkeley, and then at UCLA. After moving to Sweden he received the Fil.Lic. degree in philosophy from Stockholm University in 1964 and a Ph.D. from Uppsala University in 1968. His dissertation, "Logics without existence assumptions", was an early work in what is now known as free logic and has often been cited by scholars in the field. Schock wrote many other works in logic and the philosophy of science. He never held a permanent appointment, although he was a lecturer in Sweden for brief periods, and for many years the Royal Institute of Technology provided him with a base. He was also a painter, photographer, and traveler. After his death in an accident on December 5, 1986, it came to light that he had left a considerable fortune, which he had inherited from his father. Schock bequeathed half of the funds for prizes in the arts and sciences.

—From a Royal Swedish Academy of Sciences announcement
Grabovsky and McCann Receive Monroe Martin Prize

The sixth Monroe Martin Prize of the University of Maryland, College Park, was presented on March 2, 2001. Two $2,000 awards were made.

The first recipient was YURI GRABOVSKY for his paper "Exact relations for effective tensors of polycrystals. I. Necessary conditions", which appeared in Archive for Rational Mechanics and Analysis 143 (1998), 309–329. This paper describes a general method for finding all exact relations for effective moduli of polycrystals by reducing the question to an algebraic problem of characterizing the rotationally invariant families of Jordan algebras. The method is applicable to a variety of physical settings, including elasticity, thermoelasticity, and piezoelectricity. Grabovsky was an undergraduate and graduate student at New York University and received his Ph.D. in 1994. He is currently on the faculty of Temple University.

The second recipient was ROBERT McCANN for his paper "Exact solutions to the transportation problem on the line", which appeared in Proceedings of the Royal Society of London A455 (1999), 1341–1380. This paper analyzes the solution of a classical optimization problem formulated by Monge in 1781. Couched in an economic setting, the problem is as follows: Given a distribution of iron mines and a distribution of factories that require iron ore, decide how the mines should supply the ore to the factories so as to minimize the total transportation costs. When the cost is a strictly concave increasing function of the distance traveled, this problem has a unique, geometrically characterized solution that exhibits a hierarchical structure. The paper elegantly exploits this structure in the one-dimensional setting to derive an algorithm that obtains the solution by a combinatorial sequence of finite-dimensional optimizations involving convex, separable network flows. After obtaining his B.S. from Queen's University at Kingston, McCann received his Ph.D. from Princeton University in 1994. He is currently on the faculty of the University of Toronto.

The Monroe Martin Prize was established to honor the outstanding contributions of Monroe H. Martin, professor emeritus at the University of Maryland, College Park. He was chair of the Department of Mathematics from 1942 until 1954 and was the founding director of the Institute for Fluid Dynamics and Applied Mathematics (a forerunner of the Institute for Physical Sciences and Technology) from 1952 until 1968. The prize is awarded every five years by the Institute for Physical Sciences and Technology to honor outstanding sole-authored papers by junior mathematicians. As on all previous occasions, the presentation of the awards was made by Martin, now in his ninetieth year. Previous prize winners are Neil Berger (1975), Marshall Slemrod (1980), Jonathan Goodman (1985), Marek Rychlik (1990), A.M. Stuart (1995), and Z. Xia (1995).

—From a University of Maryland announcement

Hitchin Receives Sylvester Medal

The 2000 Sylvester Medal of the Royal Society of London was awarded to NIGEL HITCHIN. He was recognized for his important contributions to many parts of differential geometry, in combination with complex geometry, integrable systems, and mathematical physics. His work interweaves the most modern ideas with the classical literature. This bronze medal is awarded triennially for the encouragement of mathematical research. A gift of £1,000 (about US$1,500) is also awarded.

—from a Royal Society announcement

National Academy of Sciences Elections

The National Academy of Sciences has announced the election of seventy-two new members and fifteen foreign associates. Following are the names and affiliations of those among the newly elected members who work in the mathematical sciences: ROBIN C. KIRBY, University of California, Berkeley; GREGORY A. MARQUELS, Yale University; DONALD G. SAARI, University of California, Irvine; LESLIE G. VAJANT, Harvard University; MICHAEL S. WATERMAN, University of Southern California; and EFIM I. ZELMANOV, Yale University. Among the newly elected foreign associates are JACOB PALIS, Instituto de Matematica Pura e Aplicada, Brazil; and MICHAEL POWELL, University of Cambridge.

—from an NAS announcement

Putnam Prizes Awarded

The winners of the 61st William Lowell Putnam Competition have been announced. The Putnam Competition is administered by the Mathematical Association of America and consists of an examination containing mathematical problems that are designed to test both originality and technical competence. Prizes are awarded to both individuals and teams.

The five highest ranking individuals, listed in alphabetical order, were GABRIEL D. CARROL, University of California, Berkeley; ABHINAV KUMAR, Massachusetts Institute of Technology; CIPIAN MANOLESCU, Harvard University; PAOLO PLYAVSKYY, Massachusetts Institute of Technology; and ALEXANDER B. SCHWARTZ, Harvard University.

Institutions with at least three registered participants obtain a team ranking in the competition based on the rankings of three designated individual participants. The five top-ranked teams (with team members listed in alphabetical order) were: Duke University (John J. Clyde, Jonathan G. Curtis, Kevin D. Lacker); Massachusetts Institute of Technology (Aram W. Harrow, Abhinav Kumar, Ivan Petrukiev); Harvard University (Lukasz Fidkowski, Davesh Maulik, Curtis, Kevin D. Lacker); Massachusetts Institute of Technology (Aram W. Harrow, Abhinav Kumar, Ivan Petrukiev); Harvard University (Lukasz Fidkowski, Davesh Maulik,
Christopher C. Mihelich; California Institute of Technology (Kevin P. Costello, Christopher M. Hirata, Michael Shulman), and University of Toronto (Jimmy Chui, Pavel T. Gyrya, Pompiliu Manuel Zamfir).

Carroll, Schwartz, and Lacker are all former competitors and winners in the U.S. and International Mathematical Olympiads.

The top five individuals in the competition received cash awards of $2,500; the next ten received $1,000. The first-place team was awarded $25,000, with each team member receiving $1,000. The team awards for second place were $20,000 and $800; for third place, $15,000 and $600; for fourth place, $10,000 and $400; and for fifth place, $5,000 and $200.

—Elaine Kehoe

Tarokh Receives Waterman Award

VAHID TAROKH of the Massachusetts Institute of Technology is the recipient of the Alan T. Waterman Award of the National Science Foundation.

Tarokh is a recognized leader in the research field of wireless communications and the primary inventor of "space-time coding", a technique that significantly improves the speed and reliability of wireless data transmission. He built on highly complex mathematical models to develop protocols that can be transmitted via multiple antennas and received by sites that may or may not use multiple antennas.

The annual Waterman Award honors an outstanding young U.S. scientist or engineer who is at the forefront of his or her research field. The honorée receives a medal and a $500,000 grant over three years for scientific research or advanced study in any field of science or engineering.

—From an NSF announcement

Deaths

GARY L. AMENDE, of Sheridan, WY, died on September 18, 2000. Born on April 22, 1969, he was a member of the Society for 4 years.

NORMAN V. FELLERS, Keane Inc., Rockville, MD, died on April 9, 2001. Born in 1932, he was a member of the Society for 42 years.

GERALD B. HUFF, of Falls Church, VA, died on April 17, 2001. Born on May 23, 1909, he was a member of the Society for 58 years.

GUENTER M. SCHINDLER, retired, Rockwell International, Seal Beach, CA, died on December 19, 2000. Born on September 15, 1928, he was a member of the Society for 42 years.
Travel Grants for ICM 2002, Beijing, China

The American Mathematical Society has applied to the National Science Foundation (NSF) for funds to permit partial travel support for U.S. mathematicians attending the 2002 International Congress of Mathematicians (ICM2002), to be held August 20-28, 2002, in Beijing, China. In anticipation of the availability of funds, the Society is preparing to administer the selection process, which would be similar to those for previous programs funded in 1990, 1994, and 1998.

This program is open to U.S. mathematicians (those who are currently affiliated with a U.S. institution). Early-career mathematicians (those within six years of the doctorate), women, and members of U.S. groups under-represented in mathematics are especially encouraged to apply. ICM2002 Invited Speakers from U.S. institutions should submit applications if funding is desired.

Applications for support are included in the back of this issue, and forms will be available on the AMS Website (http://www.ams.org/careers-edu/icmapp.html) beginning August 1, 2001. All completed application forms must be mailed to the AMS by October 31, 2001. This travel grants program, if funded, will be administered by the Professional Services Department, AMS, P.O. Box 6248, Providence, RI 02940. The department may be contacted by e-mail at ICM02@ams.org or by telephone at 800-321-4267, ext. 4105, or 401-455-4105.

Applications will be evaluated by a panel of mathematical scientists under the terms of a proposal submitted to the NSF by the Society. Should the proposal to the NSF be funded, the following conditions will apply. Mathematicians accepting grants for partial support of travel to ICM2002 may not supplement them with any other NSF funds. Currently, it is the intention of the NSF's Division of Mathematical Sciences to provide no additional funds on its other regular research grants for travel to ICM2002. However, an individual mathematician who does not receive a travel grant may use regular NSF grant funds, subject to the usual restrictions and prior approval requirements.

Call for Nominations for AWM Hay and Schafer Awards

The Executive Committee of the Association for Women in Mathematics (AWM) is calling for nominations for the Louise Hay Award for Contributions to Mathematics Education and the Alice T. Schafer Mathematics Prize.

The Louise Hay Award is intended to recognize outstanding achievements in any area of mathematics education, interpreted in the broadest possible sense. The award is presented annually 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 nomination document(s) should include: (1) a one- to three-page letter of nomination highlighting the exceptional contributions of the candidate; (2) a curriculum vitae of the candidate, not exceeding three pages; and (3) three letters supporting the nomination. It

All information currently available about the ICM2002 program, organization, and registration procedure is located on the ICM2002 Website, http://www.icm2002.org.cn/.

—AMS Professional Services Department

Funding Opportunities at NIH

The National Institute of General Medical Sciences (NIGMS) of the National Institutes of Health (NIH) seeks to forge interdisciplinary partnerships between biomedical researchers and mathematical scientists and engineers.

For more information about new funding opportunities that include grants for research, training, and workshops, please visit the NIGMS Website at http://www.nigms.nih.gov/funding/complex_systems.html.

—From an NIGMS announcement
is strongly recommended that the letters represent a range of constituents affected by the nominee's work.

The Alice T. Schafer Prize is awarded to an undergraduate woman for excellence in mathematics. The nominee may be at any level in her undergraduate career but must either be a U.S. citizen or have a U.S. school address. A letter of nomination for the Schafer Prize should include, but not be limited to, an evaluation of the nominee on the following criteria: (1) quality of performance in advanced mathematics courses and special programs, (2) demonstration of real interest in mathematics, (3) ability to do independent work in mathematics, and (4) performance in mathematical competitions at the local or national level, if any. A copy of transcripts and an indication of the candidate's undergraduate level should be included with a letter of nomination. Supporting materials (e.g., reports from summer work using mathematics, copies of talks given in student chapters, recommendations, etc.), if applicable, should be enclosed with the nomination.

Five complete copies of nomination material for these awards should be sent to either: The Hay Award Selection Committee or The Alice T. Schafer Award Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, MD 20742-2461. For further information call the AWM at 301-405-7892 or send e-mail to awm@math.umd.edu. Please note that nominations via e-mail or fax are not acceptable. The deadline for nominations for both awards to be received at the AWM office is October 1, 2001.

—AWM announcement

Call for Proposals for CARGO Program

The Division of Computer and Communications Research (CCR) and the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF), together with the Defense Sciences Office of the Defense Advanced Research Projects Agency (DARPA), plan to support research and development teams focusing on mathematical and computational innovations relevant to representation and computational manipulation of geometrical objects. The title of the program is Computational and Algorithmic Representations of Geometric Objects (CARGO).

These awards will be administered by the NSF. Areas of specific interest include: computational topology and geometry; computational and geometric cartography, including spatial statistics; and geometric aspects of graphics and computer-aided design (CAD).

Especially encouraged are efforts involving collaborations of experts in the mathematical and computational sciences with other scientists, engineers, and practitioners representing diverse application areas. Proposals for incremental improvements or ongoing efforts will not be selected for funding.

Two types of projects are anticipated: (1) Incubation grants: Standard awards of up to $100K for one or two years to develop collaborations of mathematical scientists, computer scientists, and application experts relevant to the objectives of the CARGO program; and (2) Team grants: Continuing awards of up to three years at $200,000-$300,000 per year to support teams of investigators. The total anticipated funding amount is $4 million in fiscal year 2002.

The deadline for proposals is September 4, 2001. The following three program officers may be contacted for further information: William Randolph Franklin, CCR, telephone 703-292-8912, e-mail: wfrankli@nsf.gov; Alvin I. Thaler, DMS, telephone 703-292-4863, e-mail: thaler@nsf.gov; Douglas Cochran, DARPA, telephone 703-696-2287, e-mail: dcochran@darpa.mil.


—From an NSF announcement

Call for Nominations for NAS Award

The National Academy of Sciences is accepting nominations for the NAS Award in Applied Mathematics and Numerical Analysis, a $10,000 prize awarded approximately every three years for outstanding work in applied mathematics and numerical analysis by a candidate whose research has been carried out in institutions located in North America.

Nominations will be accepted through August 31, 2001. For more information contact: National Academy of Sciences, Awards Program, Room NAS 185, 2101 Constitution Avenue, NW, Washington, D.C. 20418; phone: 202-334-1602; fax: 202-334-1682; e-mail: awards@nas.edu; Web: http://www.national-academies.org/nas/awards/.

—From an NAS announcement

NSF Focused Research Groups

The Focused Research Groups (FRG) activity of the Division of Mathematical Sciences (DMS) of the National Science Foundation supports small groups of researchers in the mathematical sciences.

The DMS has announced tentative deadline dates for the fiscal year 2002 competition for FRG grants. The anticipated deadline for the required letters of intent to submit FRG proposals is August 21, 2001. The anticipated deadline date for full FRG proposals is September 21, 2001. At the time of this writing, these deadline dates were subject to change (but will not be any earlier than stated here).

Last year's FRG solicitation is the same as this year's, except for the deadline dates, and may be found on the Web at http://www.nsf.gov/cgi-bin/getpub?nsf00114/.

—Allyn Jackson
Douglas Arnold to Be Next IMA Director

At the end of August 2001, Douglas N. Arnold will become the director of the Institute for Mathematics and its Applications (IMA). He succeeds Willard Miller, who has served in the post for the past four years. The IMA is part of the University of Minnesota and is one of three mathematical sciences institutes funded by the National Science Foundation (NSF).

Arnold is currently Distinguished Professor of Mathematics at Pennsylvania State University. He holds other positions at the university as well: he is a codirector of the Center for Computational Mathematics and Applications, the associate director of the Institute for High Performance Computing Applications, and a member of the Center for Gravitational Physics and Geometry. Arnold has had a long association with the IMA and spent two years in residence there. He also recently served on the IMA Board of Governors.

Arnold’s primary research interests are numerical analysis, partial differential equations, mechanics, and, in particular, the interplay among these fields. He has made major contributions to the numerical simulation of elastic plates and shells and also of incompressible fluids. Two years ago he used an NSF Interdisciplinary Grant in the Mathematical Sciences to immerse himself in the nascent area of computational relativity, which seeks computational and numerical solutions to Einstein’s field equations. One of the big challenges is the detection and interpretation of gravitational wave data. Detectors for these waves are now being built and will for the first time give scientists a way of collecting astronomical data outside the electromagnetic spectrum. Arnold sees abundant opportunities for mathematical scientists to contribute to this research.

Since its founding in 1979 the IMA has established itself as one of the premier institutes in the world for applied, interdisciplinary, and industrial mathematics. One direction in which Arnold hopes to lead the IMA is toward more involvement with computation. “The digitalization of all areas of science and technology means that there is a place for computation in all programs of the IMA,” Arnold remarked. Such an emphasis would require increased computational resources, but, more importantly, it would require bringing the right people together. “A major goal of the IMA is to connect people,” Arnold said. “We want to bring to people who are at the state of the art in computing, problems that they might not be aware of. We also want to convince scientists to bring their problems” to mathematical and computational scientists who have expertise to help solve them.

“People sometimes ask, Is IMA a conference center? or is it a research institute where people actually do mathematics?” Arnold remarked. “It’s both. But it is also a place for changing what people do. They spend some time at the IMA and return to their home institutions more connected to important problems and more productive.” He is particularly interested in continuing to develop the institute’s role as a training center where people can learn about new areas of research in which the mathematical sciences can make contributions. “Mathematics departments suffer from a perceived isolation from other sciences,” and many are just now starting to reach out, he noted. “If we are going to flourish, those connections have to be made.”

Avner Friedman, who preceded Miller as IMA director, was responsible for establishing many of the institute’s strong ties to industry. As Arnold put it, Friedman “redefined what people think of when they say ‘industrial mathematics’.” Arnold hopes to continue to build this aspect of the IMA agenda. To this end, Fadil Santosa, who has served part-time as associate director for industrial relations at the IMA, has now been made a full-time associate director. Arnold also plans to continue the “hot topics” workshops initiated by his predecessor, Willard Miller. These workshops are centered on problems of current interest to industry; Arnold hopes to expand them to include problems coming from other scientific disciplines. Another emphasis for Arnold will be fundraising. Currently about $2.2 million of the IMA’s $3.5 million budget comes from the NSF, and Arnold would like to increase the fraction coming from non-NSF sources.

Arnold received his Ph.D. from the University of Chicago in 1979 under the direction of Jim Douglas. He was on the faculty of the University of Maryland before taking a position as professor at Pennsylvania State University in 1989. In 1991 he received the first International Giovanni Sacchi Landriani Prize of the Accademia di Scienze e Lettere in Milan. Arnold has been invited to give a Plenary Lecture at the International Congress of Mathematicians in Beijing in August 2002.

Willard Miller will be returning to the mathematics faculty of the University of Minnesota after his four-year term as IMA director, during which he led the IMA through a successful national recompetition for funding of mathematics institutes by the NSF. He coordinated the
original 1979 proposal for the founding of the IMA and was associate director for seven years.

"We are entering a period in which mathematics should become a vital component of many fields and industries in which its presence has been limited until now—the life sciences and information technology, for example,” Arnold said. "There is a wealth of new opportunities and challenges for the IMA in the coming years. I am greatly excited and honored by the chance to direct it through that period."

—Allyn Jackson

ICM2002 Satellite Conferences

Before or after the 2002 International Congress of Mathematicians (ICM2002) in Beijing, a series of satellite conferences will be held in different parts of China as well as in neighboring countries and areas. ICM2002 will be held August 20-28, 2002.

Below is a list of the titles and locations of the ICM2002 satellite conferences. Further information is available on the Web at http://www.icm2002.org.cn/satellite/index.htm.

