NOTICES

OF THE

AMERICAN MATHEMATICAL SOCIETY

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Calendar of AMS Meetings and Conferences

This calendar lists all meetings which have been approved prior to the date this issue of *Notices* was sent to the press. The summer and annual meetings are joint meetings of the Mathematical Association of America and the American Mathematical Society. The meeting dates which fall rather far in the future are subject to change; this is particularly true of meetings to which no numbers have been assigned. *Programs* of the meetings will appear in the issues indicated below. *First* and *supplementary* announcements of the meetings will have appeared in earlier issues.

Abstracts of papers presented at a meeting of the Society are published in the journal *Abstracts of papers presented to the American Mathematical Society* in the issue corresponding to that of the *Notices* which contains the program of the meeting, insofar as is possible. Abstracts should be submitted on special forms which are available in many departments of mathematics and from the headquarters office of the Society. Abstracts of papers to be presented at the meeting must be received at the headquarters of the Society in Providence, Rhode Island, on or before the deadline given below for the meeting. Note that the deadline for abstracts for consideration for presentation at special sessions is usually three weeks earlier than that specified below. For additional information, consult the meeting announcements and the list of organizers of special sessions.

Meetings

Meeting #		Date	Place	Abstract Deadline	Program Issue
860	*	October 20-21,1990	Amherst, Massachusetts	Expired	October
861	*	November 2-3, 1990	Denton, Texas	Expired	October
862	*	November 10-11,1990	Irvine, California	Expired	October
863	*	January 16-19, 1991	San Francisco, California	October 10	December
	†	(97th Annual Meeting)			
864	*	March 16-17, 1991	South Bend, Indiana	January 3	March
865	*	March 22-23,1991	Tampa, Florida	January 3	March
866	*	June 13-15, 1991	Portland, Oregon	March 26	May/June
867	*	August 8-11, 1991	Orono, Maine	May 29	July/August
		(94th Summer Meeting)			
868	*	October 12-13, 1991	Philadelphia, Pennsylvania	August 1	October
869	*	October 25-26, 1991	Fargo, North Dakota	August 1	October
870	*	November 9-11, 1991	Santa Barbara, California	September	November
871	*	January 8-11, 1992	Baltimore, Maryland	October 2	December
		(98th Annual Meeting)			
		March 27-28, 1992	Springfield, Missouri		
		March 13-14, 1992	Tuscaloosa, Alabama		
		June 29-July 1, 1992	Cambridge, England		
		(Joint Meeting with the London Mathematical Society)			
		January 13-16, 1993	San Antonio, Texas		
		(99th Annual Meeting)			
		August 15-19, 1993	Vancouver, British Columbia		
		(96th Summer Meeting)			
		(Joint Meeting with the Canadian Mathematical Society)			
		January 5-8, 1994	Cincinnati, Ohio		
		(100th Annual Meeting)			
		January 10-13, 1996	Orlando, Florida		
		(102nd Annual Meeting)			

* Please refer to page 923 for listing of Special Sessions.

† Preregistration/Housing deadline is November 16

Deadlines

	October Issue	November Issue	December Issue	January Issue
Classified Ads*	August 27, 1990	October 5, 1990	November 2, 1990	December 6, 1990
News Items	August 30, 1990	October 9, 1990	November 2, 1990	November 28, 1990
Meeting Announcements**	August 14, 1990	September 24, 1990	October 22, 1990	November 28, 1990

* Please contact AMS Advertising Department for an Advertising Rate Card for display advertising deadlines.

** For material to appear in the Mathematical Sciences Meetings and Conferences section.

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ARTICLES

FEATURE COLUMNS

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SUBSCRIPTION INFORMATION
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ADVERTISING
Notices publishes situations wanted and classified advertising, and display advertising for publishers and academic or scientific organizations.

The paper used in this journal is acid-free and falls within the guidelines established to ensure permanence and durability. ♾ Most of this publication was typeset using the TEX typesetting system.

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From the Executive Director ...

NATIONAL REPORTS

Much has been written about maintaining the vitality of mathematics research in this country and the need for reform in mathematics education. Of particular interest to our community are some recent reports to the nation undertaken at the National Academy of Sciences. Three of these reports are: "Everybody Counts: A Report to the Nation on the Future of Mathematics Education", issued by the Committee on the Mathematical Sciences in the Year 2000 (MS2000), which is jointly sponsored by the Mathematical Sciences Education Board (MSEB) and the Board on Mathematical Sciences (BMS) (the executive summary appeared in *Notices*, March 1989, pages 227-236); "Renewing U.S. Mathematics: A Plan for the 1990s" (David II Report), issued by BMS (the executive summary appeared in *Notices*, May/June 1990, pages 542-546, the body of the report appears in this issue of *Notices*, and Appendix B of the report is scheduled to appear in the October 1990 issue); and "A Challenge of Numbers: People in the Mathematical Sciences", issued by MS2000 (the executive summary appeared in *Notices*, May/June 1990, pages 547-554).

In addition, MSEB is planning a new report, which will be available before the end of 1990 and will introduce a curriculum philosophy of "strands" of mathematical concepts that run through the entire K-12 curriculum. MS2000 is also preparing a major "Report to the Nation", which reviews the state of affairs in collegiate mathematical sciences departments. And there are plans for yet more reports. These reports are very good for our community, since they identify many crucial issues and present recommendations for action. Some of these issues and recommendations will find broad acceptance in the community, while others may not; however, the thought and dialogue stimulated by these reports is important to the process of any reform and progress.

Now that we have all these reports, what's next? There are many efforts to disseminate these materials and to stimulate further dialogue. The Society is participating in these efforts by reprinting parts of the reports in *Notices*, reporting on national activities, and supporting panel discussions and other functions at Society meetings. Opportunities are available for the community to be well-informed about the reports, their issues, and their recommendations.

The committees responsible for the reports have done their work. Individual members of these committees may be active in taking recommendations to the community but no further results can be expected from the committees. Nor can we expect high-level government briefings to bring results. Results will not come from committees or from discussion alone. The community needs to mobilize and join in a national plan for action. Furthermore, successful action and results cannot be achieved if we view "Everybody Counts" as a report on K-12 education and, at the other extreme, David II as addressing only a small group actively engaged in research with strong potential to receive federal funding. All of these reports need the entire mathematical sciences community behind them.

How do we formulate a national plan for mobilization and action? The professional organizations that represent the various constituencies must get involved and lend their prestige and resources to the effort. I look forward to this call for action and the Society providing leadership in achieving the recommendations of these national reports.

William Jaco

Letters to the Editor

Euler Typeface

In their preface to *Concrete Mathematics*, Addison-Wellesley, 1989, the authors (R. Graham. D. Knuth, and O. Patashnik) state, "The typeface used for mathematics throughout this book is a new design [*AMS Euler*] ... commissioned by the American Mathematical Society ... the underlying philosophy is to capture the flavor of mathematics as it might be written by a mathematician with excellent handwriting." The typeface design achieves its objectives. The type is close to that of legible handwriting, which means of course, that it is more difficult to read than normal.

If we were to follow the philosophy inherent in the design and use of *AMS Euler* type, we would also provide mathematics books with crossouts, eraser grit, chalk dust, and coffee/tea stains. Certainly, this would also be in consonance with how "people create mathematics".

This is not to suggest that there is no place for *AMS Euler*. It could be used to represent a short excerpt from a mathematicians notebook. However, as the typeface for all mathematics in a textbook, it is a failure. It is difficult to read and intrudes into the reasoning process. It is a bit ironic that Leonard Euler, an innovator who moved mathematics forward, should have a typeface named after him which has moved us backwards.

R. Jordan Kreindler
Richard H. Warren
General Electric Company
(Received June 28, 1990)

Thank You

I would like to express my deep gratitude to all the mathematicians who took part in the battle to save my life. Professors I.C. Gohberg and B.I. Korenblum organized a collection of donations for surgery on my heart, and your journal published an announcement about it. Various mathematicians from different countries responded to the appeal and contributed money. However this money was sufficient to pay only for my trip and living expenses in the U.S.A. After that an essential role was played by Professor D.G. Ebin who spoke to Professor P. Cohn of University Hospital at Stony Brook and managed to arrange for heart surgery without cost. At the time of this letter, I am already recovered from a successful operation and am leaving for my home in the U.S.S.R.

I consider my story to be a demonstration of international solidarity which has always been typical of the world's mathematical community.

I thank you all once again.

Selim Krein
Voronzeth, U.S.S.R.
(Received July 23, 1990)

Some Thoughts on "Everybody Counts"

I would like to applaud Dr. Effros for his courage in speaking out against the potential pitfalls of the current reform movement [*Notices*, May/June 1990, pages 559-561]. Too many of us seem to have forgotten that mathematics is a discipline, not only of ideas and concepts, but also of skills, and the direction of the reform movement is dangerously close to neglecting the development of those skills. The curriculum reform, most of which is desperately needed, will only succeed if it is accompanied by a strict adherence to a minimum skills standard. Otherwise, we will be creating a generation of students who have a very good idea of what a derivative is, but who can't compute one to save their life. This is equivalent to our colleagues in the English Departments graduating a generation of students who can give the deepest interpretations of Shakespeare, but who can't speak or write in complete sentences. Would you want your children to get such an education? I hope not, which begs the question: Why are we so eager to do the same thing in our own discipline?

James F. Epperson
University of Alabama, Huntsville
(Received June 5, 1990)

Mathematics Outside of Mathematics Departments

The report "Mathematics Outside of Mathematics Departments" by S.A. Garfunkel and G.S. Young [*Notices*, April 1990, pages 408-411] is very informative. Their results did not surprise me. Their report points to a long-term policy problem facing Mathematics Departments: either re-

Policy on Letters to the Editor

Letters submitted for publication in *Notices* are reviewed by the Editorial Committee, whose task is to determine which ones are suitable for publication. The publication schedule normally requires from two to four months between receipt of the letter in Providence and publication of the earliest issue of *Notices* in which it could appear.

Publication decisions are ultimately made by majority vote of the Editorial Committee, with ample provision for prior discussion by committee members, by mail or at meetings. Because of this discussion period, some letters may require as much as seven months before a final decision is made. Letters which have been, or may be, published elsewhere will be considered, but the Managing Editor of *Notices* should be informed of this fact when the letter is submitted.

The committee reserves the right to edit letters.

Notices does not ordinarily publish complaints about reviews of books or articles, although rebuttals and correspondence concerning reviews in *Bulletin of the American Mathematical Society* will be considered for publication. All published letters must include the name of the author.

Letters should be typed and in legible form or they will be returned to the sender, possibly resulting in a delay of publication.

Letters should be mailed to the Editor of *Notices*, American Mathematical Society, P.O. Box 6248, Providence, RI 02940, and will be acknowledged on receipt.

main pure and forget the needs of natural and social scientists as well as engineers, or try to face the challenge. I urge the Mathematics Departments to face the challenge. The fact is that the disciplines like physics, chemistry, and the engineering disciplines have become more sophisticated (both experimentally and mathematically), hence have their curricula under severe time pressure. On the other hand, the technology-driven computer revolution has given scientists and engineers extremely sophisticated tools whose effective use often requires a solid mathematical culture. Hence, these disciplines teach many courses whose contents are substantially mathematical.

I have two suggestions: 1) Start a long term effort to raise the level of mathematics taught in high schools to future physicists, chemists, engineers. The goal is that every freshman in these disciplines is required, among others, to have had an elementary course in calculus. As a result, the level of the lower division physics and mathematics courses can be raised so that, entering the junior year, students would have a much more solid mathematical backgroud. (Before we start reinventing the wheel, let us first study what is done in France, Great Britain, Germany, Japan, and U.S.S.R.). One way of implementing this step up is for the top schools in Science and Engineering to announce that, say, starting from the year 2000, they will not consider applications from students who have not had calculus.

2) Mathematics departments must expand their market share. It is a fact that no one in the sciences and in engineering can afford the traditional one semester course on complex variables, or to spend 10 weeks on a detailed treatment of going from integers to real numbers. So what is needed is for mathematics departments to *identify groups of students with common needs* and, by designing courses with the help of outside faculty members, to offer well-focused, cost-effective courses. At the first-year graduate level course on analysis, I consider the Chapters 5 (Differential Calculus) and 6 (Inverse Mappings and Differential Equations) of S. Lang's *Real Analysis* (Addison-Wesley, 1983) to be a good example of a cost-effective package for theoretically minded engineers.

Charles A. Desoer
University of California, Berkeley
(Received May 22, 1990)

1990 Steele Prizes Awarded in Columbus

Three Leroy P. Steele Prizes were awarded at the Society's ninety-third Summer Meeting in Columbus, Ohio.

The Steele Prizes are made possible by a bequest to the Society by Mr. Steele, a graduate of Harvard College, Class of 1923, in memory of George David Birkhoff, William Fogg Osgood, and William Caspar Graustein.

Three Steele Prizes are awarded each Summer: one for expository mathematical writing, one for a research paper of fundamental and lasting importance, and one in recognition of cumulative influence extending over a career, including the education of doctoral students. The current award is $4,000 for each of these categories.

The recipients of the Steele Prizes for 1990 are R. D. Richtmyer for the expository award; Bertram Kostant for research work of fundamental importance; and Raoul Bott for the career award.

The Steele Prizes are awarded by the Council of the Society, acting through a selection committee whose members at the time of these selections were Luis A. Caffarelli, Alexander J. Chorin, Charles L. Fefferman, William Haboush, Jun-ichi Igusa, Arthur M. Jaffe, George Lusztig, Mark Mahowald, and Michael E. Taylor (Chairman).

The text that follows contains the Committee's citations for each award, the recipients' responses to the award, and a brief biographical sketch of each of the recipients.

Expository Writing

R. D. Richtmyer

Citation

For his book *Difference Methods for Initial Value Problems*, Interscience, first edition 1957, second edition (with K. Morton) 1967. Richtmyer's book has been the most influential book in the development of numerical methods for solving partial differential equations, and has been widely used and studied for more than 30 years since its first appearance, and is still widely used now; this is a remarkable record in a field that has changed radically over that period of time.

R. D. Richtmyer

The book (in both editions) has two parts: theory and applications. The theory part is a masterful exposition of stability and convergence theory for difference methods. The fundamental techniques have proved to be widely applicable. Most working numerical analysts have learned their stability theory from this book, and the clarity of the exposition is responsible in great part for the fact that all numerical analysts have a good, shared understanding of these important ideas. The second edition is also responsible for the wide understanding of the conditions under which the von Neumann condition is sufficient for stability and of stability theory for mixed initial-boundary value problems, theories developed between the two editions.

The part of the book devoted to applications presents a variety of numerical schemes for solving problems in fluid mechanics, neutron transport, elasticity, and related topics. It is an amazing fact that the ideas that are at the forefront of recent developments, for example Godunov's scheme, schemes based on Riemann solutions, and shock tracking, are discussed quite extensively in this book. This is in part due to the outstanding insight of the author who saw what was important and promising, clearly and at an early date; it is also a consequence of the fact that this widely used book has kept these ideas in front of the mathematical community and thus fostered later developments.

The book has been an indispensable part of the library of all numerical analysts and all applied mathematicians interested in computation for over 30 years and will remain so for a long time to come.

Response

In writing the book on difference methods, I was serving mainly as a reporter, reporting on an exciting new kind of mathematics that had come into existence through the work of many people, and it is those people who ought to be getting the credit and honor of this presentation.

Before the Second World War, difference methods had been used for ordinary differential equations. Astronomers had been doing it for years in celestial mechanics. In those problems, the instantaneous state of a physical system was represented by a small number of quantities, for example coordinates and momenta of bodies, and the equations of evolution of the system were ordinary differential equations, with time as the independent variable. Application to more complicated problems, where the instantaneous state of the system required functions (generally of several variables) for its description, could not be considered until computers became available, although important theoretical work had been done by Courant, Friedrichs, and Lewy in 1928.

Nowadays, we read in our newspapers that scientists have studied a problem such as that of global warming by computer simulation of the earth, with its atmosphere and oceans. It may seem difficult to imagine a time when the term "computer simulation" didn't exist, and the idea of it didn't exist. It was one of those ideas that hadn't even been thought of — that is, until someone thought of it. The first such simulations, to my knowledge, were the implosion calculations at Los Alamos in 1944 and 1945. It was important to predict the implosion quantitatively, in order to determine whether, and to what extent, nuclear criticality would be achieved. Just who first thought of doing it numerically by difference methods, I don't know. I would guess that many people at Los Alamos thought of it simultaneously, probably including Hans Bethe, John von Neumann, Klaus Fuchs, Rudolph Peierls, Bill Penny, and Stanley Frankel. Under the conditions of temperature and pressure in the implosion, the materials behave like fluids, so that one had to deal with the hyperbolic partial differential equations of fluid dynamics, together with shocks and other nonlinear effects. The ideas of Courant, Friedrichs, and Lewy were of course involved. The computation was done by a group of people using a large room full of old-fashioned punch-card machines, together with a staff of people operating hand computers. Each calculation took about a week.

Soon after the war, in 1947, it occurred to people at Los Alamos to use similar methods for the nuclear explosion, after criticality had been achieved. That is more complicated, because there was not only the fluid dynamics, but also heat transfer, which satisfies a nonlinear parabolic equation, and the integro-differential equations of the neutron multiplication, all these being coupled together in nonlinear ways. The planning and programming of that calculation took about a year and a half, after which the problem was put on IBM's SSEC computer at IBM World Headquarters in NYC. That was probably the physically largest computer ever built; it occupied several floors of the building, with 10,000 vacuum tubes (not miniature tubes, either), 40,000 relays, and other electronic and mechanical components. Each computation took about a month of round-the-clock operation. That provided the model for other simulations at LASL and elsewhere, in nuclear science, meteorology, and stellar evolution.

Both during and immediately after the war, the most important single person involved in all of that was von Neumann, who knew the work of Courant, Friedrichs, and Lewy and knew how to generalize it, and whose vast knowledge of both physics and mathematics provided the guiding principles that were constantly needed in order to make the work meaningful. Without von Neumann's guidance, those simulations could not have been done.

At about that time, in the early 1950s, other people became interested in difference methods, and a number of significant papers were written, too numerous to discuss in detail. Some of the most important contributions were made by Peter Lax of NYU, including what became known as the Lax Equivalence Principle, which deals with the basic problem of deciding whether the results of such a gigantic calculation really do represent the evolution of the physical system. The basic idea there was to think of the functions that describe the instantaneous state of the system as being a point in a function space, in fact a Banach space, so that powerful principles of functional analysis could be used.

The other person I feel I must mention explicitly is K. W. Morton of Great Britain, who joined me as coauthor for the second edition.

The book was indeed quite timely (but even for that I claim no credit — I just happened to be at the right place at the right time), and it was used in many countries for many years, and both editions were translated into Russian.

If we can agree that the credit belongs to the people I have mentioned and to many I have not mentioned, I am happy to accept the great honor of this award on behalf of all those people.

Biographical Sketch

R(obert) D(avis) Richtmyer was born in Ithaca, N.Y. on October 10, 1910 (i.e., 10/10/10), the son of a self-made man of great energy and motivation, F. K. Richtmyer, who made it from farm life in upper New York State to Professor of Physics and Dean of the Graduate School at Cornell University. Professor Richtmyer took his family to Europe on a sabbatical in the academic year 1927-28; there, R. D. Richtmyer, who had just completed high school, attended lectures and classes at Göttingen University in calculus, analytic geometry, topics in analysis, and basic physics, taught by J. Grandjot, B. L. van der Waerden, R. Courant, and R. W. Pohl, respectively. Back in Ithaca, he attended Cornell and received the degrees of A.B. in Physics (1931) and M.A. in Physics (1932). From 1932 to 1935, he was a graduate student at M.I.T., where he received the degree of Ph.D. in Physics in 1935. His thesis was an application of quantum mechanics to double-ionization x-ray lines. From 1935 to 1940 he taught at Stanford University as Instructor in Physics, where he became acquainted with F. Bloch, J. R. Oppenheimer, V. Weisskopf (summer visitor), W. W. Hansen, and N. E. Bradbury (later Director at Los Alamos). From 1940 to 1945, he was in Washington, DC, as civilian scientist, first with the Navy Department (magnetic and acoustic minesweeping) and then with OSRD (Manhatten Project; atomic energy). During those years he became acquainted with G. Gamow and E. Teller and was privileged to share their interest in astrophysics. At Los Alamos as Staff Member from 1945 to 1953, he became acquainted with J. von Neumann, H. A. Bethe, R. P. Feynman, O. Frisch, K. Fuchs, L. Nordheim, S. M. Ulam, J. C. Mark, and other well-known physicists and mathematicians. During that time, he conducted studies (some of them later published) on fluid dynamics, nuclear and thermonuclear reactions, the Monte Carlo method, computer programming, cosmic rays, continued-fraction expansion of algebraic numbers, and systematic sampling. From 1953 to 1964 he was at New York University, first as Associate Professor of Mathematics, then as Professor; there he had the opportunity to extend his mathematical knowledge by learning many things from P. D. Lax, L. Bers, and J. Schwartz. He worked in numerical analysis and computer methods and collected material for the book on difference methods. After 1964, he was at the University of Colorado at Boulder as Professor, for one year in computing science and then with a joint appointment in the Departments of Physics and Mathematics. He is now Professor Emeritus there. He has taught for shorter periods at the Universities of Chicago, New Mexico, Heidelberg, Munich, and Uppsala. He is the author of a two-volume work on advanced mathematical physics, based on courses taught at C.U. Boulder.

Fundamental Paper

Bertram Kostant

Citation

For his paper "On the Existence and Irreducibility of Certain Series of Representations", *Lie Groups and Their Representations* (I.M. Gelfand, editor) pages 231-329, J. Wiley, 1975. For many years one of the major problems of mathematics has been to describe all the irreducible unitary representations of a semisimple Lie group. A major force in the attack on this problem was Harish-Chandra, who produced an array of tools. Some of his results had an entirely algebraic formulation, but by and large the study of unitary representations remained almost exclusively analytic. Hilbert spaces were realized as L^2 spaces, and irreducibility results rested on Fourier transforms. The subject appeared too difficult for algebra.

Bertram Kostant

Kostant's work changed this situation completely. He used algebraic methods to solve completely a problem that had resisted analytic methods, and as a consequence found a simple and powerful construction for new families of unitary representations. The focus of the cited paper is the family $X(\lambda)$ of spherical principal series, parametrized by λ in a certain complex vector space $\mathfrak{A}^* = \mathfrak{A}_0^* + i\mathfrak{A}_0^*$; $X(\lambda)$ is unitary for $\lambda \in i\mathfrak{A}_0^*$. Extending work of Bruhat, Kostant determined precisely the set of λ for which $X(\lambda)$ is irreducible. Generally, there is an irreducible subquotient $Z(\lambda)$, and Kostant determined when $Z(\lambda)$ has an invariant Hermitian form. His approach used work with Rallis to reduce the problem to cases when G/K has rank one, which were treated by hand, in an elegant fashion.

Kostant's paper has had many interesting offshoots in analysis on symmetric spaces, influencing well known work of Helgason, Kashiwara, and others on the Poisson transform. Connections with intertwining operators have been pursued by Kostant, Wallach, and others. Deep mathematical connections with the Langlands program have surfaced in recent years.

Undoubtedly the greatest effect of Kostant's paper was that it established the algebraic approach to infinite-dimensional representation theory as a powerful and important one. It brought to bear ideas from algebraic geometry, invariant theory, and non-commutative algebra; ideas that seemed unrelated then, but seem indispensable now. What more can we ask of any mathematics?

Response

It was one of the great fortunes of my mathematical life to meet and become friendly with Hermann Weyl. It happened at the Institute for Advanced Study in the middle 50s, approximately a year or so before his death. The main topic of our conversations was representation theory and, in particular, the newly emerging infinite dimensional representation theory of non-compact semisimple Lie groups. With regard to the latter, it was my impression that Weyl was quite doubtful as to whether there would ever be much of a coherent theory. At least this was the case until one day I found out about Harish-Chandra's result on what today is referred to as K-finiteness—and told Weyl about this. I was amazed at how enthusiastically he greeted this fact. His attitude completely changed. He was now almost certain that there was indeed a beautiful theory to be developed.

Among other things Harish-Chandra's result opened the door to a serious algebraic attack on a subject which hitherto had been pretty much in the domain of analysis. It seemed to me, however, that in order to get real detailed information this way, one first needed to get a better understanding of the universal enveloping algebra U of a semisimple Lie algebra. Some time later I showed that U was nothing but "invariants" times "harmonics". Chevalley told us what the "invariants" looked like and I found out that the "harmonics" admit an elegant description involving the nilcone—which, to make matters even nicer, turned out to be a normal affine variety. At any rate with this kind of structure theory and Harish-Chandra's results, the stage was set for the paper which is being honored by this year's Steele Prize and I thank the Council of the American Mathematical Society for the honor.

Anyone who is working on some problem and making negligible progress is continually faced with the decision as to whether to stay with it—investing more time and energy—or to go on to other things. Making such a decision is as hard for me today as it was when the paper being honored here was written. The years have given me no great wisdom in dealing with this matter. Nonetheless, concerning this quit or go on business, there was an experience I had when working on the paper that I would like to tell about. At one point in order to make progress I had to know—and know very explicitly—all the roots of each member of a family of polynomials. Each day's calculation over a period of many weeks only yielded expressions of a typical such polynomial as some sort of sum—information which was totally useless for the purpose of finding the roots. Under such circumstances it surely would have been a prudent decision to abandon the whole approach. I didn't however and the reason was the fascination I had with the structure that gave rise to the polynomials. One of the cases had to do with the exceptional Lie group F_4. At some early stage in my education the last chapter in Chevalley's book *Theory of Spinors* had made an indelible impression on me. It had to do with the Principle of Triality and it was clearly the gateway to the magnificent world of the exceptional Lie groups. This gateway and more was also certainly encoded in the structure for the case of F_4. The corresponding polynomials thus took on a special personal importance for me. At any rate the point of this story is that simplistic persistence paid off. One morning the summands started collecting in strange ways and by the end of that sunny day in 1967 in a motel room in Reno, Nevada, the polynomials split into a product of linear terms and the roots were staring up at me.

I am not sure whether or not there is a lesson to be learned from the experience cited above except perhaps this. Before you invest a large amount of intellectual energy in trying to solve a problem in some area I think it is wise to be sure that (1) you care a great deal about the problem you are working on and (2) the area you picked has literally unbounded intellectual richness.

Biographical Sketch

Bertram Kostant was born on May 24, 1928 in Brooklyn, New York. He received his Ph.D. from the University of Chicago in 1954. His research interests are Lie theory, algebra, differential geometry, and geometric quantization.

At Chicago Professor Kostant won the Frank Lewis award and was University and AEC fellow. He was an NSF fellow and member of the Institute for Advanced Study from 1953 to 1955. For the year 1955-1956, he was a Higgins lecturer at Princeton University and from 1956 to 1962 he was on the faculty at the University of California where he progressed from assistant professor to professor of mathematics. Since 1962 he has held the position of professor of mathematics at the Massachusetts Institute of Technology. During this time he was a member of the Miller Institute of Basic Research (1958-1959); a Guggenheim fellow, a lecturer at Oxford University, and a professor at the University of Paris (1959-1960). He was also a professor at the Tata Institute in 1969 and the University of Paris in 1982. He has been a Sackler Institute fellow since 1982.

Professor Kostant has been a member of the AMS since 1952. He is an associate editor of *Advances in Mathematics, Revista Mathematica Iberoamerica* and was an editor of I. M. Gelfand's collected works and the *Annals of Global Analysis and Geometry*. He is a member of the Standing Committee of the International Colloquium on Group Theoretical Methods in Physics and is a member of its Advisory Committee for the next colloquium.

Professor Kostant gave an Invited Address at the International Congress of Mathematicians in Nice in 1970 and an Invited Address at the AMS Annual Meeting in Cincinnati in 1962. He delivered the AMS Colloquium Lectures in Albany in 1983.

Professor Kostant received a medal from the College de France in 1983 and was given an honorary degree from the University of Cordova in 1989. He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences.

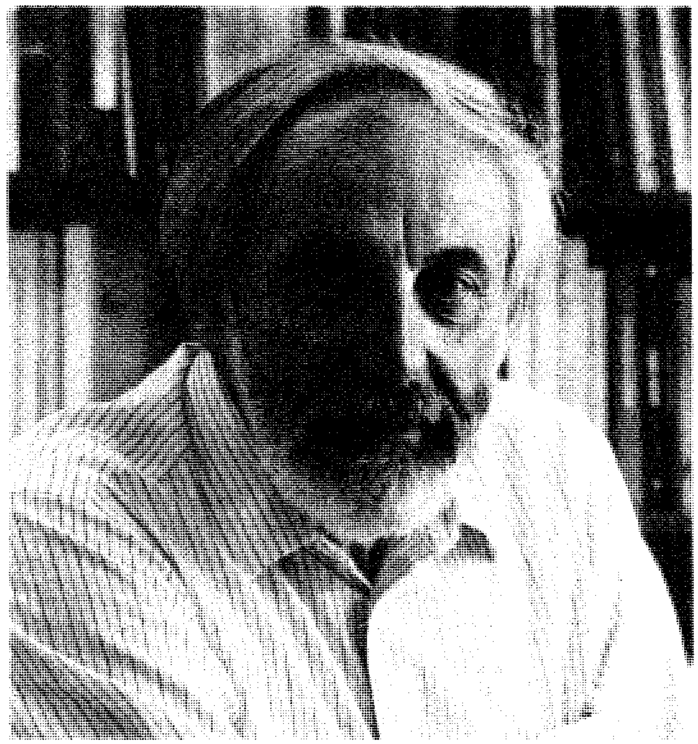
Career Award

Raoul Bott

Citation

Raoul Bott has been instrumental in changing the face of geometry and topology, with his incisive contributions to characteristic classes, K-theory, index theory, and many other tools of modern mathematics. His early spectacular success was in the application of Morse theory to the study of the homotopy of Lie groups, giving the celebrated Bott periodicity theorem. This central result has had several further incarnations, first as a cornerstone of topological K-theory, in work of Atiyah and Bott, and more recently in operator K-theory and noncommutative differential geometry.

Periodicity bears crucially on the study of the index of elliptic operators, a theory molded and made a central part of mathematics primarily by collaborations involving Atiyah, Singer, and Bott. This result is, amongst other things, both a far reaching extension of the Riemann-Roch theorem and a tool for exposing, via the Dirac operator, mysteries of the A-genus of spin manifolds. This has provided fresh insights over the decades; a notable example is its role in calculating the dimension of moduli spaces of Yang-Mills fields. It has also stimulated further development, such as Connes' work on index theory for foliations, itself a field in which Bott had done basic work, such as his introduction of secondary classes for foliations.