August 5-15 (dates not confirmed), Kyoto, Japan: New Directions in Dynamical Systems
August 11-17, Moscow State Aviation Institute, Moscow: Differential and Functional Differential Equations
August 11-19, Taiyuan: Nonlinear Functional Analysis
August 12-16, Pohang University of Science and Technology (POSTECH), Pohang, South Korea: Infinite Dimensional Function Theory
August 12-16, Shanxi Normal University, Xian: Geometric Topology
August 12-17, University of Tibet, Lhasa, Tibet: Mathematics Education
August 13-17, East China Normal University, Shanghai: Algebraic Geometry
August 13-17, Weihai Campus, Shandong University: Number Theory and Arithmetic Geometry
August 13-19, Beijing: Discrete, Combinatorial and Computational Geometry
August 14-17, Chinese University of Hong Kong (co-sponsored by Chung Chi College, Southeast Asian Mathematical Society, and UNESCO): International Conference in Algebras and Related Topics
August 14-17, Qingdao University, Qingdao: Game Theory and Applications
August 14-17, Shanghai Jiao-Tong University, Shanghai: Complex Analysis
August 14-18, Chengde: Operator Algebras and Applications
August 14-18, Chengdu: Symplectic Topology and Geometry
August 14-18, Science and Culture Center Hotel, Daejeon, South Korea: Several Complex Variables and Complex Geometry
August 14-18, Shanghai University, Shanghai: Matrix Theory and Its Applications
August 14-18, Zhejiang University, Hangzhou: Harmonic Analysis and Its Applications
August 15-17, Hong Kong University of Science and Technology, Hong Kong: Combinatorics, Graph Theory, and Applications
August 15-17, National University of Singapore: Symposium on Stochastics and Applications
August 15-18, Guolin: Mathematical Biology
August 15-18, Northwest University, Xian: International Colloquium for the History of Mathematics
August 16-19, University of Macau: Clifford Analysis
August 17-18: Nankai Institute of Mathematics, Nankai University, Tianjin: Differential Geometry and Global Analysis
August 17-19, Beijing: Mathematical Software
August 29-31, Hebei University, Baoding: Nonlinear Partial Differential Equations in Mechanics and Physics
August 29-31, Weihai, Shandong, and Beijing: Backward Stochastic Differential Equations
August 29-September 1, Huangshan: Nonlinear Evolution Equations and Dynamical Systems
August 29-September 1, Xian Jiaotong University, Xian: Scientific Computation
August 29-September 2, City University of Hong Kong, Hong Kong: Nonlinear Partial Differential Equations—Theory and Approximation
August 29-September 2, Southwest China Normal University, Chongqing: International Conference on Mathematical Logic, 8th Asian Local Conference
August 29-September 2, Suzhou University, Suzhou: Algebra
August 30-September 1, Northwestern Polytechnical University, Xian: Cybernetics and Optimization
August 30-September 2, University of Science and Technology of China, Hefei: Geometric Function Theory in Several Complex Variables
August 30-September 3, Hebei Normal University, Shijiazhuang: Combinatorics
August 30-September 3, Dalian University of Technology, Dalian: Computational Mathematics and Applications
August 30-September 4, Lanzhou (Dunhuang): Ordinary Differential Equations

—From an ICM2002 announcement

Memorial Service for Robert A. Rankin

The family of Robert A. Rankin, emeritus professor at the University of Glasgow, will hold a Service of Thanksgiving at 10:00 a.m. on Saturday, October 13, 2001, at the University of Glasgow Memorial Chapel. The service will be followed by an informal buffet. Those interested in attending should contact Rankin's daughter, F. K. C. Smith, by e-mail at fenny@smithzzz.demon.co.uk.

—F. K. C. Smith
Inside the AMS

Council Approves Collection Mechanism for Weisfeiler Investigation

At its meeting in April 2001 the AMS Council endorsed a funds collection mechanism to support the investigation of the 1985 disappearance in Chile of the mathematician Boris Weisfeiler. The mechanism, called the Boris Weisfeiler Legal Fund, was set up by the Committee of Concerned Scientists.

Weisfeiler was a professor of mathematics at Pennsylvania State University when he disappeared in Chile during a hiking trip in January 1985. Further information about his case may be found in "Letters to the Editor" (this issue, page 680, and the January 2001 issue, pages 7-8). Information is also available on the Web site of the Committee of Concerned Scientists, http://www.libertynet.org/~ccs/, and on the Web site http://weisfeiler.com/boris/.

Tax-deductible contributions can be made by writing checks payable to the Committee of Concerned Scientists, with an indication on the check that it is for the Weisfeiler Fund. They should be mailed to: Mrs. Dorothy Hirsch, Executive Director, Committee of Concerned Scientists, 53-34 208th Street, Bayside, NY 11364.

—Joel Lebowitz, Rutgers University
Chair, AMS Committee on Human Rights of Mathematicians

AMS-AAAS Media Fellow Chosen

This year the AMS is again participating in the Mass Media Science and Engineering Fellowship program of the American Association for the Advancement of Science (AAAS). This program places graduate students in internships in major media organizations for ten weeks during the summer. The purpose of the program is to improve public understanding and appreciation of science and technology and to sharpen the ability of the fellows to communicate complex technical issues to nonspecialists. RAFAEL (RAFE) JONES, a graduate student in mathematics at Brown University, has been awarded a fellowship for the summer of 2001 through the sponsorship of the AMS. He will spend the fellowship at Discovery Channel Online.

—Elaine Kehoe

AMS Web Page on Authoring Software

The AMS has created a Web page for the exchange of information on authoring software for mathematics. The purpose of the page is to serve as a forum for discussion and comparison of various authoring software tools and also as a central resource for links to software and information available on the Web.

\TeX{} has become the language of choice for writing and publishing mathematical research. But software evolves rapidly, and there are continual innovations in authoring
software that mathematicians use. New initiatives such as the mathematical mark-up language MathML could bring further rapid changes that mathematical authors need to know about.

The aim of the AMS Web page on authoring software is to provide a place where users can find out what software is currently available, which software other authors have found most useful, how to get particular software or fonts, and how to achieve various effects with current software.

The URL for the page is http://www.ams.org/tools/authoring-software.html. Comments and contributions may be sent to authoring-software@ams.org.

—Allyn Jackson

AMS Game Show Produced in Rhode Island

In celebration of Mathematics Awareness Month, the AMS game show “Who Wants to Be a Mathematician?” was presented on the campus of Rhode Island College on April 25. The second production of the event (the first took place at the Joint Meetings in New Orleans in January) drew ten high school students and one eighth-grader from around Rhode Island as participants. As in New Orleans, AMS public awareness officer Michael Breen guided students through a series of mathematical questions. Questions asked of each contestant increased in difficulty, and each correct answer led to progression up a list of prizes ranging from a graphite calculator (a pencil) to the top prize, $2,000 in cash, donated by the AMS.

Jonathan Goulet, from Classical High School in Providence, was high-achiever for the day, the only contestant to win the top $2,000 prize. On his way to the top, Goulet made use of all of his “lifelines”. Patterned after the popular television show “Who Wants to Be a Millionaire?”, the AMS version offered these lifelines: Ask Your Teacher, 50-50, Ask the Audience.

The other students who took part in the Rhode Island game were: Bryan Cole, Bishop Hendricken High School; Jeremy Gordon, Exeter-West Greenwich High School; John Hawley, Toll Gate High School; Tom Howard, Cumberland High School; Alanna Hughes, Providence Country Day; Chris King, Ponaganset High School; Alexander Marcus, The Wheeler School; Emilie Pressman, Lincoln School; Elizabeth Toher, LaSalle Academy; and Nathaniel Walker, Burrillville High School.

The AMS Public Awareness Office plans to organize more appearances of the “game show” in 2002. Plans are under way to put on the game at the Joint Mathematics Meetings in San Diego and in Rhode Island to celebrate Mathematics Awareness Month next year.

—Sandra Frost

2001 Arnold Ross Lectures

On April 3, 2001, the AMS partnered with the St. Louis Science Center to present the twelfth annual Arnold Ross Lectures for high school mathematics students. Over 125 students and teachers came to hear this year’s invited speakers, Mary Ellen Rudin (University of Wisconsin) and John H. Conway (Princeton University). Rudin’s talk was entitled “What is Topology?”, and Conway spoke on “Tangles, Bangles and Knots”.

The Arnold Ross Lecture Series was started in 1988 by Paul J. Sally of the University of Chicago. In 1993 the lectures were named after Arnold E. Ross, emeritus professor of the Ohio State University, in honor of his many contributions to developing the mathematical talent of high school students (see the interview with Ross in this issue of the Notices). The lectures have been held in Boston (1988), San Diego (1990), Chicago (1992), Columbus, Ohio (1993), Minneapolis (1994), Houston (1995), College Park, Maryland (1996), Boston (1999), and Berkeley, California (2000).


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

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

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

The electronic-mail addresses are notices@math.tamu.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 979-845-6028 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines


August 15, 2001: Applications for the third competition for NRC Research Associateships. See http://www4.nationalacademies.org/osep/rap/, or contact the National Research Council, Associateship Programs (TJ 2114), 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2760; fax 202-334-2759; e-mail: rap@nas.edu.

August 21, 2001: Deadline for letters of intent to submit Focused Research Group (FRG) proposals to NSF. September 21 is deadline for full proposals. See "Mathematics Opportunities" in this issue.

August 31, 2001: Nominations accepted through this date for the National Academy of Sciences Award in Applied Mathematics and Numerical Analysis. See "Mathematics Opportunities" in this issue.

Where to Find It
A brief index to information that appears in this and previous issues of the Notices.
AMS Bylaws—November 1999, p. 1252
AMS e-Mail Addresses—November 2000, p. 1288
AMS Ethical Guidelines—June 1995, p. 694
AMS Officers 2000 and 2001 (Council, Executive Committee, Publications Committees, Board of Trustees)—May 2001, p. 520
AMS Officers and Committee Members—October 2000, p. 1127
Conference Board of the Mathematical Sciences—September 2000, p. 913
Information for Notices Authors—January 2001, p. 39
Mathematics Research Institutes Contact Information—August 2001, p. 731
National Science Board—February 2001, p. 216
NRC Board on Mathematical Sciences and Staff—April 2001, p. 427
NRC Mathematical Sciences Education Board and Staff—May 2001, p. 517
NSF Mathematical and Physical Sciences Advisory Committee—March 2001, p. 328
Program Officers for Federal Funding Agencies—October 2000, p. 1100 (DoD, DoE); November 2000, p. 1291 (NSF)
September 1, 2001: Applications for AWM Workshops for Women Graduate Students and Postdocs. See http://www.awm-math.org/, or contact Workshop Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, MD 20742-2461; telephone 301-405-7892; e-mail: awm@math.umd.edu.


October 1, 2001: Nominations for the Louise Hay and Alice T. Schafer awards of the AWM. See “Mathematics Opportunities” in this issue.

October 1, 2001: Nominations for the Emanuel and T. Parzen Prize. Submit nominations to J. H. Matis, Department of Statistics, Texas A&M University, College Station, TX 77873-3143.

October 1, 2001: Applications for NSF/AWM Travel Grants for Women. See http://www.awm-math.org/travelgrants.htm; telephone 301-405-7892; e-mail: awm@math.umd.edu.


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American Institute of Mathematics (AIM)
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World Wide Web: http://www.aimath.org/

Stefan Banach International Mathematical Center
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World Wide Web: http://dimacs.rutgers.edu/

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World Wide Web: http://www.fields.utoronto.ca/
Reference and Book List

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e-mail: mcaa@imf.au.dk
World Wide Web: http://www.imf.au.dk/
ResearchC/MCAA/index.html

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1000 Centennial Drive, #5070
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Telephone: 510-642-0143
Fax: 510-642-8609
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World Wide Web: http://www.mpim-bonn.mpg.de/
The Book List highlights books that have mathematical themes and hold appeal for a wide audience, including mathematicians, students, and a significant portion of the general public. When a book has been reviewed in the Notices, a reference is given to the review. Generally, the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. Suggestions for books to include on the list may be sent to the managing editor, e-mail: notices@ams.org.


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

### American and Canadian Mathematicians Visiting Abroad

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<td>Nottingham Trent University, United Kingdom</td>
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<tr>
<td>Liu, Weijiu (Canada)</td>
<td>University of Cincinnati</td>
<td>Partial Differential Equations</td>
<td>8/01 - 7/02</td>
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<td>Moorhouse, G. E. (U.S.A.)</td>
<td>Memorial University of Newfoundland</td>
<td>Geometry and Combinatorics</td>
<td>9/01 - 4/02</td>
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<td>Plohr, Bradley (U.S.A.)</td>
<td>Instituto de Matematica Pura e Aplicado, Brazil</td>
<td>Hyperbolic Systems</td>
<td>1/02</td>
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<td>Scott, Peter (U.S.A.)</td>
<td>Hebrew University, Israel</td>
<td>Geometric Group Theory, 3D Topology</td>
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<td>Taylor, B. A. (U.S.A.)</td>
<td>University of Dusseldorf, Germany</td>
<td>Plurisubharmonic Functions</td>
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<td>Toth, John (Canada)</td>
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<td>Differential Geometry</td>
<td>9/01 - 3/02</td>
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### Visiting Foreign Mathematicians

<table>
<thead>
<tr>
<th>Name and Home Country</th>
<th>Host Institution</th>
<th>Field of Special Interest</th>
<th>Period of Visit</th>
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<tbody>
<tr>
<td>Alexeevski, Andrei (Russia)</td>
<td>Massachusetts Institute of Technology</td>
<td>Algebraic Groups, Lie Algebras</td>
<td>9/01-10/01</td>
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<td>Annaby, M. H. (Egypt)</td>
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<td>8/01 - 5/02</td>
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<td>Assenkrova, Irina (Russia)</td>
<td>Florida Atlantic University</td>
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<td>8/01 - 5/02</td>
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<td>Blank, Michael (Russia)</td>
<td>Georgia Institute of Technology</td>
<td>Dynamics</td>
<td>8/01-12/01</td>
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<tr>
<td>Brooks, Robert (Israel)</td>
<td>Massachusetts Institute of Technology</td>
<td>Differential Geometry</td>
<td>9/01-12/01</td>
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<tr>
<td>Buckley, Stephen (Ireland)</td>
<td>University of Michigan</td>
<td>Complex Analysis</td>
<td>9/01 - 8/02</td>
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<tr>
<td>Cabrelli, Carlos (Argentina)</td>
<td>Georgia Institute of Technology</td>
<td>Iterated Function Systems and Wavelets</td>
<td>1/02 - 5/02</td>
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<td>Chatzipantelidis, Panagiots (Greece)</td>
<td>Texas A&amp;M University</td>
<td>Numerical Analysis</td>
<td>9/01 - 5/03</td>
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<tr>
<td>Chen, Ya-Chen (Taiwan)</td>
<td>Arizona State University</td>
<td>Combinatorics</td>
<td>8/01 - 5/02</td>
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<tr>
<td>Cheung, Leungfu (Hong Kong)</td>
<td>University of Connecticut</td>
<td>Geometry/Partial Differential Equations</td>
<td>7/01 - 8/01</td>
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<td>Chung, Chy-Eong (Korea)</td>
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<td>Partial Differential Equations</td>
<td>9/01 - 5/02</td>
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<td>Copetti, Maria (Brazil)</td>
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<td>4/01 - 5/02</td>
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<td>DeLeener, Patrick (Belgium)</td>
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<td>Systems Theory, Control</td>
<td>8/01 - 5/02</td>
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<td>Diederich, Klas (Germany)</td>
<td>University of Michigan</td>
<td>Mathematics, Analysis</td>
<td>9/01 - 12/01</td>
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<td>Elezi, Artur (Albania)</td>
<td>Oklahoma State University</td>
<td>Algebraic Geometry</td>
<td>8/00 - 8/01</td>
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<tr>
<td>Englert, Berthold-Georg (Germany)</td>
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<td>Mathematical Physics</td>
<td>9/01 - 5/02</td>
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<tr>
<td>Esteyes, Eduardo (Brazil)</td>
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<td>Algebraic Geometry, Commutative Algebra</td>
<td>8/01 - 7/02</td>
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<tr>
<td>Fujikoshi, Yasuori (Japan)</td>
<td>Bowling Green State University</td>
<td>Multivariate Analysis</td>
<td>8/01-12/01</td>
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<td>Glovbevnik, Josip (Yugoslavia)</td>
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<td>Complex Analysis</td>
<td>9/01-12/01</td>
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<tr>
<td>Guillo, Jean-Claude (France)</td>
<td>University of California, Los Angeles</td>
<td>Partial Differential Equations</td>
<td>1/02 - 3/02</td>
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<tr>
<td>Hajlasz, Piotr (Poland)</td>
<td>University of Michigan</td>
<td>Analysis</td>
<td>9/01 - 8/02</td>
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</table>

The list of visiting mathematicians includes both foreign mathematicians visiting in the United States and Canada, and Americans and Canadians visiting abroad. Note that there are two separate lists.
<table>
<thead>
<tr>
<th>Name and Home Country</th>
<th>Host Institution</th>
<th>Field of Special Interest</th>
<th>Period of Visit</th>
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<tbody>
<tr>
<td>Held, Martin (Austria)</td>
<td>SUNY at Stony Brook</td>
<td>Computational Geometry</td>
<td>6/01-10/01</td>
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<td>Mathematical Physics</td>
<td>9/01-12/01</td>
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<td>Hu, Zejun (People's Republic of China)</td>
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<td>9/01-6/02</td>
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<td>Hwang, Jinsoo (Korea)</td>
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<td>Statistics</td>
<td>8/01-5/02</td>
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<td>Ishiwata, Makiko (Japan)</td>
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<td>Knot Theory</td>
<td>3/01-10/01</td>
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<tr>
<td>Jiang, Qiming (People's Republic of China)</td>
<td>West Virginia University</td>
<td>Waves</td>
<td>8/00-5/02</td>
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<tr>
<td>Karoński, Michal (Poland)</td>
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<td>Randomized Algorithms</td>
<td>1/02-5/02</td>
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<td>Katriel, Jacob (Israel)</td>
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<td>Combinatorics</td>
<td>9/01-2/02</td>
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<tr>
<td>Kim, Kang-Tae (South Korea)</td>
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<td>Koskela, Pekka (Finland)</td>
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<td>9/01-8/02</td>
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<td>Krouglikov, Natan (Russia)</td>
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<td>8/01-5/02</td>
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<tr>
<td>Kutyniok, Gitta (Germany)</td>
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<td>Time-Frequency Analysis and Wavelets</td>
<td>8/01-12/01</td>
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<td>Leiva, Hugo (Venezuela)</td>
<td>Brown University</td>
<td>Applications of Dynamical Systems to Ocean Flows</td>
<td>7/01-6/02</td>
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<td>Lee, Dae-Wong (Korea)</td>
<td>Wayne State University</td>
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<td>8/00-8/01</td>
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<td>8/01-5/02</td>
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<td>Li, Hong (People's Republic of China)</td>
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<td>Little, Charles (New Zealand)</td>
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<td>Loebi, Martin (Czech Republic)</td>
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<td>Łuczak, Tomasz (Poland)</td>
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<td>Ma, Xia (People's Republic of China)</td>
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<td>Turbulent Flows</td>
<td>6/01-5/02</td>
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<td>Marchal, Philippe (France)</td>
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<td>Probability and Stochastic Processes</td>
<td>8/01-5/02</td>
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<td>Marchesin, Dan (Brazil)</td>
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<td>10/01</td>
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<td>Matsumoto, Hiroyuki (Japan)</td>
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<td>Probability, Stochastic Analysis</td>
<td>3/02-12/02</td>
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<td>Mueller, Ursula (Germany)</td>
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<td>Munoz, Gustavo (Spain)</td>
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<td>Oliver, Bob (France)</td>
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<td>Ortega, Josue Ramirez (Mexico)</td>
<td>The College of William and Mary</td>
<td>Toeplitz Operators</td>
<td>7/01-7/02</td>
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<td>Paulauskas, Vygnatas (Lithuania)</td>
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<td>1/02-5/02</td>
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<td>Ramazan, Birant (Romania)</td>
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<td>Functional Analysis; Quantum Theory; Global Analysis; Analysis on Manifolds</td>
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<td>2/01-3/02</td>
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<td>Shi, Zhongrui (People's Republic of China)</td>
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<td>Shlosman, Sonya (France)</td>
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<td>Snashall, Nicole (England)</td>
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<td>Name and Home Country</td>
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<td>Field of Special Interest</td>
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<td>4/01 - 3/02</td>
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<td>Yasuhara, Akira (Japan)</td>
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<td>Yoon, Jungho (Korea)</td>
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<td>Approximations and Expansions; Numerical Analysis; Fourier Analysis</td>
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<td>Yuan, Guo-Cheng (People's Republic of China)</td>
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<td>Zubik-Kowal, Barbara (Poland)</td>
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<td>Partial Differential Equations; Numerical Analysis</td>
<td>8/01 - 5/02</td>
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</table>
From the AMS Secretary

Executive Director's Report to the 2001 Council

I have often said in past reports that the American Mathematical Society is a complicated organization. It has different faces — publisher, membership organization, and professional society — and its health can be measured in different ways — finances, satisfaction, or achievements. In the past, my annual report to the Council tried to emphasize one of these aspects each year. This year, however, I'd like to simplify my presentation by reducing the operation of the Society into its two simplest components — making money and spending it. I'll take the least amount of time describing the ways in which we make money, mainly because it's easier to describe (although not easier to do). Spending money is harder to describe because we have found so many new ways to do it.