Raoul Bott

There are many other subjects graced by Bott's thoughts, such as his lovely extension of the Borel-Weil theorem, complementing the realization of irreducible representations of a compact semisimple Lie group on spaces of holomorphic sections of natural line bundles with a result on vanishing of higher $\bar{\partial}$-cohomology. This leads to valuable insights, such as connections between character formulas and the Atiyah-Bott-Lefschetz fixed point formula. The Atiyah-Bott-Gårding work on lacunas is an inspiring piece of work involving applications of algebraic geometry to the fine structure of solutions to hyperbolic partial differential equations.

Also to be remembered is his work on meromorphic sections of vector bundles, giving rise to Bott-Chern forms. These developments will continue to influence generations of mathematicians, inspiring them by the breadth and depth of a truly magnificent career.

Response

Thank you for this great honor. The fact that it is most probably not deserved makes it only the more enjoyable! Thank you also for the very generous citation. When in the early days of my academic life I would tell my step-father that I had given a Colloquium at some prestigious place, he would lean forward intensely in his chair and ask: "Now tell me precisely how they introduced you". And then I could always see the restrained disappointment in his face when I would counter with: "Well, they said that now Raoul Bott would speak on such and such". For, you see, he was reared in the Austro-Hungarian empire where they were used to rich and pungent rhetoric on such occasions. Now finally I could have shown him a citation with some teeth in it!

This occasion comes some forty years after I gave my first "three minute talk" to the Society, right here in Columbus. Yes, they had three minute talks in those days and actually I remember it more vividly than any of the hour talks I have delivered to the Society since. My dear friend and at that time research director Dick Duffin rehearsed me for the talk. After my first presentation he said: "Very good Raoul, but cut it in half". When I had done so I tried again. "Excellent", he said, "but cut it in half". And I must say this principle of cutting one's lectures in half twice has stood me well ever since. Would that all my professional brethern had learned it also.

Of course I learned other things from Richard Duffin as well. First of all, I liked and have ever tried to emulate his way of being a sort of mathematical Samurai. From the moment I walked into his office at Carnegie Tech. and explained to him the network problem I had brought with me from my engineering days at McGill, we became collaborators. And many months later we resolved the question—this is now called the Bott-Duffin theorem in engineering circles—in a manner which addicted me to joint work for life. After a long and hard session at the blackboard, we parted to go home exhausted and again defeated. But walking along the busy road it suddenly became clear to me that the answer had been staring us in the face all afternoon! I rushed home and called Dick. The phone was busy—he, of course, had made the same observation and was calling me!

This then was the first of many joyous collaborations that I now look back upon: with Hans Samelson—the geometry of Lie Groups; with Chern—equidistribution theory; with Michael Atiyah—our fixed point theorem in Woods Hole, and the many ramifications of the index question and K-theory. There are also those exciting ten days when we teamed up with Lars Gårding, dealing with lacunas in partial differential equations—when we were essentially locked up in Gårding's institute. With Graeme Segal-Gelfand Fuchs cohomology; with Andre Haefliger the secondary characteristic classes of foliations, and with Paul Baum the residue formulas for holomorphic vector fields. In a different vein there is the work with Loring Tu on our book, and in more recent times, now already under the influence of ideas from Physics, the Yang-Mills theory on Riemann Surfaces—again with Michael Atiyah, and most recently, with Cliff Taubes the rigidity questions in elliptic cohomology. These were all wonderful rejuvenating experiences during which our subject seemed all the more alive because it was shared so intimately, and the collaboration let the mathematics shine through the formidable ego's that, after all, beat in all of us. In accepting this award my first word of thanks is then to you, my long-suffering collaborators.

But there are also so many teacher-friends and near-collaborators and students that deserve my gratitude that I don't know where to begin or end.

I doubt that I would have had the courage to switch from Engineering to Mathematics but for the constant support of Lloyd Williams at McGill, or the inspired bending of all the rules at Carnegie by J.L. Synge to make such a switch viable. Thereafter I was fortunate enough to be brought to the Institute at Princeton by Hermann Weyl and then received personal instruction by a truly stellar cast: Ernst Specker, Kurt Reidemeister, Norman Steenrod in topology; Armand Borel, Fritz Hirzebruch, Iz Singer and Arnold Shapiro in characteristic classes. J.P. Serre tried to teach me sheaf theory and I attended the famous Kodaira Spencer seminars. Marston Morse was my first mentor in Morse theory, and Reneé Thom and Steve Smale—my first Student!—later added finishing touches.

I have now been at Harvard over thirty years and there is not a single colleague or student who has not added to my education, or uncovered some hidden mystery of our subject. To all of you then I address my second word of thanks.

But let my final *Thank You* be to this Country which has accepted so many of us from so many shores with such greatness of spirit and generosity. Accepting us—accent and all—to do the best we can in our craft as we saw fit. Having just returned from a brief visit to my newly liberated homelands, the dimensions of this gift has only now came truly into perspective.

Biographical Sketch

Raoul H. Bott was born on September 24, 1923 in Budapest, Hungary and received his early education in Europe. He received his Bachelor's degree in Engineering in 1945 and his Master's in Engineering in 1946, both from McGill University. He then switched to mathematics and received his Sc.D. from the Carnegie Institute of Technology in 1949. He spent the next two years at the Institute for Advanced Study. From 1951-1959, he was at the University of Michigan, with a leave of absence to return to the Institute in 1955-1956. In 1959, he moved to Harvard University where he is currently the William Caspar Graustein professor of mathematics. During his years at Harvard, he has held numerous visiting positions; the longer-term of these include Oxford University, Tata Institute, University of California at

Berkeley, the Institute for Advanced Study, the Institut des Hautes Etudes Scientifiques, and the University of Bonn.

Professor Bott has served as editor of *Topology* (1965-1985) and on the Board of Editors of the *American Journal of Mathematics* (1969-1971). He has been a member of the Society since 1950 and has served the Society in a number of ways. He was elected a Member-at-large of the Council (1961-1963 and 1968-1970); served on the Executive Committee of the Council (1961-1962 and 1971); and was elected Vice-President in 1975. In addition, he has served on numerous AMS committees.

Professor Bott has presented Invited Addresses at several AMS meetings; the Summer Meeting in Ann Arbor (August, 1955), the Sectional Meeting in Philadelphia (October, 1966), the Summer Meeting in Providence (August, 1978), and the Centennial Celebration in Providence (August, 1988). He spoke at the 1958 International Congress of Mathematicians in Edinburgh and presented a Plenary Address at the 1970 International Congress of Mathematicians in Nice. He was the AMS Colloquium Lecturer at the Summer Meeting in Eugene (August, 1976).

Professor Bott was a Sloan Fellow in 1956-1960 and received a Guggenheim Fellowship in 1976. He received an Oswald Veblen Prize in 1964. In 1964, he was elected to the National Academy of Sciences and, in 1987, was awarded a National Medal of Science. He is an honorary member of the London Mathematical Society and an honorary fellow of St. Catherine's College, Oxford. He has received honorary degrees from Notre Dame University (1980), McGill University (1988), and Carnegie Mellon University (1989).

NOMINATIONS FOR THE 1991 FULKERSON PRIZE

This is call for nominations for the D. Ray Fulkerson Prize in discrete mathematics that will be awarded at the XIVth International Symposium on Mathematical Programming to be held in Amsterdam, The Netherlands, August 5 - 9 1991.

The specifications for the Fulkerson Prize read:

"Papers to be eligible for the Fulkerson Prize should have been published in a recognized journal during the six calendar years preceding the year of the Congress. This extended period is in recognition of the fact that the value of fundamental work cannot always be immediately assessed. The prizes will be given for single papers, not series of papers or books, and in the event of joint authorship the prize will be divided.

"The term 'discrete mathematics' is intended to include graph theory, networks, mathematical programming, applied combinatorics, and related subjects. While research work in these areas is usually not far removed from practical applications, the judging of papers will be based on their mathematical quality and significance."

The nominations for the award will be presented by the Fulkerson Prize Committee (Martin Grötschel, Chairman, Louis Billera, and Paul D. Seymour) to the Mathematical Programming Society and the American Mathematical Society.

*Please send your nominations by **January 15, 1991** to:*

Professor Dr. Martin Grötschel
Institute of Mathematics, University of Augsburg, Universitätsstr. 8, 8900 Augsburg, West Germany

1990 Norbert Wiener Prize in Applied Mathematics Awarded in Columbus

The Norbert Wiener Prize in Applied Mathematics was awarded at the Joint Mathematics Meetings in Columbus, Ohio. The 1990 Wiener Prize was awarded jointly to MICHAEL AIZENMAN, New York University - Courant Institute of Mathematical Sciences, and to JERROLD E. MARSDEN, University of California at Berkeley.

The Prize was established in 1967 in honor of Professor Norbert Wiener and was endowed by a fund from the Department of Mathematics of the Massachusetts Institute of Technology. The Prize is normally awarded every five years, beginning in 1970, and is awarded jointly by the American Mathematical Society (AMS) and the Society for Industrial and Applied Mathematics (SIAM). The current award is $4,000.

Previous recipients of Wiener Prizes are Richard E. Bellman (1970), Peter D. Lax (1975), Tosio Kato (1980), Gerald B. Whitham (1980), and Clifford S. Gardner (1985).

The Prize is awarded by action of the Councils of the AMS and SIAM on the recommendation of the joint AMS-SIAM Committee to select the Winner of the Wiener Prize for 1990. The members of this Committee are I. M. Singer, Elliott H. Lieb, and Stephen Smale.

The text that follows contains the Committee's citations for each award, the recipients' responses to the award, and a brief biographical sketch of each of the recipients.

Michael Aizenman

Citation

To Michael Aizenman for his outstanding contribution of original and non-perturbative mathematical methods in statistical mechanics by means of which he was able to solve several long open important problems concerning critical phenomena, phase transitions, and quantum field theory.

Response

I am delighted to receive the Norbert Wiener Prize awarded by the American Mathematical Society and the Society for Industrial and Applied Mathematics. The citation offers a generous portrayal of my work, but I also take the award to be an implicit recognition of the depth of an area of research, which was acquired through the contributions of a larger collection of individuals. One of my earliest debts is to Gideon Cain, a friend and a fellow student, for discussions in which our scientific orientations were shaped and some early insights were developed. Since Gidi did not live to fulfill his potential, I would like to honor his memory at this opportunity.

Michael Aizenman

As a research area, mathematical physics is rewarding in a number of ways. For a mathematician the requirement of relevance of the work to theories of physics is an added pressure, but it is also a guide to fertile grounds. Although much of the progress in physics has occurred without the immediate presence of mathematical rigor, its structure becomes very brittle in the absence of firm mathematical support for its concepts, claims, and conjectures—for at least several not uncharacteristic cases. That task often requires new mathematical notions and leads to ideas of novel mathematical content. Thus mathematical physics enriches both fields. Working in an interdisciplinary area makes one strongly aware that a subject may be perceived and analyzed from a variety of perspectives. I find this observation to be both profoundly intriguing and very useful at the level of problem solving. Related to it, is the wide diversity of methods which have been applied and developed in the study of topics arising, for example, in mathematical statistical mechanics. In works extending beyond my own contributions, insights were derived from a range of fields including probability, harmonic analysis, partial differential equations (and inequalities), complex analysis, topology, and some elementary number theory. At least some of these fields have in return benefited from this contact. While the nominal goal of mathematical physics is to address issues of physics, we have seen—and one should expect to see more—contributions flowing truly in both directions.

Biographical Sketch

Michael Aizenman, born on August 28, 1945, grew up in Israel, though his birthplace is N. Tagil U.S.S.R. and his first few years were spent in Poland. His undergraduate education was at the Hebrew University in Jerusalem, and his Ph.D. is from Yeshiva University (1975), where his thesis advisor was Joel Lebowitz.

Professor Aizenman had postdoctoral positions at the Courant Institute of Mathematical Sciences (Visiting Member 1974-75) and at Princeton University (1975-1977). During 1977 to 1982 he was an assistant professor at Princeton University in the Physics Department. He then moved to Rutgers University as an associate professor of mathematics and physics and was promoted to professor in 1984. He was also a member of the Institute for Advanced Study in 1984-85, and has repeatedly been a visitor at the Institut des Hautes Etudes Scientifiques. In 1987 he returned to Courant Institute as a professor of mathematics, with a joint appointment in the NYU physics department. In September 1990 he will assume a position of professor of physics and mathematics at Princeton University.

Michael Aizenman was a Sloan Fellow from 1981 to 1984, and a Guggenheim Fellow in 1984-85. He shared the Guido Stampacchia Prize awarded by the Scuola Normale Superiore di Pisa in 1982, was awarded the Rutgers' Board of Trustees award for excellence in research in 1987, and was invited to give the Britton Lectures at McMaster University in 1989. He presented an Invited Address at the International Congress of Mathematicians in Warsaw (1983) and made a number of presentations at AMS meetings, including an AMS Invited Address in Denver in 1984.

Professor Aizenman is a section editor for *Communications in Mathematical Physics.* He was on the editorial boards of *Journal of Mathematical Physics* and *Communications in Pure and Applied Mathematics,* and he is currently on the editorial boards of *Journal of Statistical Physics, Annals of Probability,* and *Reports in Mathematical Physics.*

Michael Aizenman has broad interests in areas related to mathematical physics. The main focus in his publications has been on mathematical analysis of issues arising in statistical mechanics and quantum field theory.

Jerrold E. Marsden

Citation

To Jerrold E. Marsden for his outstanding contributions to the study of differential equations in mechanics: he proved the existence of chaos in specific classical differential equations; his work on the momentum map, from abstract foundations to detailed applications, has had great impact.

Jerrold E. Marsden

Response

I am delighted to be a recipient of the 1990 Norbert Wiener Prize. Norbert Wiener was a model mathematician in many ways, but a trait I find especially admirable is that he was not classifiable as a pure or an applied mathematician. He had breadth and depth that worked together in a mutually supportive way. I will return to the pure-applied question at the end.

Before going on, I want to acknowledge that, like others who deal with "applied" mathematics, I often do joint work. My collaborators, students, and colleagues, many, but not all, of whom are mentioned below, have my deepest thanks for their help and support.

My main area of research is mechanics. That is a large field—it is like one saying their research area is analysis. To be more specific, I have been interested in *geometric mechanics* and the role of *symmetry.* This interest was already evident in my 1967-68 thesis, written under the direction of Arthur Wightman at Princeton, with much inspiration from Ralph Abraham who was at Princeton at the time. One has to admit that, in graduate school, those of us who were lucky enough to mingle with the masters had a tremendous advantage. Those days were inspiring with Bargmann, Wigner, Wheeler, Kruskal, Wightman, and Abraham there. Building on my undergraduate professors at Toronto, especially Ray Vanstone and Hanno Rund, I had the geometric mechanics treasure chest in front of me. The thesis itself was in fact not very eventful—the most interesting thing was that I independently discovered some of the basic properties of momentum maps, but not as elegantly as the masters Kostant and Souriau, and I developed some things about Hamiltonian semigroups, including quantum mechanics. Shortly after this, Abraham or Wightman (I cannot remember which) suggested I read Arnol'd's 1966 paper on fluid mechanics that had just come out and, in light of my thesis, see what I could say about it. This was probably the most important suggestion in my career. At this time of course Arnol'd was not able to travel, but his writings did travel. I got to meet him only in 1989 at the Mathematical Sciences Research Institute in Berkeley.

I moved to Berkeley in the fall of 1968 and there teamed up with David Ebin to write what I still think is one of the nicest papers of my career (it appeared in the *Annals* in 1970). We built directly on Arnol'd's work—not only did we make his setting analytically precise with the right function spaces, etc., but we showed that the Euler equations when written in material form (as geodesic equations on the group of volume preserving diffeomorphisms) are a smooth vector field, so in fact are not pde's at all, but are ode's!! This result had a number of nice consequences and more are being found to this day. These first years at Berkeley were very exciting times. Being able to talk with the likes of Smale and Kato, and attend their lectures, was quite an experience. How I managed to get so much done with a newborn son (Chris) in the house now baffles me.

I must confess that I never seriously thought about quitting "classical" mechanics, because it has been so full of life. I could not understand my physics friends who said that classical mechanics was dead and I should stop wasting my time—I never remembered Wigner or Wheeler saying such things. (Today I like to rebut this by pointing out that quantum mechanics is a *special case* of classical mechanics—commutators *really are* Poisson brackets and unitary transformations *really are* classical canonical transformations, *etc.*)

In 1972 more exciting things started to happen. I began a collaboration with Arthur Fischer on relativistic field theories, which started as an exercise to see what the Hamiltonian structure was for general relativity, but ended in a very beautiful work some 15 years later with Judy Arms, Vince Moncrief, Jim Isenberg, Mark Gotay, Richard Montgomery, Jedrez Sniatycki and Phil Yasskin on the structure of the space of solutions of relativistic field theories. We were able to show that even though the equations of general relativity (and other field theories as well) were algebraically complex, the singularities in the space of solutions were *only quadratic.* In this project (the *GIMMSY* project—an acronym for the authors' names), we attempted to break a record for the longest non-dead project in preparation—it had its 10th anniversary recently.

The second exciting thing in 1972 occurred while I was thinking about the new edition of my book with Abraham on *Foundations of Mechanics*, first published in 1967. I was trying to understand Smale's work on simple mechanical systems with symmetry (*Inventiones*, 1970) in the general context of symplectic manifolds, and what it had to do with all the examples I had been studying. At this point, I hooked up with Alan Weinstein and we wrote our paper on reduction theory. Later, we applied this to fluid and plasma dynamics. Since then, the literature on reduction theory has grown so fast that it is hard to keep up with it; a situation both gratifying and frustrating. This work had an excellent impetus with work we both did with Darryl Holm at the Center for Nonlinear Studies in Los Alamos. We pushed the Arnol'd stability technique for many fluid and plasma stability problems. It was fun to recognize former Princetonians like Martin Kruskal who was one of the early major players in this subject. Henry Abarbanel and Tudor Raţiu were also key players in this whole enterprise.

Starting around 1975 I turned attention to questions in nonlinear elasticity. I learned much on the subject from my friends Tom Hughes and Juan Simo in Applied Mechanics at Stanford, but with Berkeley training. My book with Tom on *The Mathematical Foundations of Elasticity* was the result. It has been very gratifying that geometric mechanics has proven itself useful in the development of specific numerical codes; in fact some of Simo's codes for shells are amongst the best anywhere. We have continued the work to the present and in fact in the last couple of years have written a series of recent papers with Tom Posbergh (Minnesota) and Debra Lewis (Institute for Mathematics and its Applications and Santa Cruz) on an improved version of the Arnol'd work on stability of relative equilibria, separation of rotational and internal modes that I think are quite important. We began by trying to fix a problem with the nonexistence of Casimir functions in the original Arnol'd method that I mentioned in the last paragraph. We were rewarded in a very lucky way and stumbled into some real miracles. I still remember sitting in the student lunch room at Cornell in the fall of 1988 with Juan Simo (a Mathematical Sciences Institute visitor at the time) and seeing several hundred terms in a big calculation all cancel—we had bumbled across a fundamental normal form in mechanics. I was so happy!! More recently I have also turned some attention to control of mechanical systems; here work with P. S. Krishnaprasad, Tony Bloch, and Richard Montgomery has been especially stimulating.

I have worked off and on in bifurcation and dynamics with excellent people like Marge McCracken, David Chillingworth, Steve Wan and Jürgen Scheurle. In particular, around 1980 Phil Holmes and I started some work on chaos in mechanical systems—here I was fortunate to link up with someone of extraordinary quality. We were able to merge his work on the Poincaré-Melnikov method for detecting Smale horseshoes, with reduction theory and with work I had done on pde's. Simultaneously with work of Kopell and Howard on reaction diffusion equations, we were able to demonstrate the existence of homoclinic chaos in a realistic pde. My work with Phil led to pleasant times at Cornell University.

During the last few years, I have become even more convinced that an extremely important role for mathematics is its outreach to other disciplines and in education. My own work in nonlinear elasticity, fluids, plasmas, and dynamics and bifurcation theory has often been driven by such goals. When in a cynical mood, I sometimes point out the *unpleasant* but *true* statement that too large a majority of pure mathematicians think that applied mathematics consists of plugging special numbers into or taking special cases of preexisting theorems, while a majority of nonmathematical scientists think that pure mathematics consists of useless philosophical ramblings. Both are of course wrong. Is it conceivable that the great heritage of Poincaré, Hilbert, Gauss, Lagrange, Birkhoff, Wiener, etc. is being slighted? I have worked hard to help heal these rifts and will continue to do so. It is to the benefit of science that the pure and applied aspects work in harmony. (Sometimes divorce is necessary, but it is not what nature intended.)

I hope you agree that these comments partially reflect Wiener's work and ideals—I encourage the community to sustain and strengthen them.

Biographical Sketch

Jerrold E. Marsden was born August 17, 1942 in British Columbia. He received his Ph.D. in 1968 from Princeton University. After holding a position as instructor at Princeton (1967-1968), he became a lecturer at the University of California at Berkeley, where he advanced to the rank of professor in 1976. While at Berkeley, he was appointed Miller Research Professor during 1981-1982 and served as director of the Research Group in Nonlinear Systems and Dynamics from 1984 to 1986.

Professor Marsden has held visiting positions at numerous institutions, including the Institute for Advanced Study in Princeton (1971), Institut des Hautes Etudes Scientifiques (1972), University of Toronto (1970-1971, 1975), University of Warwick (1980), Center for Nonlinear Studies in Los Alamos (1983), and University of Hamburg (1989). In addition, he has held the position of Professeur d'Echange at the University of Paris VI (1975, 1979), Carnegie Fellow at Heriot-Watt University (1977), and Killam Visiting Scholar at the University of Calgary (1979). He has also been associated with Cornell University, in the Mathematics Department and the Mathematical Sciences Institute (1988-1989).

Professor Marsden has received a number of awards and honors, including First Prize (with Arthur Fischer) in the Relativity Essay Contest sponsored by the Gravity Research Foundation (1973) and the Humboldt Prize (1990-1991). In 1989-1990, he presented the Aisenstadt Lectures in Montreal, and has been named a Fairchild Fellow at the California Institute of Technology for 1991-1992.

Professor Marsden serves as editor for a number of journals and is a prolific author of papers, research monographs, and textbooks. Sixteen students have received doctorates under his direction. A member of the Society since 1971, he has served on the Committee on Joint Summer Research Conferences (1983-1986) and the Committee on Science Policy (1989-1992).

During his career, Professor Marsden's research interests have ranged over a number of mathematical areas, including Hamiltonian systems and fluid mechanics, general relativity, geometric mechanics, nonlinear elasticity, and bifurcation theory and dynamical systems. His current research interests center on the application of mathematical techniques to mechanical systems of importance in physics and engineering.

American Mathematical Society

Associate Executive Director

Position Open

The American Mathematical Society is seeking applications and nominations of candidates for an open position of Associate Executive Director of the Society.

Much has been written recently about concerns of maintaining the vitality of mathematics research in this country and renewing the mathematical sciences research enterprise. These concerns are often coupled with those indicating a need for reform in mathematics education. The Society is committed to lending its prestige and resources to assist in addressing these concerns. To this end, the Society is developing a plan of programmatic initiatives in the mathematical sciences.

The person filling this position will work in the Society's Providence office with the Executive Director and be responsible for the development and administration of the programmatic activities of the Society. The Associate Executive Director will assist in all phases of these initiatives and, as such, will work with the AMS Board of Trustees, Council, committees, and staff; as well as governmental agencies, corporations and foundations, professional societies, and mathematicians throughout the world.

The Society is seeking a candidate who is sensitive to the concerns of the mathematical research community and understands the need for involvement of research mathematicians in addressing the broad issues of the profession. Such a candidate should

- have earned a Ph.D. in one of the mathematical sciences
- have a good command of the English language and be capable of writing well and easily
- have an interest in administration and an ability to work harmoniously with mathematicians and nonmathematicians alike
- be familiar with national issues and activities that impact on the mathematics profession.

The initial appointment will be for two years and can be continued thereafter on an indefinitely renewable term or continuing basis.

Applications and nominations should be sent to:

Dr. William H. Jaco
Executive Director
American Mathematical Society
P.O. Box 6248
Providence, R.I. 02940

Completed applications and appropriate letters of reference received by 15 November 1990 will be assured of full consideration. It is preferable (but not essential) that duties begin no later than 1 January 1991.

The Society is an equal opportunity employer and has a generous fringe benefit program including TIAA/CREF. Salary for the position will be commensurate with the background of the appointee.

Renewing U.S. Mathematics

A Plan for the 1990s

The following is the main body of the so-called David II report. The Executive Summary was reprinted in the May/June 1990 issue of *Notices* on pages 542-546. Appendix A of the report is the Executive Summary of the 1984 Report, "Renewing U.S. Mathematics: Critical Resource for the Future". The main body of the 1984 Report was reprinted in the August 1984 issue of *Notices*, pages 435-466; therefore, Appendix A of this report will not be reprinted in *Notices*. Appendix B, "Recent Research Accomplishments and Related Opportunities," will be reprinted in the October 1990 issue of *Notices*.

This report was prepared by the Committee on the Mathematical Sciences: Status and Future Directions, under the Board on Mathematical Sciences, Commission on Physical Sciences, Mathematics, and Applications, of the National Research Council.

It is reprinted with permission of the Board on Mathematical Sciences, National Research Council, 2102 Constitution Avenue, Washington, D.C. 20418 and was published by the National Academy Press, Washington, D.C., 1990.

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1. Background and Introduction

The Situation in 1984

In the early 1980s the Office of Mathematical Sciences of the National Research Council (NRC), chaired by William Browder, presented to the Assembly of Mathematical and Physical Sciences[1] of the NRC startling evidence suggesting the deterioration of federal support for mathematical sciences[2] research in the United States. Because of the critical dependence of science and technology on continued generation of new mathematical methods and concepts, the Ad Hoc Committee on Resources for the Mathematical Sciences was established by the NRC to review the health and support of the field. This panel of scientists, engineers, and mathematicians was asked in particular to determine whether federal and/or university support had in fact deteriorated and, if so, how this had come about and what should be done about it to provide for the future health of the discipline.

After three years of investigation and analysis, the ad hoc committee presented its findings and recommendations in *Renewing U. S. Mathematics: Critical Resource for the Future* (the "David Report"; National Academy Press, Washington, D.C., 1984), referred to herein as the 1984 Report. It told a story that was deeply disturbing to both practitioners and policymakers in science:

- *Federal support for mathematical sciences research had come to be markedly out of balance with support for related fields of science and engineering. Discrepancies in support for essential research needs were very large.* The 1984 Report summarized that committee's estimate of the number of funded senior investigators needed in the mathematical sciences as follows (p. 64):

> Apply to the mathematics faculty the lowest percentage for those with federal support in other fields, 54% [from a 1980 National Science Foundation report]. One obtains 2400 as a base figure for the number of mathematicians to support. The mathematical sciences faculty is 1.3 times the size of that in mathematics, suggesting that ... 3100 is about right for the number of mathematical science faculty members on grants. From this, subtract 400 young investigators (Ph.D. age three to five years), to obtain 2700 as an appropriate number of established investigators ... Guido Weiss of our committee surveyed chairmen of mathematical science departments nationally, asking them to examine their faculties and judge how many researchers without support were doing research of the quality done by those with support. Extrapolation from the responses led to the estimate 2600-2900 for the total of "supported" plus "equally qualified" ... we adopt 2600 as the threshold level for the number of established investigators to support.

Goals given in the 1984 Report for other categories of support were estimates of the numbers of young people needed at each stage in the mathematical sciences pipeline in order to replenish this necessary core of 2600 senior researchers at the rate of some 100 per year.

- *This situation had come about through a combination of (1) abrupt losses of support for mathematics in the five-year period from 1968 to 1973 caused by shifts in* *federal policy (e.g., the Mansfield Amendment, fellowship cutbacks), and (2) steady deterioration of support over the decade 1973 to 1983*, during which the growth of computer science as a discipline and the practice of lumping this field together with mathematics in aggregate federal research data masked the deterioration of funding for the mathematical sciences.

- *The infrastructure supporting the mathematical research enterprise had been seriously weakened*, especially in university mathematical sciences departments, which contained 90% of the mathematical researchers, with the result that the field was in serious danger of being unable to renew itself.
- *This weakening had also gone largely unnoticed*, for two closely related reasons: (1) the mathematical sciences community did not bring its growing problems to the attention of the broader scientific community until the early 1980s; and (2) the spectacular performance of American mathematics, which had risen to a position of world leadership in the decades immediately following World War II, continued unabated throughout the 1970s, relying heavily on creative talent developed and incorporated into the field before the deterioration began to take its toll.

The conclusions of the 1984 Report were supported by data such as that given in Figures 1.1 and 1.2 and in Table 1.1, which are reprinted here from that report. These data document the imbalances in support experienced at that time by the U.S. university mathematics sector. Then, as now, the academic research communities of mathematics, chemistry, and physics were of comparable size. However, the numbers of active mathematical scientists and trainees who were supported, and thus encouraged to perform or learn to perform research, were strikingly out of balance with the numbers supported in chemistry and in physics. The low ratios of graduate research assistants per mathematical researcher and postdoctoral researchers per mathematical researcher pointed to a great many missed opportunities for better training of young people.

In fact, there were so few research grants in mathematics that many qualified researchers were without support, while the level of support for graduate students and postdoctoral researchers was so low that the mathematics Ph.D. pipeline suffered both in quality and quantity. There was clear evidence that the field was not renewing itself and therefore legitimate concern that research progress would diminish in the future. The prospect of becoming a professional mathematician had begun to look less and less inviting to students.

This situation developed during the 1970s, largely due to causes mentioned above. Rather than arguing for increasing Ph.D. production and hiring, mathematical sciences departments adapted to increased teaching responsibilities by expanding the use of graduate teaching assistants, thus freeing up some faculty time for research, but at the expense of providing quality research training for those entering the field.