Making Money

When it comes to revenues, members usually think of their dues first, associating each expenditure of the AMS directly with their most recent payment. But individual dues account for about 7% of the Society's revenue, and institutional dues account for only 3%. (And institutional dues are less than the discounts afforded to members on their subscriptions.)

![Revenue, 2000 ($21 million)](image)

The Society obtains revenue from meetings, but the direct costs of its entire meetings program slightly exceed the revenue. The Society also gets revenue by temporarily investing its cash from advanced payments, and it gains revenue from a variety of things such as mailing list sales, advertising, and contributions. But the Society makes most (75%) of its revenue from its publications, including books, journals, and the Math Reviews database.

- The book program (17% of revenues) continued to mature in 2000. The Society published 105 new titles, and unit sales of books increased by almost 10% over 1999. Unfortunately, the average revenue per unit was lower, and the revenue from book sales was essentially the same as the year before. Our book program is more visible and healthier than at any time in the past, and it will continue to expand in the coming years.

- The journals program (24% of revenues) remains a substantial part of the AMS publication program. There is steady attrition of subscriptions, but attrition is less than expected. The four primary AMS journals, which constitute the largest part of the program, have been electronic for more than 5 years, and the latest version makes them more functional and more widely used. We continue to look for ways to improve the electronic versions and to encourage mathematicians to make better use of them.

- Math Reviews (34% of revenues) gets better and better each year. We added 71,327 items to the database in 2000, including 54,386 reviews. There are now over 120,000 links to original articles, allowing users to navigate the electronic literature (even without a subscription to Math Reviews!). We added a free tool (MR Lookup) for authors and publishers to create links using the resources of Math Reviews. The formation of consortia has made it possible for previously non-subscribing institutions to obtain access to MathSciNet at minimal cost, and the consortia now include more than 300 new subscribing institutions as well as many previous...
subscribers. During the coming year, we will add an entirely new element to the Math Reviews database, including the original reference lists for many items in the database. Over time, this new aspect of the database will allow MR to create a citation index in addition to the database of reviews and bibliographic information. MathSciNet—the most popular electronic product—is upgraded each year in a steady cycle of development.

The total revenue of the Society is approximately twenty-one million dollars. In recent years, that revenue has exceeded our operating expenses by a healthy amount, and the difference (operating income) has been roughly 8% of revenues. The excess is added to our reserves, which have grown (until recently!) as the market grew. Our growing reserves provide financial security for the Society. The steady operating income, however, masks an underlying problem faced by the Society in the next few years. Our revenues have been relatively constant for a period of time, and we have maintained operating income only by increased efficiency. Faced with inexorably increasing expenses, we must find ways to increase revenues in the future.

**Spending Money**

Of course, it's natural that most of the money we spend goes to the publication program—it is a large enterprise involving most of the 225 staff of the Society. On the other hand, the publishing operations of the Society are both scholarly endeavors and programs designed to make extra revenue in order to pay for other activities. Investments in our publication program are therefore investments in the entire Society.

Most scientific societies would divide their other expenses into two categories, those directed at members and those directed at the scientific community as a whole. That division is hard to accomplish for the AMS, however, because we tend to blur the lines between member service and professional outreach. For example, our two member journals, the *Bulletin*
and the Notices, are major member benefits, but both journals are available online to all mathematicians for free. The AMS website has become a central way to communicate information to members, but all the information is made available to all mathematicians at no cost (to them). Employment services are accessible to everyone because restricting them to members (either individuals or institutions) seems unthinkable. Even discounts on meetings registrations are extended to people beyond our membership, often because our meetings are joint with other organizations. Our members (especially when it comes time to pay dues) sometimes ask what they get in return, and this blurring of member benefits and professional outreach makes it hard to give a direct answer.

On the other hand, many of our members understand that member services are often extended to the entire mathematics community, and they understand precisely because they represent many different communities. It is important to remember that more than a third of our membership is international, and that we have many types of members—ordinary, reciprocity, Category-S, emeritus, nominee. With the exception of the Bulletin and the Notices, there are no activities of the AMS that all groups view as a "benefit of membership".

A list of activities on which we spend our money, therefore, often looks like a list of outreach, that is, things we do for the entire mathematics community. It's important to keep in mind that almost every one of these things benefits members, either directly or indirectly, and hence a part of every activity is a "member benefit" as well as outreach.

Here is a list of some of that outreach, divided into categories that reflect the part of the Society most directly responsible for the activity.

**Washington Office**
The Washington Office is our largest single outreach activity. The most important goal of the Office is to network with various groups in Washington, including Congress, the agencies, and (especially) the other scientific societies. Providing a visible presence for mathematics in these communities is critically important. But the Office also carries out a number of specific projects each year.

**Mass Media Fellows Program**
Through the American Association for the Advancement of Science, the AMS has sponsored one or two Mass Media Fellows per year since 1997. The cost is approximately $7,500 per student (in addition to travel costs to attend the Joint Meetings). Through this program mathematics graduate students spend ten weeks in a mass media organization, including major magazines and newspapers. The participants are able to observe and participate in the process by which events and ideas become news, and improve their communication skills by learning to describe complex technical subjects in a manner understandable by the general public.

**Congressional Luncheon**
The Washington Office has organized Congressional Luncheon Briefings for the last four years. These briefings are held on Capitol Hill and are for Members of Congress and congressional staff. About 75-100 people attend the luncheon, which is organized and paid for by the Society. The overarching theme of these briefings is the importance of mathematics in today's society. Each briefing focuses on mathematics related to applications that benefit society, such as image reconstruction, communications security, brain function, and groundwater contamination.

**Joint Public Service Award**
The American Astronomical Society-American Mathematical Society-American Physical Society Public Service Award is awarded to a public figure in recognition of his or her sustained and exceptional contributions to public policies that foster support for research, education, and industrial innovation in the physical sciences and mathematics. The first awards were presented in 2000 to Senator Bill Frist, Senator Joseph Lieberman, and Dr. Harold Varmus, former Director of the National Institutes of
Health. Those awards were made at a reception in Washington, supported by the three societies and organized by the AMS. The 2001 awards will honor U.S. Representative Vernon Ehlers and Dr. Neal Lane, former Science Advisor to President Clinton.

**Department Chairs Workshop**
Each January since 1998, on the day before the Joint Meetings, the AMS has held a Department Chairs Workshop. The aim of these workshops is to provide information that can help chairs successfully manage and lead their departments. Workshop sessions, led by current and former chairs, focus on a range of issues and practical matters. Topics covered include the promotion and tenure process, various personnel issues, long-range planning, budget management, technology, and instruction. The workshop format encourages group discussion and a sharing of ideas and experiences. A small registration fee covers part of the cost, but these are mainly subsidized by the Society.

**Secondary Teachers Prize Breakfast**
Since 1998 the AMS has sponsored a breakfast honoring the secondary school teachers who win the Presidential Award for Excellence in Mathematics Teaching each year. One teacher from each state achieves this honor, and the AMS invites the teachers, as well as representatives from other mathematics organizations, to this breakfast.

**Preparing Future Faculty (PFF)**
The preparing future faculty program is a program in which doctoral granting degree departments collaborate with mathematics departments from other types of institutions (two year, four year, or master's degree institutions). The PFF program addresses the scope of faculty roles and responsibilities in all these institutions. Participating graduate students are mentored by faculty from their doctoral department, as well as by faculty from the non-doctoral granting institutions. The AMS and MAA, through an NSF grant awarded to the Council of Graduate Schools and the Association of American Colleges and Universities, sponsor four institutions in the PFF program—Arizona State University, SUNY at Binghamton, Virginia Tech, and the University of Washington. The Society contributes administrative time and travel to this project.

**Wonder Science**
WONDER SCIENCE was a science publication of the American Chemical Society (ACS) and the American Institute of Physics (AIP) directed toward elementary and middle school children. In 1997 the AMS began cooperating with the ACS and AIP on this publication. In 1998 the AMS became a co-publisher, paying for a part-time consultant to work with the publication staff. WONDER SCIENCE was meant to help teachers and parents increase student interest in science. At one point WONDER SCIENCE had over twenty thousand subscribers. Unfortunately, for a complicated set of reasons, WONDER SCIENCE ceased publication in 1999.

**AMS/MER Master's Degree Workshops**
Supported by a NSF grant, the AMS and the Mathematicians and Education Reform Forum (MER), in cooperation with SIAM, have organized two workshops on professional master's degrees. A third workshop will be held in the fall of 2001. These workshops focus on creating a forum for mathematics departments to discuss the issues related to professional master's degrees, and to gain insights about how to successfully implement a professional master's degree in their departments. The workshops look at the overall picture in graduate education, examine professional master's degrees and their place in a department's overall graduate program, and provide nuts-and-bolts information on how to develop professional master's degrees.

**AMS/MER Project on Excellence in Undergraduate Mathematics:**
"Excellence in Undergraduate Mathematics: Confronting Diverse Student Interest" is a three-year project aimed at mathematical sciences departments. The joint project of the American Mathematical Society and the Mathematicians and Education Reform Forum is an integrated program of six national workshops, networks of mathematical sciences departments, programs at national meetings, and publications. While highlighting the needs of particular student groups, the programs will focus also on critical issues that cut across all instruction. Reform efforts will be put in the context of the institutional role of mathematical sciences departments and their relationships with partner disciplines.

**Non-Traditional Employment**
Supported by a Sloan Foundation grant, the AMS and SIAM, in cooperation with the MAA, have developed a CD-ROM and video on non-academic employment directed at undergraduate mathematical sciences majors. Through the CD one can view and hear the experiences of mathematicians, as well as learn about the day-to-day responsibilities of mathematicians working in a variety of industries. Students also find out what to expect after completing a degree in mathematics. The same grant has also supported a website on non-academic employment (http://www.ams.org/careers/).

**Public Awareness**
The new Public Awareness office is staffed by two people (with secretarial support). A great deal of its work in the first year has been devoted to planning, but it has already established contacts with the press and provided publicity for our Joint Meeting. The Office fields calls from reporters seeking information about math-related topics, and the staff has supplied information or referred reporters to experts on topics including Congressional apportionment, the expected value of a hole-in-one golf promotion, the number of minority Ph.D.'s in math, the odds of picking a four-leaf clover, and chain letters. The Office maintains the Public Awareness Office Web pages (including outreach activities and special events of the AMS and other organizations), posts news releases, and acts as liaison with the Math on the Web editor. The Public Awareness Office is also represented on the AMS Staff Membership Council, which analyzes, revises and generates AMS communications to members and to potential members. In addition, the Office has worked on some specific projects in the past few months.

**Mathematical Moments**
The Public Awareness Office will produce a steady supply of one-page promotions called Mathematical Moments.
These are intended to illustrate the importance of research mathematics in everyday life, and the material can be used in written or oral presentations by mathematicians and non-mathematicians alike. Fifteen have been produced and more are on the way. The Moments are available to download from the AMS website (http://www.ams.org/ams/mathmoments.html). Hard copies have been sent to key NSF officials, and plans are underway to print and distribute sets to math departments across the country.

Discoveries and Breakthroughs in Science (DBIS)
The American Institute of Physics (AIP) produces a syndicated series of science stories (90 seconds long) for local news programs. There are about three stories per week, and the syndication is professionally marketed to television segments across the country. The Society is now contributing a small portion of the substantial funding for the program, and joining with several other societies to assist AIP. The Public Awareness Office offers ideas for shows, makes suggestions on the portions of scripts that deal with mathematics, and reviews the shows each month. (A story that was suggested on the mathematics of scheduling has already been produced.)

Who Wants To Be A Mathematician
A mathematical version of the popular TV game show was a success in New Orleans, attracting groups of high school students both as contestants and as members of the audience. Another show is scheduled for April 25th in Rhode Island as part of Math Awareness Month. Our Public Awareness Officers write questions, search for contestants, arrange sponsorship and host the show. A story on the show done at the Joint Meetings aired on the New Orleans news.

Arnold Ross Lectures
The Arnold Ross Lectures are given each year at a science museum and are partially funded by an endowment from Paul Sally. Traditionally, the lectures are given by two distinguished mathematicians, aimed at talented high school students, and concentrate on an aspect of mathematics that will help to attract such students into mathematics. There is also an opportunity for the students to interact with the speakers on a personal level. For the most recent lectures (held in St. Louis) the Public Awareness Office worked with the Meetings Department on the production (content and presentation) of both the invitation and the Program for the event, attended the lectures, and posted a write-up about the event on the Web. Starting in 2002, the Public Awareness Office will work more closely with the host site and organizer to publicize the event, incorporating more innovative elements.

Publicity for Sectional Meetings
Beginning this year, the Public Awareness Office has emailed news releases of upcoming sectional meetings to the information office of the host institution. The releases contain some broad details about the meeting, the participation of the hosting department's faculty, and the AMS.

Math Medley
The Public Awareness Officers have worked with Pat Kenschaft to suggest guests for her weekly radio show and to post updates about the show on the AMS website. Chris Jones will appear in April to promote Math Awareness Month. Mike Breen, one of the two Public Awareness Officers, will be a guest host in May. His guest will be Donald Saari.

Math Awareness Month
SIAM carried out the work of producing material for MAM this year. Our Public Awareness Office acted as a liaison with the 2001 Committee Chair to set guidelines and deadlines for the announcements and website; wrote or revised the announcement and sample news release; scheduled and handled the bulk mailing; provided wording, layout and related resources suggestions for the website. This is one of the strengths of having full-time staff working on public awareness, making it possible to coordinate efforts such as this.

AMS Member Newsletter
The Public Awareness Office is producing the first in a regular series of Member Newsletters—brief communications on subjects or more in-depth coverage not published in Notices. The first issue is focusing on the current activities of the Public Awareness Office, Washington D.C. Office, and the Epsilon Fund.

Programs and Services
For many years, the Society has carried out a variety of ongoing activities that are connected to employment, either helping young mathematicians secure jobs or helping not-so-young mathematicians understand the situation. More recently, the Department has extended its work to include outreach to the international community and support of other organizations. Its projects now include a wide variety of activities. While some of this work is supported by grants, the Society has a policy of either accepting minimal overhead or forgoing overhead altogether. Every grant therefore costs the Society money, and often substantial amounts.

Annual Survey
The Annual Survey effort consists of three surveys sent annually to over 1,500 mathematicians, applied mathematicians, and statistics departments in the U.S. together with occasional surveys addressing topics of concern. The annual surveys include 1) a census of doctoral recipients with a focus on their employment status following the receipt of their
degree, 2) a survey of faculty salaries, and 3) a survey of key departmental data such as faculty counts, graduate student counts, course enrollments and faculty hiring. Results of the surveys are reported in the Notices and the AMS Website. The Annual Survey is cosponsored with the American Statistical Association, the Institute for Mathematical Statistics, and the Mathematical Association of America, but the Society bears most of the cost and carries out all administrative work.

**Assistantships and Graduate Fellowships in the Mathematical Sciences**

This annual publication contains information on the graduate programs of mathematics and statistics departments in the U.S. Its purpose is to provide prospective graduate students with a current and reliable source of basic information on graduate programs as a first step in their exploration of programs to which they might apply. The information is updated annually, and the publication is provided free to AMS members upon request. A copy is provided free to every department of mathematics and statistics listed in the AMS's Professional Directory. It is also available on the AMS website.

**CBMSSurvey**

This detailed investigation of undergraduate programs in the mathematical sciences in the U.S. has been conducted every five years since 1965 under the auspices of the Conference Board on the Mathematical Sciences (CBMS), with funding provided by the NSF. The AMS became a partner in the actual conduct of this survey in 1990, held the NSF grant and provided survey infrastructure support for the 1995 survey, and is doing the same for the ongoing 2000 survey. The AMS and MAA will publish reports of the current survey in early 2002.

**Employment Information in the Mathematical Sciences (EIMS)**

EIMS has become a standard location for advertising academic, and some industrial, positions in mathematics. While the traditional yellow print publication still exists, most job seekers access the ads over the Web. The ads are heavily browsed by mathematicians from all over the world.

**Employment Center**

The Employment Center at the Annual Meetings is a centralized site for employers and job applicants to meet while at the January meetings. Complete listings are printed and mailed in advance. A sophisticated message center and optional scheduling system help with appointments. This project is jointly sponsored by the American Mathematical Society, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics, but it is carried out entirely by AMS staff. The Employment Center will mark its 50th anniversary in January, 2002.

**AMS Coversheet Service**

AMS Coversheet Service was launched in 2000 to help departments download "AMS Coversheets" submitted by applicants, to use in their own databases of applications. Applicants also add the paper form—as usual—to each application packet that they send. This service may serve as a step, for the AMS, on the way to electronic centralization of some of the job applications in mathematics. The service also serves as a substitute for the old "Job Seekers List", which provides names of candidates still on the market in the spring of each year.

**Young Scholars Program**

The Epsilon Fund, established in 1999, offers small grants to summer "young scholars" programs aimed at mathematically talented high school students. During its first two years, the Society awarded $155,000 in grants to a variety of programs, all paid from the Program Development Fund. The AMS is working to build an endowment, which will provide the funds for these grants in the future. To further help all such programs with the expensive task of publicity, the AMS keeps a central list of such programs on the Web, and has developed a small poster, and plans for wider dissemination.

**REU Conference**

The "Research Experience for Undergraduates" conference took place in 1999, with funding from the National Security Agency. In addition to a valuable proceedings volume (http://www.ams.org/employment/REUproceedings.html), the conference resulted in an AMS effort to increase the available data on REU programs. This project involves tracking the location of participants from summer 1999 and summer 2000 REU programs, in order to be able to conduct a study 5 or 6 years in the future on the impact of the REU experience on career paths. Also, the AMS maintains a central list of all REU programs on its Web site.

**Math in Moscow Semester for Undergraduates**

The Independent University in Moscow approached the AMS for support of their semester-long study program for undergraduates in Moscow. This is a unique opportunity for intensive mathematical study and research, as well as a chance for U.S. students to experience life in Moscow. It is an REU-like experience for students with talent and interest in mathematics. The NSF agreed to a three year grant in support of 10 students per year. The first students will be supported in fall 2001.

**Evaluation Panel for NSA Public Grants Program**

The AMS assists the National Security Agency (NSA) in its annual evaluation of the research proposals submitted to its non-classified grants program. The AMS President appoints individuals to a panel of twelve mathematical scientists who are experts in the mathematical areas eligible for NSA support. AMS staff handle all the logistics associated with soliciting reviews of the proposals based on
reviewers selected by the panel of experts and convening a panel meeting to make final funding recommendations to the NSA.

**NSF Postdoc Administration**
The AMS has administered the selection process for the NSF Postdoctoral Fellowships each year since the program began 20 years ago. The AMS assembles a highly qualified panel of researchers appointed by the AMS, the Institute for Mathematical Statistics, and the Society for Industrial and Applied Mathematics each year. Even (or perhaps especially) in these days of Fastlane, young applicants often have questions or problems as they go through their first application process, which are handled by the AMS staff.

**Minority Database (Mathematics/Math Education Interest data collection)**
This project attempts to collect areas of research interest on a variety of professionals in mathematics and mathematics education who are from groups underrepresented in mathematics. This is a collaborative effort among the AMS, the Mathematical Association of America, the National Association of Mathematicians, the National Council of Teachers of Mathematics, and the Mathematical Sciences Research Institute. Over time, the goal is to have enough data in order to fill requests from conference organizers for appropriate invitation lists.

**SACNAS Annual Meeting**
The AMS provides partial financial support of the mathematics program at the annual meeting of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS). A central goal for this annual meeting is supporting outstanding undergraduates who show an interest in pursuing advanced degrees in science and mathematics. The major portion of AMS support provides travel grants for talented undergraduate mathematicians. The AMS also provides an exhibit with materials of interest to the undergraduate math majors attending the meeting and acquaints general meeting attendees with our programs and services.