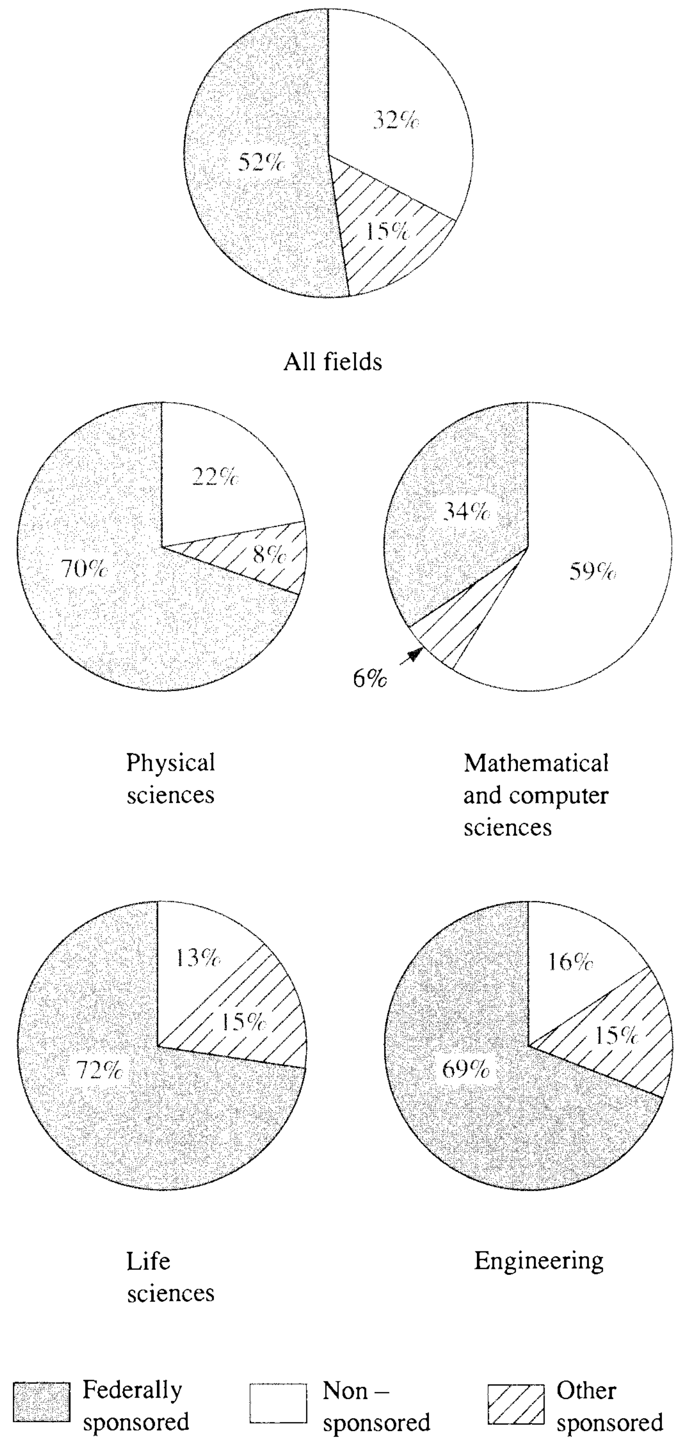

FIGURE 1.1 Research time in universities, November 1978 to October 1979.

SOURCE: From National Science Foundation Report 81-323, reprinted from National Research Council, *Renewing U.S. Mathematics: Critical Resource for the Future* (National Academy Press, Washington, D.C., 1984), p. 32.

The noteworthy productivity of mathematics researchers in 1984, as now, was at least partly due to a trio of singular events: the emergence of mathematics tools from World War II, the post-Sputnik alarms, and the ongoing expansion of the field as computer use widened the demand for mathematics. As the first two of those stimuli fade, the intellectual momentum they sparked is certain to run out. Just as today's mathematicians are prolific due in part to events and support levels of decades ago, tomorrow's mathematics will suffer because of the more recent underfunding and concomitant fading of career opportunities.

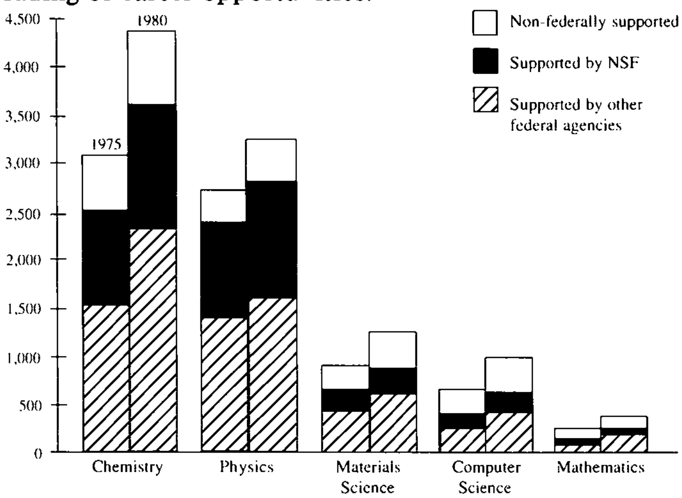

FIGURE 1.2 Graduate students with research assistantships enrolled full-time in doctorate-granting institutions, mathematical and physical sciences.

SOURCE: From National Science Foundation Report 82-260, reprinted from National Research Council, *Renewing U.S. Mathematics: Critical Resource for the Future* (National Academy Press, Washington, D.C., 1984), p. 33.

Table 1.1 Postdoctorals in Graduate Institutions, 1981

	Total	Federally Supported	Non-Federally Supported
Chemistry	2870	2465	405
Physics	1450	1217	233
Mathematical Sciences*	99	56	43

* This number excludes about 75 university-sponsored "research instructors" in mathematics.

SOURCE: National Science Foundation; reprinted from National Research Council, *Renewing U.S. Mathematics: Critical Resource for the Future* (National Academy Press, Washington, D. C., 1984), p. 33.

Imbalance in Support for Research

The interdisciplinary committee that wrote the 1984 Report quickly realized that problems resulting from insufficient research support for U.S. mathematical sciences were so severe that they threatened the entire scientific enterprise. Due to the enormous disparity in the number of people supported in the mathematical sciences vis-à-vis other sciences and engineering, the overall science and technology base was in poor balance, thus threatening its effectiveness. Reversing the underfunding of the mathematical sciences was therefore necessary as much to restore a healthy balance to the overall scientific enterprise as to assure a healthy mathematics research capability. The 1984 committee concluded that the extreme imbalance in the numbers of junior people involved in research, while partly attributable to the differing needs of laboratory and nonlaboratory fields, nonetheless indicated a distinct shortcoming in mathematical sciences researcher training. Without attempting to define "ideal" balance, that group was able to make recommendations for levels of supported research designed to restore balance. The actions of the mathematical sciences community and the federal funding agencies in response to the 1984 Report make it clear that they have accepted the conclusions that an imbalance existed and needed to be countered.

Balance does not necessarily imply funding parity, nor the achievement of equity between fields; rather, it implies supporting each field of science to whatever degree is required to keep it and the totality of science functioning efficiently. The 1984 committee saw the science and engineering disciplines as an ecosystem: while the components have different needs and roles, they must all function in a balanced way for the system as a whole to thrive.

The present committee agrees with this analysis and believes that elimination of the imbalance documented clearly in the 1984 Report—and still present, as demonstrated by Table B (Executive Summary) and Tables 2.3 and 2.4 (Chapter 2) of this report—is still the most pressing need of the mathematical sciences as a field. Since the arguments and underlying premises of the 1984 Report were widely accepted, the present report does not reargue that case but instead refers the reader to the Executive Summary of the 1984 Report, reprinted in this Report as Appendix A.

The 1984 National Plan

The 1984 Report challenged the Administration and the Congress, the universities, and the mathematical sciences community to implement, through a decade or more of sustained effort, a national plan for renewing the mathematical research enterprise in the United States. The seven principal elements of this 1984 National Plan for Graduate and Postdoctoral Education in the Mathematical Sciences—discussed in Section IV of Appendix A—called for the following:

- *Restoring* a reasonable degree of balance between federal support for mathematical sciences research and support for related fields by increasing mathematics support from $79 million to $180 million per year over a five-year period (figures in 1984 dollars);

- *Restructuring* the general pattern of use of resources, once they were made available to the mathematical sciences, by moving away from a pattern of small research grants supporting only principal investigators, which was especially prominent at the National Science Foundation (NSF), and toward a grants model consistently supporting graduate students, postdoctorals, and other components of the research infrastructure as well.[3] Briefly, the 1984 National Plan called for annual summer support for 2600 senior investigators, 24-month research positions for 200 postdoctorals, 15 months plus two summers of research support for 1000 graduate students, and 400 research grants for young investigators. These goals were based on the premise that more young mathematical scientists need thorough training with mentors.
- *Reducing* the unusual dependency of the mathematical sciences on the NSF and the service agencies of the Department of Defense (DOD) by fostering development of new mathematics programs at other agencies, especially programs concerned with research having long-term payoffs;
- *Extending* the lines of contact and support outward from the mathematical sciences departments to business and industry;
- *Initiating* within research universities in-depth reviews of the health of their mathematical sciences departments, focusing on the working circumstances of their faculties, the relationship of federal support to university support, and the widespread university practice of justifying allocations to mathematics departments solely on the basis of the department's instructional role;
- *Developing* within the mathematical sciences community a greater sense of responsibility for its own fate and a greater unity of purpose and action, drawing together professional organizations from across the varied subdisciplines to act in concert in (1) presenting regularly to government and universities the research needs of the field; (2) creating a long-term, coordinated public information effort aimed at increasing understanding of the roles and the importance of mathematics in science, technology, and culture; and (3) accelerating the efforts of mathematical scientists to attract brillant young people into their field; and finally
- *Expanding* the mathematical sciences community's commitment to and involvement in the revitalization of mathematics education, with special attention to the precollege level.

The present committee reconsidered the 1984 National Plan and determined that its goals remain valid and necessary today.

Complete implementation of the 1984 National Plan would assure the continued replenishment of the field's personnel base with talented new scientists. This, in turn, would assure continued intellectual production by the discipline. This intellectual output is valuable in itself, contributes substantially to other quantitative fields, provides the environment necessary for training mathematical scientists and educators, and—when explained well—serves as a beacon to draw students into the mathematical sciences.

The Current Report

Purpose and Emphasis. This report was prepared at the request of the NSF and the Interagency Committee for Extramural Mathematics Programs (ICEMAP). Specifically, this committee was charged to (1) update the 1984 Report, describing the infrastructure and support for U.S. mathematical sciences research; (2) assess trends and progress over the intervening five years against the recommendations of the 1984 Report; (3) briefly assess the field scientifically and identify significant opportunities for research, including cross-disciplinary collaboration; and (4) make appropriate recommendations designed to ensure that U.S. mathematical sciences research will meet national needs in coming years.

While recognizing that many critical issues face the mathematical sciences—especially demographic and educational ones—this report focuses on university research departments. These are the intellectual wellsprings of the field and the source of many teachers who set the pace for educational progress. By so focusing, this report complements other recent and ongoing efforts within the mathematical sciences community.[4]

Definition of the Mathematical Sciences. The discipline known as the mathematical sciences encompasses core (or pure) and applied mathematics, plus statistics and operations research, and extends to highly mathematical areas of other fields such as theoretical computer science. The theoretical branches of many other fields—for instance, biology, ecology, engineering, economics—merge seamlessly with the mathematical sciences.

This intellectual definition does not correspond exactly to the administrative definitions under which data are collected. Most data included in this report adhere to the NSF definition of mathematical sciences, which is somewhat more restrictive than the intellectual definition given above. By using these data, the committee sought to maintain continuity with the 1984 Report, being confident that trends and conclusions would not be skewed by such a small mismatch in the basis. The research progress reports included in Appendix B were deliberately chosen to span the broader definition of the field.

Notes

[1]The Assembly of Mathematical and Physical Sciences at the NRC subsequently evolved into the newly constituted

Commission on Physical Sciences, Mathematics, and Applications.

[2]See below, section headed "Definition of the Mathematical Sciences."

[3]The specific issue addressed in this part of the 1984 National Plan was not individual investigators versus group research. Rather it was grants that support only the research time of principal investigators versus grants that do and also support graduate students, postdoctorals, and so on. In the early 1980s the average NSF research grant in mathematics supported two months of summer research time for a principal investigator and little else.

[4]For example, the National Research Council reports *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Academy Press, Washington, D.C., 1989) and *A Challenge of Numbers: People in the Mathematical Sciences* (National Academy Press, Washington, D.C., 1990).

2. Response to the 1984 National Plan

Federal Response

The responses of science-intensive federal agencies to the recommendations of the 1984 Report have been highly variable, ranging from bold and sustained action in some cases to moral support with virtually no action in others. The two major agencies most directly involved are the NSF, which accounts for 55% of the total federal support for the mathematical sciences and more than 90% of the support for pure mathematics, and the DOD, which provides nearly 40% of the total federal support for the mathematical sciences and 65% of the support for applied mathematics and statistics.

Nearly two years before its 1984 Report was published, the Ad Hoc Committee on Resources for the Mathematical Sciences had gathered comprehensive data comparing federal support of mathematical sciences research with support for related fields. These data were used as part of the research briefing on mathematics given in October 1982 to George A. Keyworth, director of the Office of Science and Technology Policy (OSTP), by a panel of the Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academy of Sciences. The data had been developed under the aegis of the government's Interagency Committee for Extramural Mathematics Programs (ICEMAP) and were used extensively throughout the years 1982 to 1986 in staff presentations within several of the agencies, particularly NSF. The early response to these data by OSTP and NSF was swift, resulting in a 20% increase in the budget of NSF's Division of Mathematical Sciences[1] from FY 1983 to FY 1984.

Total federal agency academic support for the mathematical sciences over the five years since the 1984 Report's appearance is profiled in constant dollars in Table 2.1. (Some federal agencies also support significant internal research in the mathematical sciences, which is not included in Table 2.1.)

Table 2.1. Federal Agency Academic Support for the Mathematical Sciences, Constant 1984 Dollars (Millions)

Agency	FY 1984	FY 1986	FY 1988	FY 1989	Percent Increase, FY 1984 to FY 1989
Dept. of Defense					
AFOSR	10.20	11.94	11.81	13.04	28
ARO	6.80	7.54	8.76	9.11	34
ONR	11.90	11.50	9.50	9.53	-20
DARPA	—	4.94	9.91	7.13	N.A.
NSA	—	—	1.60	2.04	N.A.
Total DOD	28.90	35.92	41.58	40.85	41
Dept. of Energy	2.90	3.54	5.48	5.43	87
Other agencies*	2.00	1.80	0.83	0.79	-61
Total non-NSF	33.80	41.26	47.89	47.07	39
NSF					
DMS	41.20	46.45	52.67	52.20	27
Other	4.00	4.94	4.54	6.34	59
Total NSF	45.20	51.39	57.21	58.54	30
TOTAL Federal Academic Support	79.00	92.65	105.10	105.61	34

* Estimate, including the National Aeronautics and Space Administration, the National Institutes of Health, and the National Institute of Standards and Technology. Also includes NSA prior to FY 1988.

Acronym Key: AFOSR = Air Force Office of Scientific Research, ARO = Army Research Office, ONR = Office of Naval Research, DARPA = Defense Advanced Research Projects Agency, NSA = National Security Agency, NSF = National Science Foundation, DMS = Division of Mathematical Sciences; N.A. = Not appropriate.

SOURCE: FY 1990 Joint Policy Board for Mathematics submission to the American Association for the Advancement of Science (AAAS). Higher Education Price Index used as dollar deflator.