**Ky Fan China Program**
Thanks to the generosity of Ky and Yu-fen Fan, the AMS has embarked on a plan to facilitate collaboration between Chinese and U.S./Canadian researchers. The Ky and Yu-fen Fan Endowment provides funds for program grants, and all administrative costs are borne by the Society. The portion of this program currently underway is travel support for U.S./Canadian-based mathematicians to visit colleagues in China, and for Chinese mathematicians to visit institutions in the U.S. and Canada. The other two components are support for the purchase of mathematical books and journals by Chinese departments, and support for conferences to be held in China.

**Book & Journal Donation Program**
This program matches individual donations of research-level mathematics books and journals with libraries and mathematics departments at educational institutions located in the developing world, including the former Soviet Union and Eastern Europe, for which there is a mathematics research "heartbeat." Donors are reimbursed for the cost of shipping their donation to the receiving institution.

Funding for this program is provided by the Stroock Family Foundation. Work is currently underway to expand the visibility of this program.

**ICM Travel Grants**
The AMS has administered NSF funding in 1990, 1994, and 1998 for travel support of U.S. mathematicians attending, or speaking at, the International Congress of Mathematicians (ICM). Approximately $250,000 in travel grants have been awarded each time through the program. The same effort is planned for ICM 2002 in Beijing, China. Approximately 125-150 awards are administered, with a portion going to recent Ph.D.s.

**European Mathematical Society Summer School**
The European Summer School in St. Petersburg will concentrate on Asymptotic Combinatorics with applications to mathematical physics and will be held at the Euler Mathematical Institute in July, 2001. The AMS has obtained a travel grant from NSF to support two U.S. invited speakers and more than a dozen U.S. graduate students who will attend the summer school.

**Fellowships and Prizes**
Everyone is aware of the major research prizes awarded by the Society. Most recently, the frequency and amounts of such prizes have been increased to reflect the growth of the endowments. In addition to the well-known prizes, the AMS makes annual awards to undergraduates and young mathematicians.

**Trijitzinsky Fellowships**
Each year, the Society awards eight scholarships of $4,000 each to undergraduates named by eight institutional member departments. These are funded by a bequest of Waldemar J. Tjitzinsky in 1988. Over the past several years, the Tjitzinsky endowment has grown considerably, and we have been able to increase the size and number of these awards. The awards are made to outstanding undergraduate mathematics students with demonstrated need. The recipients are selected by the departments themselves.

**Intel International Science and Engineering Fair**
The AMS provides $3,000 in prizes for the outstanding mathematics-related projects presented at the annual Intel Science Fair. The Karl Menger Fund helps support this activity, and the Menger Prize Committee forms the core of a panel of judges that evaluates over fifty mathematics projects at each year's fair.

**Centennial Fellowships**
The Centennial Fellowships have been awarded for a number of years, most recently to 3-4 young mathematicians each year. The goals have changed slightly over time, shifting from young mathematicians to mid-career and back again. Most recently, these fellowships have been made more flexible, aimed at mathematicians from 3-12 years past the Ph.D. The program is supported directly by contributions from members, matched up to $50,000 each year using income from our endowment.
Miscellaneous Projects
There are many other projects, large and small, that are carried out from time to time by various parts of the Society. Here are a few examples.

Task Force for Excellence
This was funded by major grants from Exxon and NSF, but as with all such grant-supported projects required a substantial investment of time and money from the AMS. The Task Force worked for seven years, carrying out focus groups and making site visits. The resulting book, Towards Excellence, has been widely distributed throughout the academic community. University administrators have praised the book along with the mathematics community for producing it. Mathematicians are still evaluating the message. Several other important efforts came from this project, however, including the Chairs Workshops, continuing focus groups, and increased survey work.

Website hosting for AWM/YMN
Web hosting is a good example of the day-to-day, relatively small outreach activity of the AMS. Because we have the infrastructure, hosting websites for organizations like the Association for Women in Mathematics (AWM) and the Young Mathematicians Network (YMN) is a natural service we can provide. We do this at no charge to the organizations.

UCLA Symposium "Mathematical Challenges"
This six-day meeting held during the summer of 2000 was the AMS's contribution to World Mathematical Year 2000 activities of the International Mathematical Union. The program consisted of 31 plenary lectures by a selection of the world's leading mathematicians. Approximately 1,000 mathematicians from the U.S. and other countries attended the meeting, including 143 U.S.-based mathematicians in the early stages of their career whose attendance was supported by an NSF grant administered by the AMS. While the meeting was expensive (costing the Society nearly $100,000), it was viewed as a great success by everyone involved.

Summer Research Conferences
These conferences are sponsored jointly with the Society for Industrial and Applied Mathematics as well as the Institute for Mathematical Statistics. They are funded by a grant from the National Science Foundation, but carried out by AMS staff. These are the most recent version of a program that has been held for many years, including summer institutes and seminars. The conferences are normally a week long (but can be flexible), attract a group of 40-60 mathematicians in a particular area, and often produce a proceedings or other written material. Approximately 4-7 conferences are held each summer.

What's Happening in Math
In general, publications of the Society are viewed as revenue-producing activities. The series of What's Happening

books (there are now four of them and a fifth is underway) are not designed to make money for the Society, however. These are aimed at the scientifically literate public, and they have been praised by the science community as excellent examples of awareness of science for scientists. While the books are sold to the public, the project loses a substantial amount of money with each book.

Mathematical Sciences Professional Directory
This annual publication of the AMS provides detailed governance information on the AMS and other professional societies in the mathematical sciences. It includes a comprehensive list of mathematical sciences departments in the U.S. and Canada. The publication is provided free to AMS institutional members and is offered free to all departments listed in the publication.

Viewing the operations of the Society as a balance sheet can be misleading, of course, and the AMS does much more than merely earn money and spend it. But making lists of the programs that produce revenue, and the programs that consume it, is a useful exercise. It helps the membership, the leadership, and the staff gain perspective by reminding us all of the breadth and the interdependence of our activities.

I have observed on several occasions that many people involved in the AMS have special interests—meetings, publications, advocacy, professional development—and most view their special interests as most important, that is, as things that should be supported by the rest of the Society's operations. But we cannot sustain a society in which all activities lose money (at least for long), and the notion that important things are supported by unimportant ones is flawed. All activities of a professional society are connected: Those that generate revenue are important because they support operations and because they have intrinsic value; those that require revenue are important because they define the mission of the organization. A healthy society consists of many parts, all of them woven together in a connected web—and all of them important.

Sometimes, it's easy to forget that essential idea in a balance sheet.

—John Ewing
From the AMS Secretary

Preliminary List of Candidates for 2001 AMS Election

President (one to be elected)
David Eisenbud
David A. Vogan Jr.

Vice President (one to be elected)
Raymond L. Johnson
Hugo Rossi

Board of Trustees (one to be elected)
Andy R. Magid
Carol S. Wood

Member at Large of the Council (five to be elected)
Colin C. Adams
Bruce E. Blackadar
Sylvia T. Bozeman
Percy A. Deift
Irene M. Gamba
Henri A. Gillet
David R. Morrison
Douglas C. Ravenel
Frank Sottile
W. Stephen Wilson

Nominating Committee (three to be elected)
Alejandro Adem
Sheldon Axler
Robert Fossum
Jane Hawkins
Michael Starbird
Daniel W. Stroock

Editorial Boards Committee (two to be elected)
Clifford Earle
Benson S. Farb
Robert Friedman
Svetlana Jitomirskaya
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Private Rate: EUR 125.00 / USD 155.00
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Mathematics Calendar

The most comprehensive and up-to-date Mathematics Calendar information is available on e-MATH at http://www.ams.org/mathcal/.

August 2001

*12–18 International Conference on Applicable General Topology, Hacettepe University, Ankara, Turkey.

Keynote Speakers: A. Edalat (London), M. Escardo (Birmingham), K. Keimel (Darmstadt), H.-P. Kunzi (Cape Town), R. Lowen (Antwerp), S. Watson (Toronto), R. Wilson (Mexico City) and D. Shakhmatov (Matsuyama).

Program: Conference Topics: Asymmetric Topology (non-Hausdorff separation, order, bitopology, quasi-metrics, quasi-uniformities); Symmetric Topology (application oriented aspects of general topology more rooted in classical analysis, topological groups, uniformities, etc.); Point-free, Constructive or Categorical Aspects (frame/locale theory, domain theory, formal topology, categorical methods); Topology on Lattices (fuzzy topology, texture spaces, generalizations); Digital Topology (discretisation versus continu­ity, finite L2 spaces); Applications (to algebra, analysis, computer science, logic, etc.). In addition to the eight Keynote Talks of 55 minutes each on the main themes of the conference, there will be 25 minute Contributed Talks by the participants, Problem Sessions and opportunities for informal contacts between Turkish research students and experts in their areas of interest.

Abstracts: Abstracts of talks should be submitted to the Topology Atlas Abstract Service. There is a link from the features page of the Conference Web Site at http://www.mat.hacettepe.edu. tr/topconf/main.html. Alternatively, those without access to the Internet may send their abstract by e-mail to the organizers at topconf@hacettepe.edu.tr. The closing date for abstracts is July 20.


This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found on the last page of each issue.

An announcement will be published in the Notices if it contains a call for papers and specifies the place, date, subject (when applicable), and the speakers; a second announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in every third issue until it has been held and a reference will be given in parentheses to the month, year, and page of the issue in which the complete information appeared. Asterisks (*) mark those announcements containing new or revised information.

In general, announcements of meetings and conferences held in North America carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. Meetings held outside the North American area may carry more detailed information. In any case, if there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the Notices in care of the American Mathematical Society in Providence or electronically to notices@ams.org or mathcal@ams.org.

In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the Notices prior to the meeting in question. To achieve this, listings should be received in Providence 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.)
moduli spaces, the classification of topological group actions on 4-manifolds, just to name a few. Not concentrated completely on 4-dimensions, the program will also present these topics of high-dimensional manifolds and related topics. In fact, it is the design of the conference to bring about formal and informal discussion between different perspectives to compare questions, methods and applications.

**Participants:** S. Cappell (Courant Institute), R. Cohen (Stanford), J. Davis (Indiana), A. Edmonds (Indiana), T. Farrell (SUNY at Binghamton), P. Feehan (Dublin), R. Fintushel (Michigan State), K. Froyshov (Harvard), R. Gompf (Univ. of Texas at Austin), C. Herald (Univ. of Nevada at Reno), R. Kirby (UC Berkeley), T. Leness (Florida International Univ.), T.-J. Li (Princeton), M. Marcoli (Max-Planck-Institut für Mathematik, Bonn), M. McCooey (McMaster), E. Miller (Polytechnic Univ. of New York), J. Morgan (Columbia), L. Nicolaescu (Notre Dame), P. Ozsvath (Michigan State), E. Pedersen (SUNY at Binghamton), F. Quinn (Virginia Polytech Inst. & State Univ.), D. Ruberman (Brandeis), R. Schultz (UFR), D. Sullivan (CUNY), V. Tence (University of Grenoble), M. Ventsel (Yale), D. Wise (Warwick), C. Zomeo (ETH Zürich).

**Information:** Those wishing to participate in the above activities are invited to write to: L. Pelletier, Centre de Recherches Mathématiques (CRM), Université de Montréal, C.P. 6128 Succ. Centre-ville, Montreal (Québec), Canada H3C 3J7; e-mail: activites@crm.umontreal.ca.

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**October 2001**

- **5-9 Trends in Banach Spaces and Operator Theory, The University of Memphis, Memphis, Tennessee.**
  **Sponsors:** National Science Foundation, The University of Memphis and The University of Mississippi.
  **Organizing Committee:** J. Jamison, A. Kamińska, P. K. Lin (Univ. of Memphis), P. Kranz (Univ. of Mississippi).
  **Principal Speakers:** Y. Abramovich (Indiana University-Purdue, Indianapolis), A. B. Ash (San Francisco State University), J. B. Conway (University of Tennessee, Knoxville), C. C. Cowen (Purdue University), N. Kalton (University of Missouri in Columbia), B. MacCluer (University of Georgia in Charlotteville), E. W. Odell (University of Texas at Austin), A. Pełczyński (Polish Academy of Sciences in Warsaw, Poland), C. Piñeiro (Université de Paris VI, Texas A&M University), T. Berthéil Schumpecht (Texas A&M University in College Station), J. A. C. Schlenker (University of Alberta in Edmonton, Canada).

**Information:** The principal speakers will deliver one-hour plenary lectures. Twenty-minute contributed talks will be organized in parallel sessions. The pre-registration deadline is 1 April 2001. Partial funding for advanced graduate students and beginning researchers may be available through the organizers. For further information on the conference organization, registration, location, lodging, submission of abstracts and other details, visit the conference web site at http://www.mscu.memphis.edu/banachconf.html.

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**November 2001**

- **28-29 November 2 School on Semigroups Applied to Evolution Equations, Grand Hotel Bellavista Levico, Terme (Trento), Italy.**
  **Scientific Organizers:** M. Iannelli (Trento), R. Nagel (Tuebingen), and S. Piazzera (Ulm).
  **Deadline for Applications:** September 30, 2001.
  **Information:** A. Micheletti, Secretary of CIRM, Centro Internazionale per la Ricerca Matematica, Istituto Toscino di Cultura, 38050 Povo (Trento); tel: +39-0461-881628; fax: +39-0461-810629; e-mail: michelet@science.unitn.it; http://www.science.unitn.it/cirm/.

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**November 2001**

- **29-November 1 Introductory Lectures by A. A. Kirillov (Pensylvania) and V. Guillemin (MIT), Centre de Recherches Mathématiques (CRM), Université de Montréal, Montréal (Québec), Canada.**
  **Information:** Those wishing to participate in the above activities are invited to write to: L. Pelletier, Centre de Recherches Mathématiques (CRM), Université de Montréal, Montréal (Québec), Canada.
November 2001

*2–6 Workshop on the Geometry of Infinite-Dimensional Lie Groups, Centre de Recherches Mathématiques (CRM), Université de Montréal, C.P. 6128, Succ. Centre-ville, Montréal (Quebec), Canada H3C 3J7; e-mail: ACTIVITES@CRM.Umontreal.CA; or visit http://www.CRM.Umontreal.CA/geometry/.

*31–November 2 Computational Issues in Game Theory and Mechanism Design, DIMACS Center, Rutgers University, Piscataway, New Jersey.
Organizers: V. Vazirani, Georgia Tech; and N. Nisan, Hebrew Univ.
Short Description: The research agenda of computer science is undergoing significant changes due to the influence of the Internet. Together with the emergence of a host of new computational issues in mathematical economics, as well as electronic commerce, a new research agenda appears to be emerging. This area of research is collectively labeled under various titles, such as "foundations of electronic commerce", "computational economics", or "economic mechanisms in computation", and deals with various issues involving the interplay between computation, game-theory, and economics.
Information: V. Vazirani, Georgia Tech, vazirani@cc.gatech.edu; Local Arrangements: J. Herold, DIMACS Center, jessicah@dimacs.rutgers.edu, 732-445-5928. WWW Information: http://dimacs.rutgers.edu/Workshops/index.html.

December 2001

*2-4 DIMACS-CTS (Chiaotung University) Conference on the Interconnections among Codes, Designs, Graphs and Molecular Biology, Center of Theoretical Science, Chiaotung University, Hsinchu, Taiwan.
Sponsors: DIMACS Center, Rutgers University; and Chiaotung University.
Deadlines: If you are interested in giving a talk, please submit a short abstract (maximum two pages) by October 10, 2001. Abstracts should be submitted via e-mail to any one of the organizers. Notification will be made on November 1, 2001.
Contacts: F. Hwang, Chiaotung Univ., fhwang@math.nctu.edu.tw; F. Roberts, DIMACS, Rutgers Univ., froberts@dimacs.rutgers.edu; D. Torney, Los Alamos National Labs, dct@lanl.gov.
Local Arrangements: J. Herold, DIMACS Center, jessicah@dimacs.rutgers.edu, 732-445-5928.
Information: http://dimacs.rutgers.edu/Workshops/index.html.

January 2002

*7–12 School on Stochastic Partial Differential Equations and Applications—VI, Grand Hotel Bellavista, Levico, Terme (Trento), Italy.
Scientific Organizers: L. Accardi (Roma II) and T. Matsu (Fukuoka).
Information: A. Micheletti, Secretary of CIRM, Centro Internazionale per la Ricerca Matematica, Istituto Trentino di Cultura, 38050 Povo (Trento); tel: +39-0461-881628; telefax: +39-0461-810629; e-mail: michellet@science.unitn.it; http://www.science.unitn.it/cirm/.

*21–28 Winter School on Computations in Coxeter Groups, Centre de Recherches Mathématiques (CRM), Université de Montréal, Montréal (Québec), Canada.
Organizers: W. Casselman (UBC), R. Bédard (UQAM), F. Du Cloux (CIM). 
Description: These short courses are designed to show how techniques from computer algebra can be applied to effective computation in Coxeter groups.
Information: Those wishing to participate in the above activities are invited to write to: L. Pelletier, Centre de Recherches Mathématiques (CRM), Université de Montréal, C.P. 6128, Succ. Centre-ville, Montréal, (Québec), Canada H3C 3J7; e-mail: ACTIVITES@CRM.Umontreal.CA; or visit http://www.CRM.Umontreal.CA/geometry/.

February 2002

*27–March 3 Group Actions on Rational Varieties, Centre de Recherches Mathématiques (CRM), Université de Montréal, Montréal (Québec), Canada.
Organizer: P. Russell (McGill).
Focus: The workshop will focus on recent developments in automorphisms of affine spaces and related algebraic varieties with simple topology, in particular exotic affine spaces (algebraic varieties homeomorphic to an affine space).
March 2002
*21–23 Spring Topology and Dynamics Conference, University of Texas, Austin, Texas.

Program: The areas covered will include set-theoretic topology, continuum theory, dynamical systems, geometric topology, and geometric group theory. The program will include both invited and contributed talks.

Organizing Committee: C. Gordon, J. Lueck, A. Reid.

*26–30 The 2002 UAB International Conference on Differential Equations and Mathematical Physics, University of Alabama at Birmingham, Birmingham, Alabama.

Program: Topics in the general area of linear and nonlinear differential equations and their relation to mathematical physics will be emphasized. This will include topics such as the analysis of Schrödinger operators, quantum electrodynamics, fluid dynamics, conservation laws, evolution equations, spectral and scattering theory including inverse problems, wave transport in disordered media, dynamical systems, as well as related topics.

Organizing Committee: Y. Karpeshina, G. Stolz, R. Weikard, Y. Zeng.

Plenary Speakers: M. Aizenman, Princeton Univ.; J. Fröhlich, ETH, Zürich; F. Gesztesy, Univ. of Missouri; J. Grimm, SUNY at Stony Brook; S. Jitomirskaya, UC Irvine; A. Laptev, KTH, Stockholm; J. Lebowitz, Rutgers Univ.; E. Lieb, Princeton Univ.; T.-P. Liu, Stanford Univ. and Academia Sinica (Taiwan); J. Sjöstrand, École Polytechnique, Paris; R. Weder, UNAM, Mexico City.

Special Sessions (organizer in parentheses): Conservation Laws (G.-Q. Chen, Northwestern Univ.); Dynamics and Mathematical Physics (N. Smirnov, UAB); Incompressible Flow (S. Friedlander, Univ. of Illinois at Chicago); Inverse Problems (J. McLaughlin, Rensselaer); Quantum Mechanics and Spectral Theory (G. M. Graf, ETH, Zürich); Spectral Problems in Solid State Physics (P. Kuchment, Wichita).

Information: http://www.math.uab.edu/uab02/.

April 2002
*8–19 Invariant Theory, Queen’s University, Kingston, Ontario.

Organizers: D. Wehlau (Queen’s), E. Campbell (Queen’s).

Description: The first week will be devoted to introductory lectures aimed at graduate students by P. Fleischmann (Kent), H. Kraft (Basel), W. W. Schwarz (Brandeis), and H. Derksen (MIT). The second week will be devoted to a workshop on invariant theory.


Information: Those wishing to participate in the above activities are invited to write to: L. Pelletier, Centre de Recherches Mathématiques (CRM), Université de Montréal, C.P. 6128, Succ. Centre-ville, Montréal, Québec, Canada H3C 3J7; e-mail: ACTIVITES@CRM.UMontreal.CA; or visit http://www.CRM.UMontreal.CA/geometry/.