National Science Foundation

By the start of the 1980s, the Division of Mathematical Sciences at the NSF had already begun an effort to better support the mathematical sciences research infrastructure as well as research per se. A new postdoctoral program was initiated after discussions in the National Science Board, led by G. D. Mostow and others. Intensive debate over proposed "research institutes" led eventually to the funding of the Mathematical Sciences Research Institute (MSRI) at the University of California-Berkeley and the Institute for Mathematics and its Applications (IMA) at the University of Minnesota, both now regarded as highly successful. The debate also led to emphasis on "alternative modes," which encompassed several other programs, notably an expanded postdoctoral program.

Following the June 1984 publication of the National Plan in the 1984 Report, a strong NSF response was sustained. In November 1984, the National Science Board, the governing body of the NSF, passed a resolution calling on all federal science agencies to join with NSF in remedying the marked imbalance in support that the report had pointed out. Strong leadership by Erich Bloch, NSF director, his predecessor Edward Knapp, and Richard Nicholson, associate director for the Directorate for Mathematical and Physical Sciences, resulted in continued high priority for mathematics in the allocation of its funds. As a result, NSF support of mathematical sciences research nearly doubled (almost 50% real growth compared to 29% for total NSF R&D) over the six years from FY 1983 to FY 1989. Equally important was the way these funds were used. With strong backing from their advisory panels, three successive directors of the Division of Mathematical Sciences, E. F. Infante, John Polking, and Judith Sunley, led an effort to restructure the support patterns of NSF mathematics programs, balancing support for the research infrastructure (as represented by graduate students, postdoctoral researchers, computing facilities, and so on) with research support for principal investigators.

This ordering of priorities continues to be recommended by the NSF's Mathematical Sciences Advisory Panel. Thus virtually all of the real growth in the division's budget over the last six years has gone into infrastructure support.

These priorities, consistent with the thrust of the 1984 National Plan, have had a significant impact on the Ph.D. pipeline. An undesired side effect is that, because of funding limitations, no progress has been made on another important part of the plan: increasing the number of principal investigators supported. It should also be noted that, although the profile of grants in the Division of Mathematical Sciences has changed for the better because of the consistent application of these priorities, balance within the grants to the extent recommended by the 1984 National Plan has not yet been attained. Thus future priorities will need to emphasize both principal investigators and the infrastructure for support.

Department of Defense

The percentage growth of total DOD support for the mathematical sciences has been nearly the same as that at NSF, 94% over the six-year period from FY 1983 to FY 1989 (about 46% real growth compared to a 23% increase in the total DOD R&D budget). The form of the growth has been quite different, however.

The three service agencies—the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), and the Office of Naval Research (ONR)—have been in a period of flat funding and have not evolved comprehensive plans for strengthening their support of the mathematical sciences. However, when the DOD's University Research Initiative program was launched in 1986, high priority was assigned to mathematics by the directors of the service agencies and the civilian R&D management of DOD, notably Undersecretary Richard DeLauer and Deputy Undersecretary Ronald Kerber. Still, there has been no net increase in funding except in support of computational facilities.

Support at DOD has grown principally because two new mathematical sciences research programs were created, one at the Defense Advanced Research Projects Agency (DARPA) and the other at the National Security Agency (NSA).

The new DARPA program in Applied and Computational Mathematics, currently funded at the $9 million level (7% of total federal support), was initiated by Craig Fields, now DARPA's director. It has emphasized relatively large ($500,000 to $2 million) project grants to groups of mathematicians working on broad problems in areas identified by DARPA staff as (1) important to the DOD and/or DARPA mission; and (2) particularly promising scientifically. Orginally, the principal areas were dynamical systems, turbulent flow, computational algorithms, data/image compression, and harmonic analysis/clustering algorithms. The contracts have greatly strengthened the research efforts in those areas and have provided exciting models of problem-focused group (or team) research. This program has generated increased appreciation of the importance of mathematics to the DOD mission well beyond the boundaries of DARPA. At the same time the DARPA program has caused some concern within the mathematical community for two reasons: (1) the program has tended to provide more support for a few mathematicians who were already well supported, and therefore has done little to increase the number of people supported in the field; and (2) initially the program has remained independent of the broader mathematical community.

With 600 mathematicians on its staff, the NSA is one of the largest employers of mathematicians in the country. Though still producing large amounts of classified research, mathematicians at NSA—backed by successive directors W. E. Odom and W. O. Studeman and Chief Scientist Kermith Speierman—have broadened their interaction with the larger mathematical sciences community. The extramural Mathematical Sciences Program at the NSA has had a positive impact on federal support for the field far greater than its size ($2.5 million, or 2% of total federal support) might indicate. It has established a program of "small science" research grants that support some 80 mathematicians, most of whom work in areas traditionally labeled as pure mathematics. Awards are made subject to a peer review system organized by the NRC's Board on Mathematical Sciences (BMS). The program has helped to increase somewhat the number of principal investigators supported in the field. The building of both formal and informal bonds with the mathematical sciences community is also a significant benefit.

Department of Energy

The Department of Energy (DOE) doubled its support for the mathematical sciences over the period from FY 1984 to FY 1988, focusing primarily on computational sciences and applied mathematics but also on geometry and mathematical physics. Its budget for supercomputing quadrupled over the same period. A postdoctoral fellowship program begun in 1989 supports 14 computational mathematicians at national laboratories; this program promises to strengthen ties between academic mathematicians and the DOE laboratories.

Mathematics of Computation Initiative

The 1984 Report's recommendation for a special mathematics of computation initiative—resonating with the recommendations of earlier reports, such as the "Lax Report"[2]—was implemented to a large degree. This initiative was meant to encourage mathematics graduate students and new faculty to develop the new mathematics that will be needed to effectively use the many supercomputers now in use or planned. An NSF summary of federal funding for computational mathematics research shows an increase from $4 million to $12 million over the period from 1982 to 1987.[3] In particular, the NSF created a new program in computational mathematics—with FY 1987 expenditures of nearly $3 million—to focus attention on this goal. The AFOSR and DOE doubled their budgets in this area, while the ARO increased its effort by 50%. DARPA's new program, which did not exist in 1982, supported $1 million worth of computational mathematics in FY 1987. In addition, the NSF supercomputing centers are major resources for this endeavor. Clearly, a good infrastructure for support of this initiative has been established.

Federal Progress Toward Achieving Quantitative Goals of the 1984 National Plan

The goals for federal support set forth in the 1984 Report are the quantitative elements of its National Plan for renewal. These estimates of what it would take to restore balance between support for mathematical sciences research and support for related fields were derived from an analysis of the needs of the inner core of the research enterprise in the mathematical sciences. This core was determined[4] to consist of 2600 senior investigators[5] and a renewal pipeline of 1000 graduate students, 200 postdoctorals, and 400 young investigators. Section IV.B of Appendix A adds details to these goals. The annual cost of support in 1989 was estimated to total $225 million.[6]

TABLE 2.2. Federal Support of Mathematical Sciences Research–Progress Over Five Years, 1984–1989

Category of Support	1984 National Plan Goal	1984 Level	1989 Level	Percent Change, 1984 to 1989	Percent of 1984 National Plan Goal Reached by 1989
Number of researchers supported					
Senior Investigators	2600	1800	1900	+6	73
Postdoctoral researchers	400[a]	132	188[b]	+42	47
Graduate research assistants	1000	411	661[b]	+61	66
Total dollars (millions)	225[c]	99.6[d]	133	+34	59

[a] The 1984 National Plan calls for awarding 200 two-year postdoctorals annually, resulting in a population of 400 at any given time.

[b] Most recent counts comparable to the 1984 numbers, from fall 1988. (NSF Division of Science Resources Studies, personal communications.)

[c] 1984 National Plan goal adjusted for inflation using Higher Education Price Index; revised National Plan goal is $250 million.

[d] In 1989 dollars, using Higher Education Price Index.

Table 2.2 summarizes gains made in four key categories over the five years since the 1984 Report was published. Several comments are in order about increases in total support for the field. In actual dollars, total federal support has climbed from $79 million in 1984 to $133 million in 1989, an increase of 68% over the five years. As described above, support by the two major funders, NSF and DOD, increased by roughly the same percentage but through different mechanisms—at NSF through consistent increases in the budget of its Division of Mathematical Sciences and at DOD principally through the creation of two new programs, one at DARPA and the other at NSA.

As Table 2.2 shows, the actual dollar increase of 68% translates into real growth of about 34%, most of which has gone into support for graduate students and postdoctorals,[7] in accordance with priorities set in 1984. Nevertheless, we are still far from the goals of annually funding 2600 senior investigators, 200 new postdoctoral researchers, 1000 graduate research assistants, and 400 young investigators. Furthermore, the balance called for in the 1984 National Plan between support for senior investigators, on the one hand, and emerging scholars, on the other, has not yet been achieved.

Actual dollar increases of 68% in five years (95% over the six years from 1983 to 1989) represent bona fide gains for the mathematical sciences (34% and 46%, respectively, in real dollars). This occurred in a period when funding for the sciences was less than robust. However, apparently significant incremental increases can be misleading when the base level is very small.

Table 2.2 shows vividly that there is still a long way to go. For example, total support for the field in 1984 stood at 44% of the goal recommended in the 1984 Report, and in 1989 it stood at 59% of that goal, after adjusting for inflation.

Table 2.3 Selected Ph.D. Pipeline Comparisons for 1980 and 1988

Point of Comparison	Chemistry	Physics	Mathematical Sciences
Graduate research assistants federally supported			
1980	3733	2976	421
1988	4673*	3591*	661
Annual Ph.D. production			
1980	1538	862	744
1988	2018	1172	749
Postdoctoral researchers federally supported			
1980	2255	1210	57
1988	2587	1280	188
Ratio of federally supported graduate research assistants to Ph.D. degrees produced (1988)	2.32	3.06	0.88
Ratio of federally supported postdoctoral researchers to Ph.D. degrees produced (1988)	1.28	1.09	0.25

* 1986 figures; later data not yet available.

SOURCE: National Science Foundation, Division of Science Resources Studies.

Table 2.3 updates Figure 1.2 and Table 1.1 and covers a longer period than does Table 2.2. These counts omit summer postdoctoral positions and other grants that do not reflect the spirit of the 1984 National Plan's recommendations. The absolute numbers of federally supported graduate research assistants and postdoctorals in the mathematical sciences shown in Table 2.3 remain only small fractions of the figures for comparable groups in chemistry and physics. The ratios presented in Table 2.3 more pointedly illustrate how the supported research time during the training years falls short in the mathematical sciences. Table 2.4 shows that in 1987 only 18% of full-time mathematical sciences graduate students received research-related support, compared to the 45 to 50% of graduate students in the physical sciences and engineering who had such support. Clearly, researchers in training in the mathematical sciences still have a difficult time gaining the depth and breadth of experience common among researchers in other sciences.

Table 2.4 Type of Support for Full-Time Graduate Students in Doctorate-Granting Institutions, 1987

	Number of Graduate Students	Number with Teaching Assistantships	Number with Research Support*	Fraction with Research Support
Biological sciences	37,734	8,210	22,114	0.586
Physics	11,075	4,089	5,660	0.511
Chemistry	15,664	7,005	7,630	0.487
Engineering	61,194	11,005	27,550	0.450
Social Sciences	48,699	9,745	13,644	0.280
Computer sciences	13,578	3,258	3,612	0.266
Mathematical sciences	12,354	7,089	2,231	0.181

* Includes research assistantships, fellowships, and traineeships.

SOURCE: National Science Foundation, Division of Science Resources Studies (personal communication).

The number of federally supported individual investigators in mathematics, estimated as under 1800 in 1984,[8] stood at about 1900 in 1989 (Table 2.5). The 1984 Report discussed at some length (pp. 61–64) its conservative estimates that there are at least 2600 highly productive researchers in the mathematical sciences and that the field needs a cadre of about 2600 fully active, federally funded researchers in order to be balanced with other fields that use mathematics. Supporting an additional 700 investigators not only would increase their *individual* productivity, but would also encourage a larger fraction of mathematicians to stay highly productive, thereby increasing the *field's* overall productivity.

The infrastructure of the mathematical sciences is composed primarily of people, with funded investigators constituting the supporting structure for the field. Federal support for this core is the major infrastructure requirement of the discipline. However, other elements—graduate research assistants, postdoctoral researchers, funds for travel, and support for collaborative research—are becoming increasingly important now as the field unifies internally and expands externally, because those trends require greater breadth on the part of researchers. Funding for computer time and for hardware fixed costs is a rapidly growing requirement. The evolving needs of the infrastructure are addressed by the second thrust of the 1984 National Plan as summarized in Chapter 1.

Apropos of balance with other fields of science, the fraction of scientists engaged in R&D in educational institutions who receive federal support remains significantly lower in the mathematical sciences than in chemistry or physics and astronomy. According to the 1987 NRC survey of doctoral recipients,[9] 37% of the mathematical scientists in educational institutions who identified R&D as their primary or secondary activity had federal support. Comparable figures for chemists and for physicists and astronomers were 56% and 75%, respectively.

Table 2.5 Number of Mathematical Sciences Research Investigators Supported by Federal Grants and Contracts in FY 1988

Agency	Research Investigators Supported
Department of Energy	91[a]
Department of Defense	
ONR	223
NSA	41
ARO	213
DARPA	112
AFOSR	342
Total non-NSF research	1022[b]
National Science Foundation	
Total NSF Research	1364[c]
Total federal agency count	2386
Less duplicates	–480[d]
TOTAL INDIVIDUAL INVESTIGATORS SUPPORTED	1906

[a]Since the field's renewal efforts most critically depend on university departments, 94 DOE laboratory investigators are omitted from this number.

[b]All non-NSF investigator counts listed are 95% of agency figures because those agencies advise that at least 5% of their grants are non-research.

[c]The NSF Division of Mathematical Sciences also supports 56 investigators for non-research activities such as conferences and other special projects, who are omitted from the total shown.

[d]Based on discussions with cognizant federal program officers, this committee conservatively estimates that at least 480 investigators appear on more than one federal grant.

Acronym key: AFOSR = Air Force Office of Scientific Research, ARO = Army Research Office, ONR = Office of Naval Research, DARPA = Defense Advanced Research Projects Agency, NSA = National Security Agency, NSF = National Science Foundation.

SOURCE: Program officers' counts, personal communication.

Response of the Universities

Few, if any, universities responded to the recommendations in the 1984 Report by conducting comprehensive reviews of the circumstances of their mathematics departments and formulating plans for improving those circumstances as part of strengthening the health of the discipline. It is difficult to say whether this was due to a lack of strong initiative by individual departments, to inertia of university administrations, or both. It is safe to say, however, that the general pattern of reaction does not seem to reflect awareness of the serious problems that must be overcome to achieve the renewal of the U.S. mathematical sciences enterprise.

University administrations were also urged in the 1984 Report to act as proponents of mathematical sciences research, interceding with government agencies and seeking new government and industry initiatives that could benefit their mathematical sciences departments. Again, very few universities appear to have responded.

The universities that did respond were principally those where deans, provosts and presidents were made aware of the key issues by their mathematical sciences department chairs, often acting in tandem with a federal agency or with professional society representatives. This committee's canvassing of departments indicated that such a response was not the norm, however. Actions taken by university administrations have included support for departmental computer hardware, some start-up grants for new hires, and increased salary offers to allow the departments to compete for top-quality faculty. These measures have alleviated some of the strains on these departments.

University associations have taken no action in response to the recommendations in the 1984 Report. The report, with its stark descriptions of the circumstances of mathematics departments, was brought to the attention of leaders in university ass(ciations but did not find its way onto their active agendas.

Response of the Mathematical Sciences Community

The group that has done the most and yet still has the most to do is the U.S. mathematical sciences community. It is useful to look at its response to the 1984 Report at two levels, the response of its leadership and the response of individual members of the community.

Response of Leadership. The mathematics community is engaged in a multistage, multiyear critical examination of its roles in research, education, and public policy. This ambitious undertaking, which will take several major steps forward in 1990, began in 1980 when leading mathematicians became alarmed over markedly decreased flows of talent and resources into their field, and into science and technology more broadly. They stimulated the development of a postdoctoral program and two new research institutes supported by NSF funding. They mobilized the professional societies in mathematics and enlisted the aid of the NRC in analyzing the forces undermining the infrastructures of mathematics research and education, for the purpose of developing national plans to reverse the trends of declining Ph.D. production, erosion of federal support, deterioration within mathematics departments, increasing student and public apathy toward mathematics, and growing complacency within the field itself about some of its responsibilities. The focus for the analyses was not the past, however; it was the opportunities that mathematics provides for the future well-being of science and technology, the nation, and its individual citizens.

The comprehensive assessment that these actions set in motion will continue throughout the 1990s and is generating in successive steps the plans and organizational mechanisms needed at the national level to renew and continuously maintain the vitality of this country's broader mathematical sciences enterprise. In 1990 the mathematical sciences community will have before it for widespread discussion organizational plans for its many future roles—in research, in precollege education, in college and university education, and in relating its work to various other communities. These discussions will be important elements of what is being called within the community the Year of National Dialogue.

Highlights of the major steps taken by the mathematical sciences community since 1980 to bring the dialogue to its present stage are as follows:

1980 *New postdoctoral fellowship program*—The NSF launches its Mathematical Sciences Postdoctoral Research Fellowships program to increase postdoctoral opportunities in mathematics.

1981 *Research institutes*—The Mathematical Sciences Research Institute at the University of California-Berkeley and the Institute for Mathematics and Its Applications at the University of Minnesota are created with NSF backing, further expanding the NSF's emphasis on the infrastructure for mathematical research.

1981 *The David Committee*—The NRC, the principal operating agency of the National Academy of Sciences (NAS) and the National Academy of Engineering, establishes a prestigious committee of scientists and engineers, chaired by Edward E. David, Jr., to review the health and support of research in the mathematical sciences in the United States.

1982 *The Browder briefing panel*—At the request of the White House, the NAS's Committee on Science, Engineering, and Public Policy (COSEPUP) establishes panels to brief the Science Advisor to the President on research opportunities in six fields. First to report is the Mathematics Panel, chaired by William Browder, which points out that mathematics is flourishing intellectually but that its research infrastructure is eroding rapidly.

1983 *The Joint Policy Board for Mathematics*—The American Mathematical Society (AMS), the Mathematical Association of America (MAA), and the Society for Industrial and Applied Mathematics (SIAM) create a nine-member joint executive action arm, the Joint Policy Board for Mathematics (JPBM), to begin implementing the recommendations of the David Committee. The JPBM emphasizes unity across the discipline, one of the five basic recommendations to the mathematics community later made by the David Committee.

1984 *Renewing U.S. Mathematics: Critical Resource for the Future*—The 1984 "David Report" highlights the flowering of mathematics and its uses since World War II and calls attention to serious signs of trouble: (1) the impending shortage of U.S. mathematicians and (2) a marked imbalance between federal support of mathematics research and support for related fields of science and engineering. Based on a careful analysis, it calls for more than a doubling of the FY 1984 federal support level and lays out a ten-year implementation plan, with specific roles for government, universities, and the mathematical sciences community.

1984 *The Board on Mathematical Sciences*—In December 1984 the NRC establishes the Board on Mathematical Sciences (BMS) to provide a focus of active concern at the NRC for issues affecting the mathematical sciences, to provide objective advice to federal agencies, and to identify promising areas of mathematics research along with suggested mechanisms for pursuing them. The BMS has become an important mechanism for drawing together representatives of all the mathematical sciences.

1985 *The Mathematical Sciences Education Board*—At the urging of the mathematical sciences community, the NRC establishes in October 1985 the Mathematical Sciences Education Board (MSEB) to provide "a continuing national assessment capability for mathematics education" from kindergarten through college. A 34-member board is appointed that is a unique working coalition of classroom teachers, college and university mathematicians, mathematics supervisors and administrators, members of school boards and parent organizations, and representatives of business and industry. This step reflects another of the basic recommendations of the David Committee: strong involvement of all sectors of the mathematics community in issues of precollege education.

1985 *Board on Mathematical Sciences' department chairs' colloquium*—An annual series of colloquia for chairs of mathematical sciences departments, begun by the Science Policy Committee of the AMS, is taken over and extended by the BMS. These successful meetings enable department chairs to pool their ideas and experience, focusing the ensemble into a valuable action group for addressing problems common to many mathematical sciences departments.

1986 *The Joint Policy Board on Mathematics, Washington, D.C., office*—The JPBM's Washington, D. C., activities come to embrace enhanced congressional contact and a vigorous public information effort. An office of governmental and public affairs is opened and it helps launch National Mathematics Awareness Week, which is to become an annual April event. Contact with the media and resultant coverage of mathematics are increased, thus starting the long-term coordinated effort, recommended by the David Committee, to increase public information and understanding.

1986 *Board on Mathematical Sciences' Science and Technology Week Symposium*—This symposium, which is held annually at the NAS's Washington, D. C., facility, highlights the role of research mathematics in the sciences and engineering for an audience of scientists and policymakers.

1987 *Department of Defense advisory panels*—The BMS advisory panel to the AFOSR releases a report assessing the AFOSR mathematical sciences program. The BMS Panel on Applied Mathematics Research Alternatives for the Navy (PAMRAN) produces a report for ONR on selected research opportunities relative to the Navy's mission.[10] The BMS advisory panel to the Mathematical Sciences Program of the NSA is formed.

1987 *Project MS 2000*—At the urging of JPBM, and under the supervision of the BMS and MSEB, the NRC launches a comprehensive review of the college and university mathematics enterprise through the Mathematical Sciences in the Year 2000 (MS 2000) project. This is analogous to the David Committee's review of the health and support of mathematics research nationally.

1988 *100 Years of American Mathematics*—The occasion of the centennial of the AMS is used to develop a year-long series of related events promoting discussion within the mathematical sciences community of major issues it faces in research and education.

1988 *Office of Scientific and Public Affairs*—The American Statistical Association's (ASA) public information office is established to provide an interface between statisticians, the public, and the federal government.

1989 *Challenges for the '90s*[11]—The ASA report outlining significant application areas and societal problems for statisticians to explore in the 1990s is released.

1989 *Everybody Counts*[12]—the first BMS-MSEB-MS 2000 "report to the nation" on the state of mathematics education in the United States, kindergarten through college, based on the MSEB's precollege work and on preliminary work of the MS 2000 project. It emphasizes the potential of a modified mathematics education for contributing to the national welfare and outlines a national strategy for bringing about needed change in the 1990s.

1990 *Renewing U.S. Mathematics: A Plan for the 1990s*—This report, which is a five-year update of the 1984 Report. It describes emerging research opportunities and new challenges for government, universities, and the mathematical sciences community to continue the program to renew U.S. mathematics.

1990 *Second report to the nation*—The final report of the MS 2000 project to appear near the end of 1990, will lay out a national plan for revitalizing mathematics education in U.S. colleges and universities.

Response of Individuals in the Research Community. The many mathematicians and statisticians who have peopled the advisory committees to federal agencies over the last six years have, by and large, exhibited the same bold imagination and concern with critical examination of their field that are reflected in the decade of initiatives just listed. They have continued to emphasize most strongly the support of graduate students and postdoctoral researchers. This strategy may be working: Ph.D. production appears to be turning upward after many years of decline.

Not surprisingly, the beneficial effects of the strategy to improve the research infrastructure are not experienced by many mathematicians. What *is* seen in university mathematical sciences departments is that the percentage of high-quality mathematicians with federal support is lower than the corresponding percentage in other fields of science and that the number of principal investigators supported has remained inadequate over the last six years. Hardly surprising, therefore, is the bona fide concern over the strategy to be followed in the next five or six years. This concern is most prevalent among investigators doing research in pure mathematics, the group for which the largest gap exists between the number of highly qualified researchers and the number with federal support.

Notes

[1]What is now the Division of Mathematical Sciences at the NSF grew out of the former Division of Mathematical and Computer Sciences, which was divided in 1983.

[2]*Report of the Panel on Large-Scale Computing in Science and Engineering*, P. D. Lax, chair (National Science Foundation, Washington, D.C., 1982).

[3]NSF Division of Mathematical Sciences, personal communication. Amounts quoted are in actual dollars and have not been adjusted for inflation.

[4]*Renewing U. S. Mathematics: Critical Resource for the Future*, National Research Council (National Academy Press, Washington, D.C., 1984), pp. 57–65.

[5]There are some 10,000 mathematicians and statisticians in the mathematical sciences research community, of whom one-half are productive and about one-quarter highly productive, according to criteria spelled out in the 1984 Report.

[6]This figure results from updating the 1984 estimated budget of $180 million with the Higher Education Price Index published in *Statistical Abstract of the U.S., 1990*, Bureau of the Census, U. S. Dept. of Commerce, Washington, D. C.

[7]Support has also been given to the mathematics of computation initiative, which is not itemized in Table 2.1. The number of postdoctorals in 1984 was already double the counts given in the 1984 Report (dating from 1980 and 1981) because of initiatives begun concurrent with that report's preparation.

[8]*Renewing U.S. Mathematics: Critical Resource for the Future*, 1984, p. 95.

[9]Survey of Doctorate Recipients project, National Research Council (personal communication).

[10]A second PAMRAN opportunities report is scheduled for release in 1990.

[11]*Challenges for the '90s* (American Statistical Association, Washington, D.C., 1989).

[12]*Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, National Research Council (National Academy Press, Washington, D.C., 1989).

3. Research Progress and Prospects

A survey of modern science and technology shows the mathematical sciences supporting crucial advances and giving rise to a wealth of creative and productive ideas. The mathematical achievements of this century, among the most profound in the history of the discipline, have been fundamental to the development of our technological age. And beyond their practical applications, the development of these mathematical sciences can be counted among the great intellectual achievements of humankind.

The mathematical sciences constitute a discipline that combines rigor, logic, and precision with creativity and imagination. The field has been described as the science of patterns. Its purpose is to reveal the structures and symmetries observed both in nature and in the abstract world of mathematics itself. Whether motivated by the practical problem of blood flow in the heart or by the abstraction of aspects of number theory, the mathematical scientist seeks patterns in order to describe them, relate them, and extrapolate from them. In part, the quest of mathematics is a quest for simplicity, for distilling patterns to their essence.

Of course, the nonmathematician who tries to read a mathematics research paper is bound to see the terms as anything but simple. The field has developed a highly technical language peculiar to its own needs. Nonetheless, the language of mathematics has turned out to be eminently suited to asking and answering scientific questions.

Research in the mathematical sciences is directed toward one of two objectives, and in some cases toward both: (1) to build on and expand the core areas of the discipline and (2) to solve problems or create problem-solution techniques for the increasingly numerous areas of science and technology where mathematics finds applications. Thus mathematical sciences research spans a spectrum from the examination of fundamentals to the application-driven solution of particular problems. This chapter surveys selected recent research achievements across this spectrum and mentions a sampling of current research opportunities that build on and promise to extend recent progress.

These opportunities for progress are real and exist in every major branch of the mathematical sciences. What is unusual about the mathematical sciences at this time is that, collectively, they are poised to make striking contributions across the whole spectrum of science and engineering.

The Mathematical Sciences Yesterday

This potential for progress is the result of the remarkable growth of the mathematical sciences along three more or less parallel paths, stemming from a branching point in the 1930s, when mathematics as a "pure" discipline entered a new era characterized by reexamination of its foundations and exploitation of powerful new tools of abstraction. The result was an extraordinary flourishing of the discipline and an acceleration of the development of its major branches through the post-World War II years. The pace was so rapid that specialization increased, and for a while it seemed that topologists, algebraic geometers, analysts, and other groups of mathematical scientists could barely speak to one another. Each was inventing powerful new mathematical structures to unify previously disparate ideas and shed new light on classical problems.

These developments were accompanied by independent spectacular advances in applied mathematics and statistics during the same period. A major stimulus for these efforts was World War II, which presented an array of scientific and technological challenges. In communication, control, management, design, and experimentation, the power of mathematical concepts and methods was felt in the post-war years as never before.

A third line of inquiry rooted in the 1930s resulted in the evolution of the computer. The original work of a handful of mathematicians and electrical engineers some 50 years ago gave rise to a new discipline—computer science—and a new tool, more powerful than any in history, for storing, processing, and analyzing information. Few people today need to be told of the impact computers are having on society. But many people need to have it pointed out that the computer is very much a mathematical tool that extends the reach and power of mathematics. The computer has already had an enormous impact on applied mathematics and statistics, and more generally on science and engineering (see section below, "Computers in the Mathematical Sciences").

The Mathematical Sciences Today

In more recent years several dramatic changes have begun to occur within the discipline. Ever more general and more powerful methods and structures developed within pure mathematics have begun to reunify its various branches. The gap between pure and applied mathematics has also begun to close as more of the new methods are used in other fields—for example, in biology, medicine, and finance, as well as in fields usually thought of as mathematical. And the computer continues to stimulate the need for new mathematics while opening unprecedented new directions and methods for mathematical exploration per se. The immensity and richness of the methods and ideas developed by pure and applied mathematicians and statisticians over the last 50 years constitute a huge resource being tapped by the intellectual machine of science and engineering.

It is this image of the mathematical sciences today that one should have in mind while reading this brief survey of the state of the field as a whole. This is an unusual time in the history of the discipline. The simultaneous internal unification and greater awareness of external applications have brought the mathematical sciences into an era of potentially greater impact on the world around us.

This chapter is a companion to Appendix B, which contains more-detailed, brief descriptions of 27 important research areas that have produced significant accomplishments in recent years and that offer opportunities for further research. The committee emphasizes that the achievements and opportunities discussed in Appendix B are not intended to be comprehensive,[1] nor are they intended to suggest a specific agenda for funding research in the mathematical sciences. The aim is rather to demonstrate by example the vigor and comprehensiveness of current mathematical sciences research, and how the mathematical sciences are reaching out increasingly into all parts of science and technology even as the core areas of the mathematical sciences are expanding significantly. The selection of topics discussed in Appendix B illustrates the very real progress made across that spectrum in just the last five years.

The many applications of mathematics—which are most readily visible to the larger scientific community—can be realized only if the discipline as a whole remains strong and vibrant internally. Mathematics has indeed been interacting with other disciplines in healthy and productive new ways while simultaneously receiving an infusion of new ideas.[2] This process is accelerating, and the accounts in Appendix B illustrate the extent and import of cross-disciplinary research today. There is now an ever-increasing interest in applied problems—an interest that was perhaps not so evident a decade or two ago. At the same time mathematics has developed a substantially greater sense of internal unity and has displayed healthy cross-fertilization of ideas between subdisciplines. The intellectual energy produced by these two trends—looking externally for new problems and unifying internally—represents perhaps the greatest opportunity of all for the mathematical sciences over the next five years.