*30–May 17 Concentration Period on the Langlands Programme for Function Fields, Centre de Recherches Mathématiques (CRM), Université d’Montréal, Montréal (Québec), Canada.

May 2002
*20–25 6th International Conference on Clifford Algebras and Their Applications in Mathematical Physics, Tennessee Technological University, Cookeville, Tennessee.

Description: This is a continuation of a 16-year-old sequence of international conferences devoted to the mathematical aspects of Clifford algebras and their varied applications in mathematical physics, cybernetics, robotics, image processing and engineering.


Format: Plenary invited one-hour lectures, minisymposia (45-minute talks), special sessions (30-minute talks), and contributed sessions (20-minute talks).


Information: Contact: L. Pelletier, Centre de Recherches Mathématiques (CRM), Université de Montréal, C.P. 6128, Succ. Centre-ville, Montréal, Québec, Canada H3C 3J7; e-mail: ACTIVITES@CRM.UMontreal.CA; or visit http://www.CRM.UMontreal.CA/geometry/.

27–30 June 2002 Computations Lie Theory, Centre de Recherches Mathématiques (CRM), Université d’Montréal, Montréal (Québec), Canada.

Organizers: W. Casselman (UBC) and F. Knop (Rutgers).
Focus: This extended workshop is aimed at researchers interested in explicit computations in Lie theory, in particular addition to the usual talks, there will also be several series of survey lectures suitable for graduate students by M. Brion (Grenoble), M. Geck (Lyon), F. Knop (Rutgers), P. Littelmann (Wuppertal), G. Olshanski (IITP), and J. Stembridge (Michigan), G. Lusztig (MIT) will be delivering some of his Aisenstadt lectures during the period of the conference.

Invited Participants: D. I. Alvis (Indiana), A. A. Klyachko (Bilkent), R. Bédard (UQAM), R. Bezrukovnikov (Chicago), S. Billey (MIT), M. Brion (Joseph Fourier), I. Cherednik (North Carolina), F. du Cloux (Lyon I), M. J. Dyer (Notre Dame), W. Fulton (Michigan) M. Geck (Lyon), M. Haiman (North California, San Diego), G. J. Heckman (Nijmegen), A. G. Helminck (Carolina), P. Knop (Rutgers), S. Kumar (North Carolina at Chapel Hill), P. Littelmann (Bergische), R. MacPherson (IAS), J. McKay (Concordia), M. Noumi (Kobe), A. Okounkov (California, Berkeley), G. Olshanski (Moscow), E. M. Opdam (Amsterdam), A. Ram (Wisconsin), Y. B. Sanderson (William Paterson) T. A. Springer (Utrecht), J. R. Stembridge (Michigan), B. Sturmfels (California, Berkeley), P. Trapa (Harvard), J. F. van Diejen (Chile), M. van Leeuwen (Polities), D. A. Vogan Jr. (MIT), N. R. Wallach (California, San Diego), G. S. Warrington (Harvard), A. Zelevinski (Northeastern).

Information: Those wishing to participate in the above activities are invited to write to: L. Pelletier, Centre de Recherches Mathematiques (CRM), Université de Montréal, C.P. 6128, Succ. Centre-ville, Montréal, Québec, Canada H3C 3J7; e-mail: ACTIVITES@CRM.UMontreal.CA; or visit http://www.CRM.UMontreal.CA/geometry/.

June 2002

* 10–15 Algebraic Transformation Groups, Centre de Recherches Mathématiques (CRM), Université d Montréal, Montréal (Québec), Canada.

Organizers: A. Broer (Montréal) and J. Carrell (UBC).

Description: The purpose of the meeting is to bring together experts in algebraic groups, algebraic geometry, representation theory and related areas, especially those touching on: geometric methods in representation theory using tools like equivariant cohomology and perverse sheaves, the Hilbert scheme of points on a surface and its connection with the n!-conjecture in algebraic combinatorics, equivariant versions of cohomology and Chow groups related to flag manifolds and Schubert varieties, quantum cohomology and Schubert calculus.

Participants: A. Bertram (Utah), M. Brion (Grenoble), C. De Concini (Rome), W. Fulton (Michigan), V. Ginzburg (Chicago), M. Haiman (UCSD), M. Kapranov (Toronto), A. Knutson (Berkeley), B. Kostant (MIT), S. Kumar (North Carolina), L. Manivel (Grenoble), E. Meinrenken (Toronto), I. Mirkovic (Massachusetts), H. Nakajima (Kyoto), D. Peterson (UBC), C. Procesi (Rome), E. Vasserot (Cergy-Pontoise), C. Woodward (Rutgers).

Information: Those wishing to participate in the above activities are invited to write to: L. Pelletier, Centre de Recherches Mathématiques (CRM), Université de Montréal, C.P. 6128, Succ. Centre-ville, Montréal, Québec, Canada H3C 3J7; e-mail: ACTIVITES@CRM.UMontreal.CA; or visit http://www.CRM.UMontreal.CA/geometry/.

* 30–July 14 5th Summer School/Conference: Let’s Face Chaos through Nonlinear Dynamics, Maribor, Slovenia.

Program: Nonlinear dynamics, synergetics, physics of complex systems in pure and applied sciences, including pure and applied mathematics, theoretical and experimental physics, biophysics and physiology, chemistry, astrophysics, econophysics, technology and engineering, and even sociology.


The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.

August 2002

* 20–28 Satellite Conferences for ICM 2002, Beijing, China.

New Publications Offered by the AMS

Algebra and Algebraic Geometry

Strong Boundary Values, Analytic Functionals, and Nonlinear Paley-Wiener Theory

Jean-Pierre Rosay, University of Wisconsin, Madison and Edgar Lee Stout, University of Washington, Seattle

Contents: Introduction; Preliminaries on analytic functionals and hyperfunctions; Appendix on compact sets; Analytic functionals as boundary values; Nonlinear Paley-Wiener theory; Strong boundary values; Strong boundary values for the solutions of certain partial differential equations; Comparison with other notions of boundary values; Boundary values via cousin decompositions; The Schwarz reflection principle; References; Index of notions.

Memoirs of the American Mathematical Society, Volume 153, Number 725

Ind-Sheaves

Masaki Kashiwara, Kyoto University, Japan and Pierre Schapira, University of Paris VI, France

A publication of the Société Mathématique de France.

Sheaf theory is not well suited to the study of various objects in analysis that are not defined by local properties. The aim of this paper is to show that it is possible to overcome this difficulty by enlarging the category of sheaves to that of ind-sheaves, and by extending to ind-sheaves the machinery of sheaves.

Let $X$ be a locally compact topological space and let $k$ be a commutative ring. The authors define the category $I(k_X)$ of ind-sheaves of $k$-modules on $X$ as the category of $k$-objects of the category $Mod^c(k)$ of sheaves of $k$-modules on $X$ with compact support, and they construct "Grothendieck's six operations" in the derived categories of ind-sheaves, as well as new functors which arise naturally.

A method for constructing ind-sheaves is the use of Grothendieck topologies associated with families $T$ of open subsets satisfying suitable properties. Sheaves on the site $X_T$ naturally define ind-sheaves.

When $X$ is a real analytic manifold, the authors consider the subanalytic site $X_{sa}$ associated with the family of open subanalytic subsets, and construct various ind-sheaves by this way. They obtain in particular the ind-sheaf $C_K^m$ of tempered $C^m$ functions, the ind-sheaf $C_{sa}^m$ of Whitney $C^m$-functions and the ind-sheaf $D_{sa}^X$ of tempered distributions. On a complex manifold $X$, they concentrate on the study of the ind-sheaf $O_X^0$ of "tempered holomorphic functions" and prove an adjunction formula for integral transforms in this framework.

Astérisque, Number 271

Linear Algebra and Differential Equations

Alexander Givental, University of California, Berkeley

This is based on the course, "Linear Algebra and Differential Equations", taught by the author to sophomore students at UC Berkeley.

From the Introduction: "We accept the currently acting syllabus as an outer constraint ... but otherwise we stay rather far from conventional routes."

"In particular, at least half of the time is spent to present the entire agenda of linear algebra and its applications in the 2D environment; Gaussian elimination occupies a visible but..."
Many important problems in applied sciences, mathematics, and engineering can be reduced to matrix problems. Moreover, various applications often introduce a special structure into the corresponding matrices, so that their entries can be described by a certain compact formula. Classic examples include Toeplitz matrices, Hankel matrices, Vandermonde matrices, Cauchy matrices, Pick matrices, Bezoutians, controllability and observability matrices, and others. Exploiting these and the more general structures often allows us to obtain elegant solutions to mathematical problems as well as to design more efficient practical algorithms for a variety of applied engineering problems.

Structured matrices have been under close study for a long time and in quite diverse and seemingly unrelated areas, for example, mathematics, computer science, and engineering. Considerable progress has recently been made in all these areas, and especially in studying the relevant numerical and computational issues. In the past few years, a number of practical algorithms blending speed and accuracy have been developed. This significant growth is fully reflected in these volumes, which collect 38 papers devoted to the numerous aspects of the topic.

The collection of the contributions to these volumes offers a flavor of the plethora of different approaches to attack structured matrix problems. The reader will find that the theory of structured matrices is positioned to bridge diverse applications in the sciences and engineering, deep mathematical theories, as well as computational and numerical issues. The presentation fully illustrates the fact that the techniques of engineers, mathematicians, and numerical analysts nicely complement each other, and they all contribute to one unified theory of structured matrices.

The book is published in two volumes. The first contains articles on interpolation, system theory, signal and image processing, control theory, and spectral theory. Articles in the second volume are devoted to fast algorithms, numerical and iterative methods, and various applications.

**Contents for Part I: Interpolation and approximation:**
- H. Dym, Structured matrices, reproducing kernels and interpolation;
- V. Olshevsky and A. Shokrollahi, A superfast algorithm for confluent rational tangential interpolation problem via matrix-vector multiplication for confluent Cauchy-like matrices;
- S. A. Goreinov and E. E. Tyrtyshnikov, The maximal-volume concept in approximation by low-rank matrices;

**Contents for Part II: Fast algorithms:**
- G. Heinig and V. Olshevsky, The Schur algorithm for matrices with Hessenberg displacement structure; Y. Eidelman and I. Gohberg, Fast inversion algorithms for a class of block structured matrices; S. Chandrasekaran and M. Gu, A fast and stable solver for recursively semi-separable systems of linear equations; Numerical issues: M. Stewart, Stability properties of several variants of the unitary Hessenberg QR algorithm; M. Kim, H. Park, and L. Eldén, Comparison of algorithms for Toeplitz least squares and symmetric positive definite linear systems; G. Heinig, Stability of Toeplitz matrix inversion formulas; J. Demmel and P. Koel, Necessary and sufficient conditions for accurate and efficient rational function evaluation and factorizations of rational matrices; M. Van Barel and A. Bultheel, Updating and downdating of...
Authors: I. Koltracht, and M. J. Narasimhan
Matrix: Definition and properties.

This book is geared to students and researchers. It is intended to improve their understanding of groupoids and to encourage them to look further while learning about the tools used.

Contents: A. Weinstein, Groupoids: Unifying internal and external symmetry—A tour through some examples; D. P. Williams, A primer for the Brauer group of a groupoid; C. Anantharaman and J. Renault, Amenable groupoids; G. Dela Rocca and M. Takesaki, The role of groupoids in classification theory. A new approach. The UHF algebra case; P. S. Muhly, Bundles over groupoids; A. Haefliger, Groupoids and foliations; I. Moerdijk, Etale groupoids, derived categories, and operations; A. L. T. Paterson, The analytic index for proper, Lie groupoid actions; P.-Y. Le Gall, Groupoid C*-algebras and operator K-theory; B. Monthubert, Groupoids of manifolds with corners and index theory; N. P. Landsman and B. Ramazan, Quantization of Poisson algebras associated to Lie algebroids.

Contemporary Mathematics

Equivariant Analytic Localization of Group Representations
Laura Smithies, Kent State University, OH

Contents: Introduction; Preliminaries; The category $T;$ Two equivalences of categories; The category $D_{0}^{b} (D_{X});$ Descended structures; The category $D_{0}^{b} (U_{0}(g));$ Localization: Our main equivalence of categories; Equivalence for any regular weight $\lambda;$ Bibliography.

Memoirs of the American Mathematical Society, Volume 153, Number 728

Groupoids in Analysis, Geometry, and Physics
Arlan Ramsay, University of Colorado, Boulder, and Jean Renault, Université d’Orléans, France, Editors

Groupoids often occur when there is symmetry of a nature not expressible in terms of groups. Other uses of groupoids can involve something of a dynamical nature. Indeed, some of the main examples come from group actions. It should also be noted that in many situations where groupoids have been used, the main emphasis has not been on symmetry or dynamics issues. While the implicit symmetry and dynamics are relevant, the groupoid records mostly the structure of the space of leaves and the holonomy. More generally, the use of groupoids is very much related to various notions of orbit equivalence.

This book presents the proceedings from the Joint Summer Research Conference on “Groupoids in Analysis, Geometry, and Physics” held in Boulder, CO. The book begins with an introduction to ways in which groupoids allow a more comprehensive view of symmetry than is seen via groups. Topics range from foliations, pseudo-differential operators, KK-theory, amenability, Fell bundles, and index theory to quantization of Poisson manifolds. Readers will find examples of important tools for working with groupoids.
Analysis

The Schur Algorithm, Reproducing Kernel Spaces and System Theory
Daniel Alpay, Ben-Gurion University of the Negev, Beersheva, Israel

From a review of the French edition: This excellent survey showing a rich interplay between functional analysis, complex analysis and systems science is very informative and can be highly recommended to functional analysts curious about the systems science impact of their discipline or to theoretically inclined systems scientists, in particular those involved in the realization theory.

—Zentralblatt für Mathematik

The class of Schur functions consists of analytic functions on the unit disk that are bounded by 1. The Schur algorithm associates to any such function a sequence of complex constants, which is much more useful than the Taylor coefficients. There is a generalization to matrix-valued functions and a corresponding algorithm. These generalized Schur functions have important applications to the theory of linear operators, to signal processing and control theory, and to other areas of engineering.

In this book, Alpay looks at matrix-valued Schur functions and their applications from the unifying point of view of spaces with reproducing kernels. This approach is used here to study the relationship between the modeling of time-invariant dissipative linear systems and the theory of linear operators. The inverse scattering problem plays a key role in the exposition. The point of view also allows for a natural way to tackle more general cases, such as nonstationary systems, non-positive metrics, and pairs of commuting nonself-adjoint operators.

This item will also be of interest to those working in applications.

Contents: Introduction; Reproducing kernel spaces; Theory of linear systems; Schur algorithm and inverse scattering problem; Operator models; Interpolation; The indefinite case; The non-stationary case; Riemann surfaces; Conclusion; Bibliography; Index.

SMF/AMS Texts and Monographs, Volume 5

Recommended Text

Theta Constants, Riemann Surfaces and the Modular Group
An Introduction with Applications to Uniformization Theorems, Partition Identities and Combinatorial Number Theory
Hershel M. Farkas, The Hebrew University, Jerusalem, Israel, and Irwin Kra, State University of New York, Stony Brook

There are incredibly rich connections between classical analysis and number theory. For instance, analytic number theory contains many examples of asymptotic expressions derived from estimates for analytic functions, such as in the proof of the Prime Number Theorem. In combinatorial number theory, exact formulas for number-theoretic quantities are derived from relations between analytic functions. Elliptic functions, especially theta functions, are an important class of such functions in this context, which had been made clear already in Jacobi's Fundamenta nova. Theta functions are also classically connected with Riemann surfaces and with the modular group = PSL(2, Z), which provide another path for insights into number theory.

Farkas and Kra, well-known masters of the theory of Riemann surfaces and the analysis of theta functions, uncover here interesting combinatorial identities by means of the function theory on Riemann surfaces related to the principal congruence subgroups, \( \Gamma(k) \). For instance, the authors use this approach to derive congruences discovered by Ramanujan for the partition function, with the main ingredient being the construction of the same function in more than one way. The authors also obtain a variant on Jacobi's famous result on the number of ways that an integer can be represented as a sum of four squares, replacing the squares by triangular numbers and in the process, obtaining a cleaner result.

The recent trend of applying the ideas and methods of algebraic geometry to the study of theta functions and number theory has resulted in great advances in the area. However, the authors choose to stay with the classical point of view. As a result, their statements and proofs are very concrete. In this book the mathematician familiar with the algebraic geometry approach to theta functions and number theory will find many interesting ideas as well as detailed explanations and derivations of new and old results.

Highlights of the book include systematic studies of theta constant identities, uniformizations of surfaces represented by subgroups of the modular group, partition identities, and Fourier coefficients of automorphic functions.

Prerequisites are a solid understanding of complex analysis, some familiarity with Riemann surfaces, Fuchsian groups, and elliptic functions, and an interest in number theory. The book contains summaries of some of the required material, particularly for theta functions and theta constants.
Readers will find here a careful exposition of a classical point of view of analysis and number theory. Presented are numerous examples plus suggestions for research-level problems. The text is suitable for a graduate course or for independent reading.

This item will also be of interest to those working in number theory.

Contents: The modular group and elliptic function theory; Theta functions with characteristics; Function theory for the modular group \( \Gamma \) and its subgroups; Theta constant identities; Partition theory: Ramanujan congruences and generalizations; Identities related to partition functions; Combinatorial and number theoretic applications; Bibliography; Bibliographical notes; Index.

Graduate Studies in Mathematics

On the Foundations of Nonlinear Generalized Functions I and II
Michael Grosser, Universitat Wien, Austria, Eva Farkas, Universitat Wien, Austria, and Michael Kunzinger and Roland Steinbauer, University of Vienna, Austria

Contents: Part 1. On the Foundations of Nonlinear Generalized Functions I: Introduction; Notation and terminology; Scheme of construction; Calculus; C- and J-formalism; Calculus on \( U^2(\Omega) \); Construction of a diffeomorphism invariant Colombeau algebra; Sheaf properties; Separating the basic definition from testing; Characterization results; Differential equations; Part 2. On the Foundations of Nonlinear Generalized Functions II: Introduction to Part 2; A simple condition equivalent to negligibility; Some more calculus; Non-injectivity of the canonical homomorphism from \( G^2(\Omega) \) into \( G^2(\Omega) \); Classification of smooth Colombeau algebras between \( G^2(\Omega) \) and \( G^2(\Omega) \); The algebra \( G^2 \); classification results; Concluding remarks; Acknowledgments; Bibliography.

Memoirs of the American Mathematical Society, Volume 153, Number 729

Smooth Ergodic Theory and Its Applications
Anatole Katok, Pennsylvania State University, University Park, Rafael de la Llave, University of Texas at Austin, and Yakov Pesin and Howard Weiss, Pennsylvania State University, University Park, Editors

During the past decade, there have been several major new developments in smooth ergodic theory which have attracted substantial interest to the field from mathematicians as well as scientists using dynamics in their work. In spite of the impressive literature, it has been extremely difficult for a student— or even an established mathematician who is not an expert in the area— to acquire a working knowledge of smooth ergodic theory and to learn how to use its tools.

Accordingly, the AMS Summer Research Institute on Smooth Ergodic Theory and Its Applications (Seattle, WA) had a strong educational component, including ten mini-courses on various aspects of the topic that were presented by leading experts in the field. This volume presents the proceedings of that conference.

Smooth ergodic theory studies the statistical properties of differentiable dynamical systems, whose origin traces back to the seminal works of Poincaré and later, many great mathematicians who made contributions to the development of the theory. The main topic of this volume, smooth ergodic theory, especially the theory of nonuniformly hyperbolic systems, provides the principle paradigm for the rigorous study of complicated or chaotic behavior in deterministic systems. This paradigm asserts that if a non-linear dynamical system exhibits sufficiently pronounced exponential behavior, then global properties of the system can be deduced from studying the linearized system. One can then obtain detailed information on topological properties (such as the growth of periodic orbits, topological entropy, and dimension of invariant sets including attractors), as well as statistical properties (such as the existence of invariant measures, asymptotic behavior of typical orbits, ergodicity, mixing, decay of correlations, and measure-theoretic entropy). Smooth ergodic theory also provides a foundation for numerous applications throughout mathematics (e.g., Riemannian geometry, number theory, Lie groups, and partial differential equations), as well as other sciences.

This volume serves a two-fold purpose: first, it gives a useful gateway to smooth ergodic theory for students and non-specialists, and second, it provides a state-of-the-art report on important current aspects of the subject. The book is divided into three parts: lecture notes consisting of three long expositions with proofs aimed to serve as a comprehensive and self-contained introduction to a particular area of smooth ergodic theory; thematic sections based on mini-courses or surveys held at the conference; and original contributions presented at the meeting or closely related to the topics that were discussed there.

This item will also be of interest to those working in geometry and topology.
Here, the authors replace the incomplete disk by a uniform metric space (defined as a generalization of a uniform domain in $\mathbb{R}^n$) and the space of constant negative curvature by a general Gromov hyperbolic space. They then prove that there is a one-to-one correspondence between quasimetrics classes of (proper, geodesic, and roughly starlike) Gromov hyperbolic spaces and the quasimetrics classes of bounded locally compact uniform spaces. They study Euclidean domains that are Gromov hyperbolic with respect to the quasimetric metric and the Martin boundaries of such domains. A characterization of planar Gromov hyperbolic domains is given. They also study quasiconformal homeomorphisms of Gromov hyperbolic spaces of bounded geometry; under mild conditions on the spaces they prove that such maps are rough quasimetrics. They employ a version of the classical Gehring-Hayman theorem and methods from analysis on metric spaces such as modulus estimates on Loewner spaces.

This item will also be of interest to those working in geometry and topology.

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.

Astersisque, Number 270

Applications

Eric Frederic室内 Transform and Tomography

Eric Todd Quinto, Tufts University, Medford, MA, Leon Ehrenpreis, Temple University, Philadelphia, PA, Adel Faridani, Oregon State University, Corvallis, Fulton Gonzalez, Tufts University, Medford, MA, and Eric Grinberg, Temple University, Philadelphia, PA, Editors

One of the most exciting features of the fields of Radon transforms and tomography is the strong relationship between high-level pure mathematics and applications to areas such as medical imaging and industrial nondestructive evaluation. The proceedings featured in this volume bring together fundamental research articles in the major areas of Radon transforms and tomography.

This volume includes expository papers that are of special interest to beginners as well as advanced researchers. Topics include local tomography and wavelets, Lambda tomography and related methods, tomographic methods in RADAR, ultrasound, Radon transforms and differential equations, and the Pompeiu problem.

The major themes in Radon transforms and tomography are represented among the research articles. Pure mathematical themes include vector tomography, microlocal analysis, twistor
Differential Equations

Harmonic Analysis and Boundary Value Problems

Luca Capogna and Loredana Lanzani, University of Arkansas, Fayetteville, Editors

This volume presents research and expository articles by the participants of the 25th Arkansas Spring Lecture Series on "Recent Progress in the Study of Harmonic Measure from a Geometric and Analytic Point of View" held at the University of Arkansas (Fayetteville).

Papers in this volume provide clear and concise presentations of many problems that are at the forefront of harmonic analysis and partial differential equations.

The following topics are featured: the solution of the Kato conjecture, the "two bricks" problem, new results on Cauchy integrals on non-smooth curves, the Neumann problem for sub-Laplacians, and a new general approach to both divergence and nondivergence second order parabolic equations based on growth theorems. The articles in this volume offer both students and researchers a comprehensive volume of current results in the field.


Contemporary Mathematics, Volume 277

Geometric Asymptotics for Nonlinear PDE. I

V. P. Maslov, Moscow State University, Russia, and G. A. Omel'yanov, Moscow Institute of Electronic Engineering, Russia

The study of asymptotic solutions to nonlinear systems of partial differential equations is a very powerful tool in the analysis of such systems and their applications in physics, mechanics, and engineering. In the present book, the authors propose a new powerful method of asymptotic analysis of solutions, which can be successfully applied in the case of the so-called "smoothed shock waves", i.e., nonlinear waves which vary fast in a neighborhood of the front and slowly outside of this neighborhood. The proposed method, based on the study of geometric objects associated to the front, can be viewed as a generalization of the geometric optics (or WKB) method for linear equations. This volume offers to a broad audience a simple and accessible presentation of this new method.

Contents: Introduction; Waves in one-dimensional nonlinear media; Nonlinear waves in multidimensional media; Asymptotic solutions of some pseudodifferential equations and dynamical systems with small dispersion; Problems with a free boundary; Multi-phase asymptotic solutions; Asymptotics of stationary solutions to the Navier-Stokes equations describing stretched vortices; List of equations; Bibliography.

Translations of Mathematical Monographs, Volume 202

Singular Quasilinearity and Higher Eigenvalues

Victor L. Shapiro, University of California, Riverside, CA

Contents: Quasilinear elliptic equations; Quasilinear parabolic equations.

Memoirs of the American Mathematical Society, Volume 153, Number 726

Geometry and Topology

A Geometric Setting for Hamiltonian Perturbation Theory

Anthony D. Blaom, Burwood, Victoria, Australia

Contents: Introduction; Part 1. Dynamics: Lie-Theoretic preliminaries; Action-group coordinates; On the existence of action-group coordinates; Naive averaging; An abstract formulation of Nekhoroshev's theorem; Applying the abstract Nekhoroshev's theorem to action-group coordinates; Nekhoroshev-type estimates for momentum maps; Part 2. Geometry: On Hamiltonian $G$-spaces with regular momenta; Action-group coordinates as a symplectic cross-section; Constructing action-group coordinates; The axisymmetric Euler-Poinsot rigid body; Passing from dynamic integrability to geometric integrability; Concluding remarks; Appendix A. Proof of the Nekhoroshev-Lochak theorem; Appendix B. Proof the $W$ is a slice; Appendix C. Proof of the extension lemma; Appendix D. An application of converting dynamic integrability into geometric integrability: The Euler-Poinsot rigid body revisited; Appendix E. Dual pairs, leaf correspondence, and symplectic reduction; Bibliography.

Memoirs of the American Mathematical Society, Volume 153, Number 727
Global Analysis and Harmonic Analysis
J-P Bourguignon, Institut des Hautes Etudes Scientifiques, France, T. Branson, University of Iowa, Iowa City, and O. Hijazi, University of Nancy I, France, Editors
A publication of the Société Mathématique de France.

This book presents the proceedings of a meeting intended to gather researchers working in the fields of harmonic analysis and global analysis to discuss some questions of common interest. About twenty talks covered the principal topics, illustrating the recent interactions between these two fields.

The meeting started with a survey on spin geometry and was followed by talks on the spectrum of the Dirac operator in hyperbolic, Kählerian and pseudo-Riemannian geometry.

Different aspects of representation theory were discussed: Schubert cells, unitary representations with reflection symmetry, gradient operators, and Poisson transformations. Another series of talks was devoted to the systematic use of representation theory in global analysis; in particular on the refinements of the Kato inequality in Riemannian geometry.

Various presentations ranging from general relativity to different aspects of representation theory were discussed: Schubert cells, unitary representations with reflection symmetry, gradient operators, and Poisson transformations. Another series of talks was devoted to the systematic use of representation theory in global analysis; in particular on the refinements of the Kato inequality in Riemannian geometry.

The text is suitable for a first-year graduate course, although much of it can be readily mastered by advanced undergraduate students. Included are many examples and a very rich collection of exercises. There are partial solutions to approximately one-third of the exercises. A complete solutions manual is available separately.

Solutions Manual to A Modern Theory of Integration
Robert G. Bartle, Eastern Michigan University, Ypsilanti, and University of Illinois, Urbana

The amount of algebraic topology a graduate student specializing in topology must learn can be intimidating. Moreover, by their second year of graduate studies, students must make the transition from understanding simple proofs line-by-line to understanding the overall structure of proofs of difficult theorems.

To help students make this transition, the material in this book is presented in an increasingly sophisticated manner. It is intended to bridge the gap between algebraic and geometric topology, both by providing the algebraic tools that a geometric topologist needs and by concentrating on those areas of algebraic topology that are geometrically motivated.
Prerequisites for using this book include basic set-theoretic topology, the definition of CW-complexes, some knowledge of the fundamental group/covering space theory, and the construction of singular homology. Most of this material is briefly reviewed at the beginning of the book.

The topics discussed by the authors include typical material for first- and second-year graduate courses. The core of the exposition consists of chapters on homotopy groups and on spectral sequences. There is also material that would interest students of geometric topology (homology with local coefficients and obstruction theory) and algebraic topology (spectra and generalized homology), as well as preparation for more advanced topics such as algebraic K-theory and the s-cobordism theorem.

A unique feature of the book is the inclusion, at the end of each chapter, of several projects that require students to present proofs of substantial theorems and to write notes accompanying their explanations. Working on these projects allows students to grapple with the “big picture”, teaches them how to give mathematical lectures, and prepares them for participating in research seminars.

The book is designed as a textbook for graduate students studying algebraic and geometric topology and homotopy theory. It will also be useful for students from other fields such as differential geometry, algebraic geometry, and homological algebra. The exposition in the text is clear; special cases are presented over complex general statements.

Graduate Studies in Mathematics, Volume 35

Differential Geometry, Lie Groups, and Symmetric Spaces
Sigurdur Helgason, Massachusetts Institute of Technology, Cambridge

From reviews for the First Edition:
A great book ... a necessary item in any mathematical library.
—S. S. Chern, University of California

Written with unmatched lucidity, systematically, carefully, beautifully.
—S. Bochner, Princeton University

Helgason’s monograph is a beautifully done piece of work and should be extremely useful for several years to come, both in teaching and in research.
—D. Spencer, Princeton University

A brilliant book: rigorous, tightly organized, and covering a vast amount of good mathematics.
—Barrett O’Neill, University of California

Renders a great service in permitting the non-specialist, with a minimum knowledge of differential geometry and Lie groups, an initiation to the theory of symmetrical spaces.
—H. Cartan, Secretariat Mathématique, Paris

The mathematical community has long been in need of a book on symmetric spaces. S. Helgason has admirably satisfied this need with his book, Differential Geometry and Symmetric Spaces. It is a remarkably well-written book ... a masterpiece of concise, lucid mathematical exposition ... it might be used as a textbook for “how to write mathematics”.
—Louis Auslander

[The author] will earn the gratitude of many generations of mathematicians for this skillful, tasteful, and highly efficient presentation. It will surely become a classic.
—G. D. Mostow, Yale University

The study of homogeneous spaces provides excellent insights into both differential geometry and Lie groups. In geometry, for instance, general theorems and properties will also hold for homogeneous spaces, and will usually be easier to understand and to prove in this setting. For Lie groups, a significant amount of analysis either begins with or reduces to analysis on homogeneous spaces, frequently on symmetric spaces. For many years and for many mathematicians, Sigurdur Helgason’s classic Differential Geometry, Lie Groups, and Symmetric Spaces has been—and continues to be—the standard source for this material.

Helgason begins with a concise, self-contained introduction to differential geometry. He then introduces Lie groups and Lie algebras, including important results on their structure. This sets the stage for the introduction and study of symmetric spaces, which form the central part of the book. The text concludes with the classification of symmetric spaces by means of the Killing-Cartan classification of simple Lie algebras over C and Cartan’s classification of simple Lie algebras over R.

The excellent exposition is supplemented by extensive collections of useful exercises at the end of each chapter. All the problems have either solutions or substantial hints, found at the back of the book.

For this latest edition, Helgason has made corrections and added helpful notes and useful references. The sequels to the present book are published in the AMS’s Mathematical Surveys and Monographs Series: Groups and Geometric Analysis, Volume 83, and Geometric Analysis on Symmetric Spaces, Volume 39.

Sigurdur Helgason was awarded the Steele Prize for Differential Geometry, Lie Groups, and Symmetric Spaces and Groups and Geometric Analysis.

This item will also be of interest to those working in algebra and algebraic geometry.

Graduate Studies in Mathematics, Volume 34

Stable Groups
Bruno Poizat, Université Claude Bernard, Villeurbanne, France

From a review of the French edition:
This is a beautiful book in which almost everything known about stable groups appears.
—Zentralblatt für Mathematik

This is the English translation of the book originally published in 1987. It is a faithful reproduction of the original, supple-
mented by a new Foreword and brought up to date by a short postscript. The book gives an introduction by a specialist in contemporary mathematical logic to the model-theoretic study of groups, i.e., into what can be said about groups, and for that matter, about all the traditional algebraic objects.

The author introduces the groups of finite Morley rank (those satisfying the most restrictive assumptions from the point of view of logic), and highlights their resemblance to algebraic groups, of which they are the prototypes. (All the necessary prerequisites from algebraic geometry are included in the book.) Then, whenever possible, generalizations of properties of groups of finite Morley type to broader classes of superstable and stable groups are described.

The exposition in the first four chapters can be understood by mathematicians who have some knowledge of logic (model theory). The last three chapters are intended for specialists in mathematical logic.

Mathematical Surveys and Monographs, Volume 87

Chaotic Elections! A Mathematician Looks at Voting
Donald G. Saari, University of California, Irvine

What does the 2000 U.S. presidential election have in common with selecting a textbook for a calculus course in your department? Was Ralph Nader's influence on the election of George W. Bush greater than the now-famous chads? In Chaotic Elections! Don Saari analyzes these questions, placing them in the larger context of voting systems in general. His analysis shows that the fundamental problems with the 2000 presidential election are not with the courts, recounts, or defective ballots, but are caused by the very way Americans vote for president.

This expository book shows how mathematics can help to identify and characterize a disturbingly large number of paradoxical situations that result from the choice of a voting procedure. Moreover, rather than being able to dismiss them as anomalies, the likelihood of a dubious election result is surprisingly large. These consequences indicate that election outcomes—whether for president, the site of the next Olympics, the chair of a university department, or a prize winner—can differ from what the voters really wanted. They show that by using an inadequate voting procedure, we can, inadvertently, choose badly. To add to the difficulties, it turns out that the mathematical structures of voting admit several strategic opportunities, which are described.

Finally, mathematics also helps identify positive results: By using mathematical symmetries, we can identify what the phrase "what the voters really want" might mean and obtain a unique voting method that satisfies these conditions.

Saari's book should be required reading for anyone who wants to understand not only what happened in the presidential election of 2000, but also how we can avoid similar problems from appearing anytime any group is making a choice using a voting procedure. Reading this book requires little more than high school mathematics and an interest in how the apparently simple situation of voting can lead to surprising paradoxes.

April 2001, 159 pages, Softcover, ISBN 0-8218-2847-9, LC 2001022386, 2000 Mathematics Subject Classification: 91B12, 91B14, 00A05, All AMS members $18, List $23, Order code ELECT
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Gerd Fischer, Heinrich-Heine-Universität, Düsseldorf, Germany

From a review for the German Edition:
The arrangement of the material is of outstanding instructional skill, and the text is written in a very lucid, detailed and enlightening style. Compared to the many other textbooks on (plane) algebraic curves, the present new one comes closest in spirit and content, to the work of E. Brieskorn and H. Knorrer. One could say that the book under review is a beautiful, creative and justifiable abridged version of this work, which also stresses the analytic-topological point of view. The present book is a beautiful invitation to algebraic geometry, encouraging for beginners, and a welcome source for teachers of algebraic geometry, especially for those who want to give an introduction to the subject on the undergraduate graduate level, to cover some not too difficult topics in substantial depth, but to do so in the shortest possible time.

—Zentralblatt für Mathematik

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W. J. Kaczor and M. T. Nowak, Marie Curie-Sklodowska University, Lublin, Poland

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The Game’s Afoot! Game Theory in Myth and Paradox
Alexander Mehlmann, Vienna University of Technology, Austria

From reviews of the German edition:
The author, well known for various imaginative, entertaining and instructive writings in the area of game theory, and for his game-theoretic excursions into classical literature, has now brought out this delightful little book on the basics of noncooperative games. The reader will gain an appreciation for the mathematical modelling of conflict in economics, the social sciences and biology, and get a glimpse of game-theoretic analysis of conflict in some of the classical literature.

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An Introduction to Game-Theoretic Modelling
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Michael Meserton-Gibbon, Florida State University, Tallahassee

Meserton-Gibbon’s book deals with mathematical modelling, not by an abstract discussion of how modelling should be done, but rather by presenting many concrete examples. The examples are great, and the author has clearly put enormous effort into building this collection — a perfect source of problems for a Moore method course — a valuable contribution to the literature. Everyone interested in game theory or mathematical modelling should take a look at it.

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The Prime Numbers and Their Distribution
Gérald Tenenbaum, Université Henri Poincaré, Nancy I, France, and Michel Mendès France, Université Bordeaux I, France

Nicely written. It is a pleasure to read this booklet, written by experts of number theory. Due to the many results, the elegant proofs, and the informal explanations of ideas, it is highly recommended to study this small monograph thoroughly.

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Donald G. Saari, University of California, Irvine

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Some Sums of Ramanujan and What We Can Do with Them, DICK ASKEY, University of Wisconsin-Madison
Ramanujan’s Lost Notebook, GEORGE ANDREWS, Penn State University
Some Recent Threads of Ramanujan’s Legacy, SCOTT AHLGREN, University of Illinois, Urbana-Champaign
Tantalizing Questions and Prospects for the Future, AHLGREN, ANDREWS, ASKEY, BERNDT, and ONO
Meetings & Conferences
of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the Notices. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See http://www.ams.org/meetings/. Programs and abstracts will continue to be displayed on the AMS website in the Meetings and Conferences section until about three weeks after the meeting is over. Final programs for Sectional Meetings will be archived on the AMS website in an electronic issue of the Notices as noted below for each meeting.

Columbus, Ohio
Ohio State University
September 21–23, 2001
Meeting #969
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: June 2001
Program first available on AMS Website: August 9, 2001
Program issue of electronic Notices: October 2001
Issue of Abstracts: Volume 22, Issue 3

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: July 13, 2001

Invited Addresses
Alex Eskin, University of Chicago, Title to be announced.
Dennis Gaitsgory, University of Chicago, Title to be announced.
Yakov B. Pesin, Pennsylvania State University, Title to be announced.
Thaleia Zariphopoulou, University of Texas at Austin, Title to be announced.

Special Sessions
$L^2$ Methods in Algebraic and Geometric Topology (Code: AMS SS G1), Dan Burghelea and Michael Davis, Ohio State University.

Algebraic Cycles, Algebraic Geometry (Code: AMS SS A1), Roy Joshua, Ohio State University.
Coding Theory and Designs (Code: AMS SS B1), Tom Dowling, Ohio State University, and Dijen Ray-Chaudhuri.
Commutative Algebra (Code: AMS SS C1), Evan Houston, University of North Carolina, Charlotte, and Alan Loper, Ohio State University.
Complex Approximation Theory via Potential Theory (Code: AMS SS R1), V. V. Andrievskii and Richard S. Varga, Kent State University.
Cryptography and Computational and Algorithmic Number Theory (Code: AMS SS E1), Eric Bach, University of Wisconsin-Madison, and Jonathan Sorenson, Butler University.
Differential Geometry and Applications (Code: AMS SS Q1), Andrzej Derdzinski and Fangyang Zheng, Ohio State University.
Fractals (Code: AMS SS P1), Gerald Edgar, Ohio State University.
Group Theory (Code: AMS SS F1), Koichiro Harada, Surinder Seghal, and Ronald Solomon, Ohio State University.
Multivariate Generating Functions and Automatic Computation (Code: AMS SS H1), Robin Pemantle, Ohio State University.
Proof Theory and the Foundations of Mathematics (Code: AMS SS K1), Timothy Carlson, Ohio State University.
Quantum Topology (Code: AMS SS L1), Thomas Kerler, Ohio State University.
Rings and Modules (Code: AMS SS M1), S. K. Jain, Ohio University, and Tariq Rizvi, Ohio State University.
Meetings & Conferences

Spectral Theory of Schrödinger Operators (Code: AMS SS N1), Boris Mityagin, Ohio State University, and Sergei Novikov, University of Maryland.

Stochastic Modeling in Financial Mathematics (Code: AMS SS D1), Ronnie Sircar, Princeton University.

Chattanooga, Tennessee
University of Tennessee, Chattanooga

October 5-6, 2001

Meeting #970
Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of Notices: August 2001
Program first available on AMS Website: August 23, 2001
Program issue of electronic Notices: November 2001
Issue of Abstracts: Volume 22, Issue 3

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 14, 2001

Invited Addresses
Susanne C. Brenner, University of South Carolina, Columbia, Additive multigrid theory.
Edward B. Saff, University of South Florida, Title to be announced.
Joel H. Spencer, New York University, Erdös magic.
Roberto Triggiani, University of Virginia, Differential geometric methods in the control of partial differential equations.

Special Sessions
Applications of Partial Differential Equations in Geometric Analysis (Code: AMS SS N1), Bo Guan and Changyou Wang, University of Tennessee, Knoxville.
Asymptotic Behavior of Solutions of Differential and Difference Equations (Code: AMS SS B1), John R. Graef, University of Tennessee at Chattanooga, and Chuanxi Qian, Mississippi State University.
Commutative Ring Theory (Code: AMS SS A1), David F. Anderson and David E. Dobbs, University of Tennessee at Knoxville.
Differential Geometric Methods in the Control of Partial Differential Equations (Code: AMS SS L1), Walter Littman, University of Minnesota, and Roberto Triggiani, University of Virginia.
Mathematical and Numerical Aspects of Wave Propagation (Code: AMS SS F1), Boris P. Belinskiy and Yongzhi Xu, University of Tennessee at Chattanooga.

New Directions in Combinatorics and Graph Theory (Code: AMS SS C1), Teresa Haynes and Debra J. Knisley, East Tennessee State University.
Numerical Analysis and Approximation Theory (Code: AMS SS G1), Tian-Xiao He, Illinois Wesleyan University, and Don Hong, Eastern Tennessee State University.
Additive Multigrid Theory (Code: AMS SS J1), Susanne Brenner, University of South Carolina, Columbia, and Craig C. Douglas, University of Kentucky.
Real Analysis (Code: AMS SS D1), Paul D. Humke, Saint Olaf College, Harry I. Miller, University of Tennessee at Chattanooga, and Clifford E. Weil, Michigan State University.
Recent Advances in Optimization Methods (Code: AMS SS H1), Jerald P. Dauer and Aniekan Ebiefung, University of Tennessee at Chattanooga.
Sphere-Related Approximation and Applications (Code: AMS SS M1), Edward B. Saff, University of South Florida, and Larry L. Schumaker, Vanderbilt University.
Topics in Geometric Function Theory (Code: AMS SS E1), Leila Miller-Van Wieren, Penn State Berks Campus, and Bruce P. Palca, University of Texas at Austin.
Variational Problems for Free Surface Interfaces (Code: AMS SS K1), John E. McCuan, Georgia Institute of Technology, Thomas I. Vogel, Texas A&M University, and Henry C. Wente, University of Toledo.

Accommodations
Participants should make their own arrangements directly with a hotel of their choice. Special rates have been negotiated with the hotels listed below. Rates quoted do not include sales tax of 12.25%. The AMS is not responsible for rate changes or for the quality of the accommodations. When making a reservation, participants should state that they are with the UTC-AMS meeting group.

Hampton Inn, 2420 William Street, Chattanooga, TN 37408; 423-265-0077; fax: 423-267-6700; $59/single or double for the nights of Thursday and Friday, October 4 and 5; the special rate will be extended to those who wish to stay the night of Saturday, October 6, provided rooms are available. Rates include extended continental breakfast and free parking. The hotel is about 3.5 miles from campus. Reservation deadline is September 2, 2001.

Clarion Hotel, 407 Chestnut Street, Chattanooga, TN 37402; 423-756-5150, 800-CLARION (800-252-7466); fax: 423-265-8708; $64/single, double, triple, or quad for the nights of Thursday and Friday, October 4 and 5; the special rate will be extended to those who wish to stay the night of Saturday, October 6, provided rooms are available. Rates include extended continental breakfast and free parking. The hotel is about one mile from campus. Reservation deadline is September 18, 2001.

Food Service
A list of area dining options will be available at the registration desk.
Other Activities

AMS Book Sale: Examine the newest titles from the AMS! Most books will be available at a special 50% discount offered only at meetings. Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Registration and Meeting Information

The locations of the registration desk and sessions will be announced in the next issue (or watch http://www.ams.org/amsmtgs/sectional.html for up-to-the-minute information).

Registration fees (payable on site only) are $40/AMS or CMS members; $60/nonmembers; $5/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Travel

The following specially negotiated rates on USAirways are available exclusively to mathematicians and their families for the period October 2–9, 2001. Discounts apply only to travel within the continental U.S. Other restrictions may apply and seats are limited. Receive a 5% discount off First or Envoy Class and any published USAirways promotional round-trip fare. By purchasing your ticket 60 days or more prior to departure, you can receive an additional 5% bonus discount. Or you may receive a 10% discount off unrestricted coach fares with seven-day advance purchase. For reservations call (or have your travel agent call) USAirways Group and Meeting Reservation Office toll-free at 877-874-7687 between 8:00 a.m. and 9:30 p.m. Eastern Time. Refer to Gold File number 88111579.

Directions to campus: From Interstate 75 (north or south) connect to Interstate 24 to Tennessee Chattanooga. This will put you on U.S. 41 south. Go one block to the main entrance of the UTC Arena (a very large, round building on your right that’s hard to miss). Continue east on 4th Street until you arrive at Lots 32, 33, and 34 for free parking right by the arena.

Car rental: Special rates have been negotiated with Avis Rent A Car for the period September 28 to October 13, 2001. All rates include unlimited free mileage; the weekend rates quoted are available from noon Thursday until Monday at 11:59 p.m. Rates do not include state or local surcharges, tax, optional coverages, or gas refueling charges. Renter must meet Avis’s age, driver, and credit requirements. Make reservations by calling 800-331-1600 or online at http://www.avis.com/. Higher nonweekend and weekly rates are also available. Please quote Avis Discount Number J098887 when making reservations.

Daily weekend rates are Subcompact, $21.99; Compact, $22.99; Intermediate, $24.99; Full-size (2-door), $27.99; Full-size (4-door), $29.99; Premium, $31.99; Luxury, $63.99; Minivan, $63.99; and Sport Utility, $63.99.

Weather

Average high and low temperatures in early October in Chattanooga are 74° F and 50° F respectively.

Williamstown, Massachusetts

Williams College

October 13–14, 2001

Meeting #971

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of Notices: August 2001

Program first available on AMS Website: August 30, 2001

Program issue of electronic Notices: November 2001

Issue of Abstracts: Volume 22, Issue 4

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: August 21, 2001

Invited Addresses

Hubert Bray, Massachusetts Institute of Technology, Title to be announced.

Robin Forman, Rice University, Title to be announced.

Emma Previato, Boston University, Theta functions, old and new.

Yisong Yang, Polytechnic University, Harmonic maps, gauge fields, and magnetic vortices.

Special Sessions

Abelian Varieties (Code: AMS SS K1), Alexander Polishchuk and Emma Previato, Boston University.

Algebraic and Topological Combinatorics (Code: AMS SS D1), Eva Maria Feichtner, ETH, Zürich, Switzerland, and Dmitry N. Kozlov, KTH, Stockholm, Sweden.

Commutative Algebra (Code: AMS SS C1), Susan R. Loepp, Williams College, and Graham J. Leuschke, University of Kansas.

Diophantine Problems (Code: AMS SS F1), Edward B. Burger, Williams College, and Jeffrey D. Vaaler, University of Texas at Austin.

Ergodic Theory (Code: AMS SS H1), Cesar Silva, Williams College.

Geometry and Topology of the Universe (Code: AMS SS E1), Colin C. Adams, Williams College, Glenn Starkmann, Case Western Reserve University, and Jeffrey R. Weeks, Canto, New York.
Harmonic Analysis Since the Williamstown Conference of 1978 (Code: AMS SS G1), Janine E. Wittwer, Williams College, and David Cruz-Uribé, Trinity College.

History of Mathematics (Code: AMS SS A1), Glen R. Van Brummelen, Bennington College, Della D. Fenster, Richmond University, James J. Tattersall, Providence College, and Shawnie L. McMurrain, California State University, San Bernardino.

Integrable Systems and Quantum Groups (Code: AMS SS L1), Pavel I. Etingof, Massachusetts Institute of Technology, and Emma Previato, Boston University.

Nonlinear PDEs and Calculus of Variations (Code: AMS SS J1), Yisong Yang, Polytechnic University, and Fanghua Lin and Nader Masmoudi, Courant Institute, New York University.

Number Theory, Holomorphic Dynamics, and Algebraic Dynamics (Code: AMS SS B1), Robert L. Benedetto, University of Rochester, John W. Minnor, IMS and SUNY at Stony Brook, and Kevin M. Pilgrim, University of Missouri at Rolla.

Accommodations

Fall in western Massachusetts is a very popular time for tourists, so it is strongly suggested that participants make reservations as soon as possible. All of these properties are expected to sell out during this holiday weekend. Many of these properties are very small or are holding only a very few rooms for meeting participants. Rates do not include the tax of 9.7%. The AMS is not responsible for the quality of the rooms or any rate changes.

These previously advertised properties are sold out during the meeting weekend: House on Main Street, Northside Motel, Redwood Motel, and the Orchards.

Berkeley Hills Motel, Cold Spring Road, Route 7, Williamstown, MA 01267; 413-458-3950; fax: 413-458-5878. Minimum stay is two nights, $139/single or double; five miles from campus. Reservation deadline is August 12, 2001.

Chimney Mirror Motel, 295 Main Street, Williamstown, MA 01267; 413-458-5202. Minimum stay is two nights, $99/single or double; .3 miles from campus. Reservation deadline is July 12, 2001.

Cozy Corner Motel, Sand Springs Road, Route 7, Williamstown, MA 01267; 413-458-8006. Minimum stay is two nights, $115/single or double; 1.5 miles from campus. Reservation deadline is August 12, 2001.

Four Acres Motel, 213 Main Street, Williamstown, MA 01267; 413-458-8158 (same number for fax). Minimum stay is two nights, $99-$140/single or double; 1 mile from campus. First come, first served for reservations.

Ladd Brook Motor Inn, Route 7, P.O. Box C, Pownal, VT 05261; 800-261-5233 or 802-823-7341; fax: 802-823-9359. Minimum stay is two nights, $89/single or double; five miles from campus. Reservation deadline is August 12, 2001.

Maple Terrace Motel, 555 Main Street, Williamstown, MA 01267; 413-458-9677 (same number for fax). Minimum stay is two nights, $93/single and $98/double; .8 miles from campus. Reservation deadline is August 12, 2001.

Villager Motel, 953 Simonds Road, Williamstown, MA 01267; 413-458-4046. Minimum stay is two nights, $105/single or double; 1.5 miles from campus. First come, first served for reservations.

Williams Inn, On-the-Green, Williamstown, MA 01267; 413-458-9371; fax: 413-458-2767. No minimum stay, $95/single or $125.00/double; .2 miles from campus. Reservation deadline is September 12, 2001.

Willows Motel, 480 Main Street, Williamstown, MA 01267; 413-458-5768, fax: 413-458-9317. Minimum stay is two nights, $88/single or $104/two bed double; .8 miles from campus. Reservation deadline is September 12, 2001.

Other possibilities (see www.williamstownchamber.com/docs/lodging.htm):

Crowne Plaza Hotel, One West Street, Pittsfield, MA; 413-499-2000; $189/single or double; reservation deadline is September 21, 2001.

Darling Kelly's Motel, Bennington, VT, 802-442-2322.

1896 House, Cold Spring Road, Route 7, Williamstown, MA 01267; 413-458-8125. Minimum stay is two nights, $90-$175/night for single or double (2000 rates) with six additional suites available by July 2001; rates include a generous continental breakfast; about 2.2 miles from campus. (See http://www.1896house.com/)

Fife 'n Drum Motel, Bennington, VT, 802-442-4074.

Kirkside Motor Lodge, Bennington, VT, 802-447-7596.

Food Service

The student dining halls located in Baxter, Greylock, and Dodd Halls will be open for meals on a cash basis. The hours of operation for each facility can be viewed at http://www.williams.edu/admin/dining/hours.html. There is also a snack bar on the lower level of Baxter Hall. A list of nearby restaurants will be available on site.

Local Information

Please see the Web site maintained by Williams College at http://www.williams.edu/. A campus map can be found at http://www.williams.edu/home/visitors/map/index.html.

Other Activities

AMS Book Sale: Examine the newest titles from the AMS! Most books will be available at a special 50% discount offered only at meetings. Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Reception

The Department of Mathematics invites all meeting participants to a reception from 6:00 p.m. to 7:00 p.m. on Saturday. The Society thanks the department for its gracious hospitality.

Registration and Meeting Information

Scientific sessions will take place in the Bronfman Science Center, Thompson Biology, Thompson Chemistry, Thomp-
son Physics, Clark, and Jesup buildings. The Invited Addresses will be in Bronfman Auditorium. Registration will be located in the Science Court and will operate from 7:30 a.m. to 4:00 p.m. on Saturday and from 7:30 a.m. to noon on Sunday.

Registration fees (payable on site only) are $40/AMS or CMS members; $60/nonmembers; $5/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Parking
Meeting participants should park in the Brooks Lot behind Spencer House. Enter from Spencer Court off Route 2 (Main Street).

Travel
The following specially negotiated rates on USAirways are available exclusively to mathematicians and their families for the period October 10-17, 2001. Discounts apply only to travel within the continental U.S. Other restrictions may apply and seats are limited. Receive a 5% discount off First or Envoy Class and any published USAirways promotional round-trip fare. By purchasing your ticket prior to departure, you can receive an additional 5% bonus discount. Or you may receive a 10% discount off unrestricted coach fares with seven-day advance purchase. For reservations call (or have your travel agent call) USAirways Group and Meeting Reservation Office toll-free at 877-874-7687 between 8:00 a.m. and 9:30 p.m. Eastern Time. Refer to Gold File number 88111579.

The nearest major airport is in Albany, NY, about 40 miles from Williamstown. Visitors may take a taxi or arrange transportation in advance by calling Norm’s Limousine Service (800-486-4946 or 413-663-8300/6284) or Luxury Limo (413-458-9414). Norm’s charges $63 one way for one or two people and $5 for each additional person included in one reservation (additional charge before 6 a.m. and after 10 p.m.) The Airport Limo Service/Yellow Cab at the Albany Airport (518-869-2258/2259) charges $70 for a taxi trip to campus.

Directions to campus: It is approximately three hours’ travel time to campus from either Boston or New York City. From Boston travel either Route 2 or, take the Mass Pike to the Lee (Exit 2), then Route 20 West and North to Route 7 North. From New York City the preferred route is up the Taconic Parkway to Route 295 East to Route 22 North to Route 43 East to Route 7 North. From the Albany area (about a one-hour trip), the shortest route is along Route 7, turning right onto Route 278, then left onto Route 2. The campus is about a two-hour trip from Hartford’s Bradley Airport. Follow signs to I-91 North, exit on Mass Pike (I-90) West to Lee (Exit 2), then as from Boston above.

Car rental: Special rates have been negotiated with Avis Rent A Car for the period October 6 to October 21, 2001. All rates include unlimited free mileage; the weekend rates quoted are available from noon Thursday until Monday at 11:59 p.m. Rates do not include state or local surcharges, tax, optional coverages, or gas refueling charges. Renter must meet Avis’s age, driver, and credit requirements. Make reservations by calling 800-331-1600 or online at http://www.avis.com/. Higher nonweekend and weekly rates are also available. Please quote Avis Discount Number J098887 when making reservations.

Daily weekend rates are Subcompact, $41.99; Compact, $42.99; Intermediate, 44.99; Full-size (2-door), $48.99; Full-size (4-door), $45.99; Premium, $59.99; Luxury, $75.99; Minivan, $75.99; and Sport Utility, $75.99.

Weather
Average high and low temperatures in mid-October in Williamstown are 58°F and 35°F respectively. Precipitation averages 3.8 inches.

Irvine, California
University of California Irvine
November 10-11, 2001

Meeting #972
Western Section
Announcement issue of Notices: September 2001
Program first available on AMS Website: September 27, 2001
Program issue of electronic Notices: December 2001
Issue of Abstracts: Volume 22, Issue 4

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: July 24, 2001
For abstracts: September 18, 2001

Invited Addresses
William Duke, University of California, Los Angeles, Title to be announced.
Grigory Mikhalkin, University of Utah, Title to be announced.
Gigliola Staffilani, Stanford University, Title to be announced.
Jonathan Weitsman, University of California Santa Cruz, Title to be announced.

Special Sessions
Extremal Metrics and Moduli Spaces (Code: AMS SS F1), Steven Bradlow, University of Illinois, Urbana-Champaign, Claude LeBrun, State University of New York, Stony Brook, and Yat Sun Poon, University of California Riverside.
Groups and Covering Spaces in Algebraic Geometry (Code: AMS SS D1), Michael Fried, University of California Irvine, and Helmut Voelklein, University of Florida.
Harmonic Analyses and Partial Differential Equations (Code: AMS SS H1), Gustavo Ponce, University of California Santa Barbara, and Gigliola Staffilani, Stanford University.
Harmonic Analysis and Complex Analysis (Code: AMS SS CI), Xiaojun Huang, Rutgers University, and Song-Ying Li, University of California Irvine.

Partial Differential Equations and Applications (Code: AMS SS CI), Edris S. Titi, University of California Irvine.

Quantum Topology (Code: AMS SS A1), Louis Kauffman, University of Illinois at Chicago, Jozef Przytycki, George Washington University, and Fernando Souza, University of Waterloo.

Random and Deterministic Schrödinger Operators (Code: AMS SS E1), Svetlana Jitomirskaya and Abel Klein, University of California Irvine.

Topology of Algebraic Varieties (Code: AMS SS B1), Erika Hironaka, Florida State University, and Grigory Mikhalkin, University of Utah.

San Diego, California
San Diego Convention Center
January 6–9, 2002

Meeting #973
Joint Mathematics Meetings, including the 108th Annual Meeting of the AMS; 85th Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM); the 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: John L. Bryant
Announcement issue of Notices: October 2001
Program first available on AMS Website: November 1, 2001
Program issue of electronic Notices: January 2002
Issue of Abstracts: Volume 23, Issue 1

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: August 7, 2001
For abstracts: October 2, 2001
For summaries of papers to MAA organizers: September 14, 2001

Joint Invited Addresses
Dennis DeTurck, University of Pennsylvania, Title to be announced (AMS-MAA Invited Address).

Joint Special Sessions
History of Mathematics (Code: AMS SS A1), Thomas Archibald, Acadia University, and David E. Zitarelli, Temple University (AMS-MAA).

Mathematics and Education Reform (Code: AMS SS Q1), William H. Barker, Bowdoin College, Jerry L. Bona, University of Texas at Austin, Naomi D. Fisher, University of Illinois at Chicago, and Kenneth C. Millett, University of California Santa Barbara (AMS-MAA).

Set Theory and Classification Problems (Code: AMS SS DD1), Simon R. Thomas, Rutgers University (AMS-ASL).

AMS Invited Addresses
Michael V. Berry, Bristol University, Title to be announced (AMS Josiah Willard Gibbs Lecture).
Felix E. Browder, Rutgers University, Title to be announced (AMS Retiring Presidential Address).
L. Craig Evans, University of California Berkeley, Title to be announced (AMS Colloquium Lectures).
John M. Franks, Northwestern University, Title to be announced.
Jeffrey C. Lagarias, AT&T Laboratories Research, Title to be announced.
Fanghua Lin, Courant Institute, New York University, Title to be announced.
John Preskill, California Institute of Technology, Title to be announced.
Richard L. Taylor, Harvard University, Title to be announced.

AMS Special Sessions
Algebraic Coding Theory (Code: AMS SS D1), Marcus Greth, Michael O'Sullivan, and Roxana N. Smarandache, San Diego State University.

Algebraic Combinatorics (Code: AMS SS E1), Rosa C. Orellana, Dartmouth College, and Michael Zabrocki, York University.

Algebras, Forms, and Algebraic Groups (Code: AMS SS F1), R. Skip Garibaldi, University of California Los Angeles, David J. Saltman, University of Texas at Austin, and Adrian R. Wadsworth, University of California San Diego.

Analysis and Application of Quasilinear Partial Differential Equations (Code: AMS SS G1), Suncica Canic and Eun Heui Kim, University of Houston.

Chaos, Stability, and Asymptotics in Difference Equations (Code: AMS SS H1), Saber N. Elaydi, Trinity University, Gerasimos Ladas, University of Rhode Island, and Donald A. Lutz, San Diego State University.

Computability Theory with Applications (Code: AMS SS J1), Paul C. Roberts and Anurag K. Singh, University of Utah.

Computational Commutative Algebra and Algebraic Geometry (Code: AMS SS BB1), Jeffrey B. Remmel, University of California San Diego.

Computational Commutative Algebra and Algebraic Geometry (Code: AMS SS CC1), Elizabeth Arnold, Texas A&M University, and Amelia Taylor, Rutgers University.

Dynamic Equations on Time Scales (Code: AMS SS B1), Martin J. Bohner, University of Missouri, Rolla, and Billur Kaymakcalan, Georgia Southern University.

Fractal Geometry and Applications: A Jubilee of Benoît Mandelbrot (Code: AMS SS L1), Michel L. Lapidus,
University of California Riverside, and Machiel van Frankenhuyzen, Rutgers University.

Graph Theory (Code: AMS SS M1), Andre Kundgen and K. Brooks Reid, California State University, San Marcos.

Hybrid Systems (Code: AMS SS N1), Elena Litsyn, Ben-Gurion University, and A. S. Vatsala, University of Louisiana at Lafayette.

Low Dimensional Topology (Code: AMS SS Z1), Tim D. Cochran, Rice University.


Partial Differential Equations and Their Applications (Code: AMS SS S1), Reza Malek-Madani and Peter A. McCoy, United States Naval Academy, and John W. Neuberger, University of North Texas.

Probabilistic Methods in Combinatorics and the Internet (Code: AMS SS C1), Fan Chung Graham and Van Vu, University of California San Diego.

Quantum Computation and Information (Code: AMS SS T1), Philip L. Bowers and Washington Mio, Florida State University, and John Preskill, California Institute of Technology.

Recent Developments in Analysis and Numerics of Fluid Problems (Code: AMS SS K1), Jie Shen, Pennsylvania State University and University of Central Florida, Shouhong Wang, Indiana University, and Xiaoming Wang, Iowa State University.

Research in Mathematics by Undergraduates (Code: AMS SS U1), Carl V. Lutzer and Darren A. Narayan, Rochester Institute of Technology.

Stochastic Processes and Functional Analysis (in honor of M. M. Rao) (Code: AMS SS V1), Alan C. Krinik, California State Polytechnic University, Pomona, and Randall J. Swift, Western Kentucky University.

Symbolic Dynamics (Code: AMS SS AA1), Aimee S. A. Johnson, Swarthmore College, and Kathleen M. Madden, Drew University.


The Theory and Applications of Symmetric Functions (Code: AMS SS W1), Adriano Garsia and Jeffrey B. Remmel, University of California San Diego.

Topology and Its Applications (Code: AMS SS X1), Alexander Arhangelskii, Ohio University, Melvin Henriksen, Harvey Mudd College, James E. Keesling, University of Florida, Ralph D. Kopperman, City College of CUNY, and John C. Mayer, University of Alabama at Birmingham.

Wavelets for Undergraduates (Code: AMS SS Y1), Edward F. Aboufadel and Steven J. Schlicker, Grand Valley State University.

Ann Arbor, Michigan
University of Michigan
March 1-3, 2002

Meeting #974
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: January 2002
Program first available on AMS Website: January 17, 2002
Program issue of electronic Notices: May 2002
Issue of Abstracts: To be announced

Deadlines
For organizers: August 3, 2001
For consideration of contributed papers in Special Sessions: November 13, 2001
For abstracts: January 9, 2002

Invited Addresses
Lazlo Babai, University of Chicago, Title to be announced.
Netts Katz, Washington University, Title to be announced.
Alan Reid, University of Texas at Austin, Title to be announced.
Liehe Wang, University of Iowa, Title to be announced.

Special Sessions
Quantum Topology in Dimension Three (Code: AMS SS A1), Charles Frohman, University of Iowa, and Joanna Kania-Bartoszynska, Boise State University.

Atlanta, Georgia
Georgia Institute of Technology
March 8-10, 2002

Meeting #975
Meeting held in conjunction with MAA.
Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of Notices: January 2002
Program first available on AMS Website: January 31, 2002
Program issue of electronic Notices: May 2002
Issue of Abstracts: To be announced

Deadlines
For organizers: October 8, 2001
For consideration of contributed papers in Special Sessions: November 27, 2001
For abstracts: January 22, 2002
For summaries of papers to MAA organizers: To be announced
Meetings & Conferences

AMS Invited Addresses

Nigel J. Kalton, University of Missouri, Columbia, Title to be announced.

James G. Oxley, Louisiana State University, Title to be announced.

Montréal, Quebec, Canada

Centre de Recherches Mathématiques, Université de Montréal

May 3–5, 2002

Meeting #976

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of Notices: March 2002

Program first available on AMS Website: March 21, 2002

Program issue of electronic Notices: July 2002

Issue of Abstracts: To be announced

Deadlines

For organizers: October 3, 2001

For consideration of contributed papers in Special Sessions: January 15, 2002

For abstracts: March 12, 2002

Invited Addresses

Nicholas M. Ercolani, University of Arizona, Title to be announced.

Lars Hesselholt, Massachusetts Institute of Technology, Title to be announced.

Niky Kamran, McGill University, Title to be announced.

Rafael de la Llave, University of Texas at Austin, Title to be announced.

Giovanni Gallavotti, University of Rome I, Title to be announced.

Sergio Klainerman, Princeton University, Title to be announced.

Rahul V. Pandharipande, California Institute of Technology, Title to be announced.

Claudio Procesi, University of Roma, Title to be announced.

Special Sessions

Combinatorial and Geometric Group Theory (Code: AMS SS A1), Olga G. Kharehamovich, McGill University, Alexei Myasnikov and Vladimir Shpilrain, City College, New York, and Daniel Wise, McGill University.

Portland, Oregon

Portland State University

June 20–22, 2002

Meeting #978

Meeting held in conjunction with MAA.

Western Section

Associate secretary: Bernard Russo

Announcement issue of Notices: April 2002

Program first available on AMS Website: May 9, 2002

Program issue of electronic Notices: August 2002

Issue of Abstracts: To be announced

Deadlines

For organizers: November 20, 2001

For consideration of contributed papers in Special Sessions: March 5, 2002

For abstracts: April 30, 2002

Pisa, Italy

June 12–16, 2002

Meeting #977

First Joint International Meeting between the AMS and the Unione Matematica Italiana.

Associate secretary: Lesley M. Sibner

Announcement issue of Notices: To be announced

Program first available on AMS Website: To be announced

Program issue of electronic Notices: To be announced

Boston, Massachusetts

Northeastern University

October 5–6, 2002

Meeting #979

Eastern Section

Associate secretary: Lesley M. Sibner
Madison, Wisconsin

University of Wisconsin-Madison

October 12–13, 2002

Meeting #980
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: August 2002
Program first available on AMS Website: August 29, 2002
Program issue of electronic Notices: December 2002
Issue of Abstracts: To be announced

Deadlines
For organizers: March 12, 2002
For consideration of contributed papers in Special Sessions: June 25, 2002
For abstracts: August 20, 2002

Invited Addresses

Lou P. van den Dries, University of Illinois, Urbana-Champaign, Title to be announced.
Diane Henderson, Pennsylvania State University, Title to be announced.
Christopher K. King, Northeastern University, Title to be announced.
Xiaobo Liu, University of Notre Dame, Title to be announced.

Special Sessions

Arithmetic Algebraic Geometry (Code: AMS SS A1), Ken Ono and Tonghai Yang, University of Wisconsin-Madison.
Arrangements of Hyperplanes (Code: AMS SS E1), Daniel C. Cohen, Louisiana State University, Peter Orlik, University of Wisconsin-Madison, and Anne Shepler, University of California Santa Cruz.

Biological Computation and Learning in Intelligent Systems (Code: AMS SS S1), Shun-ichi Amari, RIKEN, Amir Assadi, University of Wisconsin-Madison, and Tomaso Poggio, MIT.

Combinatorics and Special Functions (Code: AMS SS T1), Richard Askey and Paul Terwilliger, University of Wisconsin-Madison.

Dynamical Systems (Code: AMS SS P1), Sergey Bolotin and Paul Rabinowitz, University of Wisconsin-Madison.

Effectiveness Questions in Model Theory (Code: AMS SS J1), Charles McCoy, Reed Solomon, and Patrick Speissegger, University of Wisconsin-Madison.

Geometric Methods in Differential Equations (Code: AMS SS H1), Gloria Mari Beffa, University of Wisconsin-Madison, and Peter Olver, University of Minnesota.

Geophysical Waves and Turbulence (Code: AMS SS M1), Paul Milewski, Leslie Smith, and Fabian Waleffe, University of Wisconsin-Madison.

Group Cohomology and Homotopy Theory (Code: AMS SS G1), Alejandro Adem, University of Wisconsin-Madison, and Jesper Grodal, Institute for Advanced Study.

Harmonic Analysis (Code: AMS SS C1), Alex Ionescu and Andreas Seeger, University of Wisconsin-Madison.


Lie Algebras and Related Topics (Code: AMS SS N1), Georgia Benkart and Arun Ram, University of Wisconsin-Madison.

Multiresolution Analysis and Data Presentation (Code: AMS SS F1), Amos Ron, University of Wisconsin-Madison.

Partial Differential Equations and Geometry (Code: AMS SS D1), Sigurd Angenent and Mikhail Feldman, University of Wisconsin-Madison.

Probability (Code: AMS SS R1), David Griffeath, University of Wisconsin-Madison, and Timo Seppalainen, Iowa State University.

Ring Theory and Related Topics (Code: AMS SS L1), Don Passman, University of Wisconsin-Madison.

Several Complex Variables (Code: AMS SS B1), Pat Ahern, Xianghong Gong, Alex Nagel, and Jean-Pierre Rosay, University of Wisconsin-Madison.

Orlando, Florida

University of Central Florida

November 9–10, 2002

Meeting #982
Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of Notices: September 2002
Program first available on AMS Website: September 26, 2002
Meetings & Conferences

Program issue of electronic Notices: January 2003
Issue of Abstracts: Volume 23, Issue 4

Deadlines
For organizers: April 10, 2002
For consideration of contributed papers in Special Sessions: July 23, 2002
For abstracts: September 17, 2002

Baltimore, Maryland
Baltimore Convention Center

January 15–18, 2003
Joint Mathematics Meetings, including the 109th Annual Meeting of the AMS, 86th 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: Susan J. Friedlander
Announcement issue of Notices: To be announced
Program first available on AMS Website: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: April 15, 2002
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Baton Rouge, Louisiana
Louisiana State University

March 14–16, 2003
Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of Notices: To be announced
Program first available on AMS Website: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: August 14, 2002
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Bloomington, Indiana
Indiana University

April 4–6, 2003
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: To be announced
Program first available on AMS Website: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Seville, Spain

June 25–28, 2003
First Joint International Meeting between the AMS and the Real Sociedad Matematica Española (RSME)
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: To be announced
Program first available on AMS Website: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Phoenix, Arizona
Phoenix Civic Plaza

January 7–10, 2004
Associate secretary: Bernard Russo
Announcement issue of Notices: To be announced
Program first available on AMS Website: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: April 2, 2003
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced
ICM2002 TRAVEL GRANT APPLICATION
for U.S. mathematicians attending the
International Congress of Mathematicians, Beijing, China, 2002

U.S. mathematicians are those affiliated with a U.S. institution or organization. Funding by NSF for this program has been requested. An award to attend the Congress in Berlin under this program may NOT be supplemented by other NSF funds. Persons traveling under NSF grants must travel by U.S. flag carriers, if available.

All applicants fill in this section.

Last name ___________________________ first and/or middle names ___________________________

Full mailing address (usable from now until Spring, 2002):

Line one: ___________________________

Line two: ___________________________

city ___________________________ state ________ zip ________

telephone ___________________________ e-mail ___________________________

Are you an INVITED SPEAKER at the Congress?  □ Yes  □ No  If yes, send one copy of invitation letter.

Present rank or position: ___________________________

Current institution or organization: ___________________________

Highest earned degree: ___________________________ Institution: ___________________________ Year ________

Have you requested or been granted funds which might be used for travel to this Congress?  If so, give details:

_________________________________________________________

(Please notify the American Mathematical Society if this information changes)

Mathematics specialties (ICM2002 sections):

□ 1. Logic
□ 2. Algebra
□ 3. Number Theory
□ 4. Algebraic Geometry
□ 5. Differential Geometry
□ 6. Topology
□ 7. Lie Groups and Representation Theory
□ 8. Real and Complex Analysis
□ 9. Operator Algebras and Functional Analysis
□ 10. Probability and Statistics
□ 11. Partial Differential Equations
□ 12. Ordinary Differential Equations and Dynamical Systems
□ 13. Mathematical Physics
□ 14. Combinatorics
□ 15. Mathematical Aspects of Computer Science
□ 17. Applications of Mathematics in the Sciences
□ 18. Mathematical Education and Popularization of Mathematics
□ 19. History of Mathematics

Invited Speakers may skip to page 3. All others fill in this section.

Other positions held (professional, scientific, teaching, administrative): [For each give Institution or Organization, Position, and Dates]

1. ___________________________

2. ___________________________

3. ___________________________
List up to five significant publications, with title/journal/page/date references. These may include recent accepted papers (give journals).

1. 

2. 

3. 

4. 

5. 

Scholarships, fellowships, etc. Specify institution, dates held, and field of study:

List research support from all sources in the last five years, including any current support: specify sponsor, title or identification of award, and amount and duration (dates):

List research proposals which have been submitted and/or are pending at this time; specify sponsor:

Further comments in support of your application, or other relevant professional contributions not already listed:

This section should be filled out by early career mathematicians only.

Thesis title and advisor:

**Early career mathematicians only** (those within 6 years of their doctorate) are urged to have senior professional mathematicians (no more than 2) write on their behalf concerning their ability, and the value of attendance at this Congress to the research and professional interests of such early career mathematicians. Submission of these letters is strongly encouraged but not required. Letters should be sent to Professional Services, AMS, 201 Charles Street, Providence, RI 02904. LETTERS ONLY (not applications) may be sent via e-mail to icm02@ams.org. Name of applicant and "ICM02" should appear on the first line of the message. Deadline for receipt of letters is October 31, 2001.
All applicants should submit ONE copy only of this page.

You may optionally provide the following. Your application will not be adversely affected if you choose not to provide this information.

Gender:  
- Female  
- Male

Citizenship:  
- U.S. citizen or permanent resident  
- Other non-U.S. citizen

Ethnicity:  
- Hispanic or Latino  
- Not Hispanic or Latino

Race (select one or more):  
- American Indian or Alaska Native  
- Asian  
- Native Hawaiian or other Pacific Islander  
- White

☐ I do not wish to provide any of the above information on this page.
Meetings and Conferences of the AMS

Associate Secretaries of the AMS
Western Section: Bernard Russo, Department of Mathematics, University of California Irvine, CA 92697; e-mail: brusso@math.uci.edu; telephone: 949-824-5505.
Central Section: Susan J. Friedlander, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

The Meetings and Conferences section of the Notices gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Information in this issue may be dated. Up-to-date meeting and conference information at www.ams.org/meetings/.

### Meetings:

#### 2001
- **September 21-23**: Columbus, Ohio p. 771
- **October 5-6**: Chattanooga, Tennessee p. 772
- **October 13-14**: Williamstown, MA p. 773
- **November 10-11**: Irvine, California p. 775

#### 2002
- **January 6-9**: San Diego, California Annual Meeting p. 776
- **March 1-3**: Ann Arbor, Michigan p. 777
- **March 8-10**: Atlanta, Georgia p. 777
- **May 3-5**: Montréal, Québec, Canada p. 778
- **June 12-16**: Pisa, Italy p. 778
- **June 20-22**: Portland, Oregon p. 778
- **October 5-6**: Boston, Massachusetts p. 778
- **October 12-13**: Madison, Wisconsin p. 779
- **November 9-10**: Orlando, Florida p. 779

#### 2003
- **January 15-18**: Baltimore, Maryland Annual Meeting p. 780
- **March 14-16**: Baton Rouge, Louisiana p. 780

### Conferences:
(See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)
- June 10-August 9, 2001: Joint Summer Research Conferences in the Mathematical Sciences, Mount Holyoke College, South Hadley, MA. See pages 1331-1335, November 2000 issue, for details.

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Eastern Section: Lesley M. Sibner, Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: lsibner@duke.poly.edu; telephone: 718-260-3505.
Southeastern Section: John L. Bryant, Department of Mathematics, Florida State University, Tallahassee, FL 32306-4510; e-mail: bryant@math.fsu.edu; telephone: 850-644-5805.

### Important Information regarding AMS Meetings
Potential organizers, speakers, and hosts should refer to page 87 in the January 2001 issue of the Notices for general information regarding participation in AMS meetings and conferences.

### Abstracts
Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of \LaTeX is necessary to submit an electronic form, although those who use \LaTeX may submit abstracts with such coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html, or send mail to abs-submit@ams.org, typing help as the subject line; descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. There is a $20 processing fee for each paper abstract. There is no charge for electronic abstracts. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.
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introduction to the mathematics of money, Morton D. Davis invites us to take a fresh look at the numbers that underpin our financial decisions. He talks about strategies to use when we are required to bet against the odds (purchasing auto insurance) or choose to bet against the odds (wagering in a casino or at the track). He considers the ways in which we can streamline and simplify the choices available to us in mortgages and other loans. And he helps us understand the real probabilities when we accept a tip on that “one in a thousand” stock, even when the tip comes from a brilliantly successful day trader. *The Math of Money* is filled with what at first glance looks like anomaly and paradox, but it ends up showing us that a good deal of what we consider common sense actually makes no sense at all. With a wealth of entertaining and counterintuitive examples, it delights as well as informs, and will help readers treat their financial resources more rationally.

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ORTHOGONAL POLYNOMIALS FOR EXPONENTIAL WEIGHTS

The analysis of orthogonal polynomials associated with general weights has been a major theme in classical analysis this century. The use of potential theory since the early 1980’s has had a dramatic influence on the development of orthogonal polynomials associated with weights on the real line. For many applications of orthogonal polynomials, for example in approximation theory and numerical analysis, it is not asymptotics but certain bounds that are most important. In this monograph the authors define and discuss their classes of weights, state several of their results on Christoffel functions, Bernstein inequalities, restricted range inequalities, and record their bounds on the orthogonal polynomials as well as their asymptotic results. This book will be of interest to researchers in approximation theory and potential theory, as well as in some branches of engineering.

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DIOPHANTINE APPROXIMATION ON LINEAR ALGEBRAIC GROUPS

Transcendence Properties of the Exponential Function in Several Variables

This book deals with values of the usual exponential function e^x: a central open problem is the conjecture on algebraic independence of logarithms of algebraic numbers. It includes proofs of the main basic results (theorems of Hermite-Lindemann, Gelfond-Schneider, 6 exponential theorem), an introduction to height functions and Lehmer’s problem, several proofs of Baker’s theorem as well as explicit measures of linear independence of logarithms. An original feature is the systematic use, in proofs, of Laurent’s interpolation determinants.

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ANALYSIS FOR APPLIED MATHEMATICS

This textbook is designed for a course at the beginning graduate level, serving students of mathematics, engineering, physics, and other sciences. Its goal is to provide the theoretical tools, concepts, and viewpoints needed for modern applied mathematics. The book begins with a gentle introduction to normed linear spaces and Hilbert spaces, taking the reader as far as the Spectral Theorem for compact normal operators on a Hilbert space. It then discusses calculus in normed linear spaces, leading up to topics in the calculus of variations and optimization theory. Next, the book treats various practical methods for solving problems that arise in applied mathematics, such as differential equations, boundary value problems, and integral equations. To prepare the reader for work in the modern theory of partial differential equations, the subject of distributions is taken up next. A chapter on the Fourier transform and its applications follows, and includes a section on Sobolev spaces. The final chapter provides a concise account of measure theory and integration.