Computers in the Mathematical Sciences

From the convenience of a hand calculator, to the versatility of a personal computer, to the power of parallel processors, computers have ushered in the technological age. But they have also ushered in a mathematical age, since computers provide one of the main routes by which mathematics reaches into every realm of science and engineering. Computers have profoundly influenced the mathematical sciences themselves, not only in facilitating mathematical research, but also in unearthing challenging new mathematical questions. Many of the research advances described in this chapter and in Appendix B would not have been possible without computers and the associated mathematics that is concurrently being developed.

It is sometimes thought that once computers are powerful enough, mathematicians will no longer be needed to solve the mathematical problems arising in science and engineering. In fact, nothing could be farther from the truth. As computers become increasingly powerful, mathematicians are needed more than ever to shape scientific problems into mathematical ones to which computing power can be applied. And as science and engineering attempt to solve ever more ambitious problems—involving increasingly large and detailed data sets and more complicated structures—entirely new mathematical ideas will be needed to organize, synthesize, and interpret.

Computers are fundamentally connected to mathematics, in their physical design, in the way they organize and process information, and in their very history. The concept of a machine that could perform calculations automatically dates at least to the early nineteenth century. This concept became practical through the farsightedness of such mathematicians as Alan Turing, famous for cracking the German Enigma code during World War II, and John von Neumann, who was the driving force behind the design and building of the first computer.

Computer scientists continue to draw on theoretical mathematics, since advances in computing power are dependent upon mathematical ideas. Faster electronic components are continually appearing, but advances in hardware alone will not improve computing speed and efficiency, and most experts agree that the development of efficient software is not keeping pace with hardware development. Designing and analyzing the efficiency of computer algorithms are largely mathematical tasks. As machines become faster and computer memory sizes become larger, asymptotic improvements in the efficiency of algorithms become more and more important in practice. Recent research in theoretical computer science has produced significant improvements in specific algorithms and also new approaches to algorithm design, such as the use of parallelism and randomization.

The impact of the computer on the mathematical sciences has particularly broadened the domain of the mathematical modeler, who can now reliably simulate quite complex physical phenomena by computer. Widely used in all sciences and in engineering, and a research area in its own right, computer modeling plays a major role in the development of critical technologies such as the fabrication of microelectronic circuits and the understanding of fluid flow. Developing appropriate simulations for a given technology invariably involves a high degree of scientific knowledge as well as sophisticated mathematical tools to describe and evaluate the model. Validation of these models may require statistical tests and comparison with an analytically produced limiting-case solution. Ultimately the model itself has to be tuned to physical data to confirm or improve its aptness for representing a physical process or phenomenon.

Finally, and by no means least important, the computer is beginning to have a significant impact on areas of core mathematics through its use in the visualization of underlying mathematical structures. Its use in proving theorems is evidenced by the recent proofs of the four-color theorem and of the Feigenbaum conjecture.

Accomplishments and Opportunities

The committee has selected for presentation a collection of specific recent research achievements (Appendix B) that open up new opportunities for the future. It is emphasized that this is a partial list only and that lack of space precludes a fuller and more comprehensive survey. These examples of research progress and opportunities are as follows:

1. Recent Advances in Partial Differential Equations
2. Vortices in Fluid Flow
3. Aircraft Design
4. Physiology
5. Medical Scanning Techniques
6. Global Change
7. Chaotic Dynamics
8. Wavelet Analysis
9. Number Theory
10. Topology
11. Symplectic Geometry
12. Noncommutative Geometry
13. Computer Visualization as a Mathematical Tool
14. Lie Algebras and Phase Transitions
15. String Theory
16. Interacting Particle Systems
17. Spatial Statistics
18. Statistical Methods for Quality and Productivity
19. Graph Minors
20. Mathematical Economics
21. Parallel Algorithms and Architectures
22. Randomized Algorithms
23. The Fast Multipole Algorithm
24. Interior Point Methods for Linear Programming
25. Stochastic Linear Programming
26. Applications of Statistics to DNA Structure
27. Biostatistics and Epidemiology

A description in some detail of the specifics of each of these is given in Appendix B. What follows here is a discussion of how these achievements and opportunities (referred to by the Appendix B section number that also corresponds to the numbers in the listing of topics above), as well as some others not included in Appendix B, fit into the overall landscape of the mathematical sciences and their many and varied applications. It is hoped that this brief narrative will convey an appreciation of the breadth, scope, and usefulness of the mathematical sciences and how they are changing the contours of science and technology. At the same time it is hoped that this discussion will illustrate the vitality of mathematics as a discipline and show not only how ideas flow from the core of mathematics out to applications but also how the applications of mathematics can, in turn, result in ideas flowing to the core areas of the discipline. These interchanges affect almost every area of core mathematics.

For instance, developments in such core areas as number theory, algebra, geometry, harmonic analysis, dynamical systems, differential equations, and graph theory (see, for instance, Sections 1, 7, 8, 9, 10, 11, 12, and 19 in Appendix B) not only have significant applications but also are themselves influenced by developments outside of core mathematics.

The Living World. The mathematical and the life sciences have a long history of interaction, but in recent years the character of that interaction has seen some fundamental changes. Development of new mathematics, greater sophistication of numerical and statistical techniques, the advent of computers, and the greater precision and power of new instrumentation technologies have contributed to an explosion of new applications. Testifying to the impact of mathematics, computers are now standard equipment in biological and medical laboratories. Several recent fundamental advances seem to indicate a revolution in the way these areas interact.

The complexity of biological organisms and systems may be unraveled through the unique capability of mathematics to discern patterns and organize information. In addition, rendering problems into mathematical language compels scientists to make their assumptions and interpretations more precise. Conversely, biologists can provide a wealth of challenging mathematical problems that may even suggest new directions for purely mathematical research. Great differences in terminology and in the cultures of the two fields require a core of researchers with understanding of both areas.

Mathematical techniques for understanding fluid dynamics have made possible computational models of the kidney, pancreas, ear, and many other organs (Section 4). In particular, computer models of the human heart have led to improved design of artificial heart valves. Mathematical methods were fundamental to the development of medical imaging techniques, including CAT scans, magnetic resonance imaging, and emission tomography (Section 5). In the neurosciences the mathematical simulation of brain functions, especially through computer modeling, has come close enough to reality to be a powerful guide to experimentation. For instance, mathematical models have recently helped to elucidate studies in the formation of ocular dominance columns, patches of nerve cells in the visual cortex that respond to signals from only one eye. In addition, advances in neural network simulations are starting to have a significant impact on predicting how groups of neurons behave.

Recently DNA researchers have collaborated with mathematicians to produce some striking insights. When a new experimental technique allowed biologists to view the form of DNA under an electron microscope, researchers saw that DNA appeared tangled and knotted. Understanding the mechanism by which DNA unknots and replicates itself has led to the application of knot theory (a branch of mathematics that seeks to classify different kinds of knots) to DNA structure. At about the same time a breakthrough in knot theory gave biologists a tool for classifying the knots observed in DNA structure (see Section 10 for details). In addition, researchers are developing three-dimensional mathematical models of DNA and are applying probability theory and combinatorics to the understanding of DNA sequencing (Section 26).

Computers have brought sophisticated mathematical techniques to bear on complicated problems in epidemiology. One major effort is the mathematical modeling of the AIDS epidemic. Analysis of data on transmission of the human-immunodeficiency virus that causes AIDS has shown that HIV does not spread like the agents of most other epidemics. Various mathematical methods have been combined with statistical techniques to produce a computer model that attempts to account for the range of factors influencing the spread of the virus.

However, because of the complexity and size of the problem, researchers are finding current computational power inadequate and are looking for mathematical ways of simplifying the problem (Section 27).

The Physical World. The physical sciences, especially physics itself, have historically provided a rich source of inspiration for the development of new mathematics. The history of science has many examples of physical scientists hunting for a theoretical framework for their ideas, only to find that mathematical scientists had already created it, quite in isolation from any application. For example, Einstein used the mathematical theory of differential geometry, and, more recently, algebraic geometry has been applied to gauge field theories of physics.

Often the mathematical equations of physics cannot be solved precisely, and so their solutions must be approximated by the methods of numerical analysis and then solved by computer. Other problems are so large that only a sample of their solution can be found, with statistical techniques putting this sample in context. For this reason, the computer has become an indispensable tool for a great many physical scientists. The computer can act as a microscope and a telescope, allowing researchers to model and investigate phenomena ranging from the dynamics of large molecules to gravitational interactions in space.

The equations of fluid dynamics fit into the broader class of partial differential equations, which have historically formed the main tie between mathematics and physics. Global climate change is a topic of intense debate, and greater quantitative understanding—through the use of mathematical modeling and spatial statistics techniques—would greatly help in assessing the dangers and making reliable predictions (see Sections 6 and 17). One of the striking characteristics of today's applications is the range of mathematical subjects and techniques that are found to have connections to physical phenomena, from the applicaton of symplectic transformations to plasma physics (see Section 11) to the use of topological invariants in quantum mechanics (see Section 12). As the various subfields of the mathematical sciences themselves become increasingly interconnected, new and unexpected threads tying them to the physical sciences are likely to surface. Over the past decade the highly theoretical area of Lie algebras has illuminated the physical theory of phase transitions in two dimensions, which has applications to the behavior of thin films (see Section 14). The study of chaotic dynamics, which employs a range of mathematical tools, has demonstrated that unpredictable behavior can arise from even the simplest deterministic systems and has been used to describe diverse phenomena, such as the interfaces between fluids (see Section 7). Investigation of quasicrystals, a category of matter combining properties of crystals and glasses, utilizes the mathematical theory of tiling, which describes ways of fitting geometrical figures together to cover space.

Other areas of science and engineering have benefited from the close connections between the mathematical and physical sciences. Because of the increased power of instrumentation technology, many phenomena can be observed with a precision that allows questions to be formulated in terms of mathematical physics. In fact, computational methods in fluid dynamics have made it possible to model a host of phenomena in chemistry, astrophysics, polymer physics, materials science, meteorology, and other areas (see Sections 1, 2, 3, 4, 6, and 23). The degree of precision achieved by these models usually is limited partly by the modeling and physical understanding, and partly by the available computing power. Improvements to the mathematical model or algorithm can often significantly increase the actual computing power achievable with given hardware, and hence the degree of model accuracy.

Theoretical physics has often posed profound challenges to mathematics and has suggested new directions for purely mathematical research. One spectacular instance of cross-fertilization came with the advent of string theory. This theory proposes the intriguing idea that matter is not made up of particles but rather is composed of extended strings. Algebraic geometry, a highly abstract area of mathematics previously thought to have little connection to the physical world, is one of the ingredients providing a theoretical framework for string theory. In addition, string theory is supplying mathematicians with a host of new directions for research in years to come. Section 15 in Appendix B provides details.

The Computational World. Much of the research on algorithms is highly mathematical and draws on a broad range of the mathematical sciences, such as combinatorics, complexity theory, graph theory, and probability theory, all of which are discussed in Appendix B. A striking and recent algorithmic advance is the development of interior point algorithms for linear programming (Section 24), a mathematical method used in many business and economics applications. Linear algebra and geometry were used in the development of these algorithms, which have found many applications, such as efficient routing of telephone traffic.

In addition to the design of algorithms, the mathematical sciences pervade almost every aspect of computing: in designing hardware, software, and computer networks; in planning for allocation of computing resources; in establishing the reliability of software systems; in ensuring computer security; and in the very foundations of theoretical computer science. In addition, all kinds of computations are dependent upon the branch of mathematics known as numerical analysis, which seeks to establish reliable and accurate means of calculation. For example, a current success in numerical analysis is the application of wavelet analysis (Section 8), which grew out of a body of theoretical mathematics, to produce faster signal processing algorithms. Another area of current research is computational complexity, which mathematically analyzes the efficiency of algorithms.

In statistics, modern computational power has permitted the implementation of data-intensive methods of analysis that were previously inconceivable. One of these, the resampling method—which can be thought of as a Monte Carlo method in the service of inference—is finding a wide range of applications in medical science, evolutionary biology, astronomy, physics, image processing, biology, and econometrics. The subject is still in its infancy, and one can expect more sophisticated developments to be stimulated by new applications. Computers and statistics are symbiotic in other ways as well. The statistics community is becoming involved in the statistical analysis and design of computer models arising in science and industry. The use of randomization in algorithms (see Section 22) has proved to be highly successful in certain kinds of applications and has stimulated new research in the properties of pseudorandom number generators. Meanwhile, other statisticians are assisting computer science by developing statistical techniques for characterizing and improving software reliability.

As the language of computer modeling, mathematics is revolutionizing the practice of science and engineering. In many instances, computer simulations have replaced costly experiments, for instance in aircraft design (Section 3). From visualization of the folding of protein molecules (see Section 26) to calculation of combustion patterns (see Sections 2 and 3), mathematical analysis combined with computing power has produced profound insights. The development of reliable and accurate simulations requires both understanding of the scientific problem at hand and knowledge of the mathematical tools to describe and evaluate the model.

Operations researchers have applied mathematics to a range of industrial problems such as efficient scheduling and optimization of resources, and statistical methods are now commonplace in evaluating quality and productivity (see Sections 18 and 23). Control theory—an interdisciplinary field drawing on mathematics, computer science, and engineering—has applications to such problems as autopilot control systems, chemical processing, and antilock brake systems on cars.

The advent of communications technologies has depended on mathematical developments. Image processing, acoustical processing, speech recognition, data compression, and other means of transmitting information all require sophisticated mathematics. One surprising example of the application of theoretical mathematics to such areas came recently from a branch of number theory dealing with elliptic curves. It turns out that a research result from that area has produced an entirely new approach for efficiently packing spheres. Because communications signals are sometimes modeled as higher-dimensional spheres, this result will help in improving the efficiency and quality of transmissions.

Computer graphics have opened a whole world of visualization techniques that allow mathematicians to see, rotate, manipulate, and investigate properties of abstract surfaces. In particular, the subject of the mathematical properties of soap films—"minimal surfaces" that are visible analogues of the solutions to optimization problems in many fields—has witnessed a recent breakthrough and a resurgence of interest because of computer modeling, as described in Section 13. Computer visualization techniques have also contributed to understanding the mathematics of surface tension in crystalline solids. Computers are now routinely used in investigating many questions in number theory, a subject that examines properties of the integers and often finds application to such areas as computer science and cryptography. Symbolic manipulators—computers that perform operations on mathematical expressions, as opposed to numerical calculations—are powerful new instruments in the tool kit of many mathematical scientists and are increasingly being used in the teaching of mathematics.

The Unifying Science

The mathematical sciences have not only served as part of the bedrock on which science and engineering rests, but have also illuminated many profound connections among seemingly disparate areas. Problems that initially seem unrelated are later seen to be different aspects of the same phenomenon when interpreted in mathematical terms. In this way mathematics serves to unify and synthesize scientific knowledge to produce deeper insights and a better understanding of our world.

The mathematical sciences themselves are unifying in profound ways that could not have been predicted twenty years ago. The computer has lent unprecedented technological power to the enterprise, but mathematical sciences research still proceeds largely through individual creativity and inspiration. As the discipline becomes increasingly interconnected, progress in mathematics will depend on having many mathematicians working on many different areas. History has taught us that the most important future applications are likely to come from some unexpected corner of mathematics. The discipline must move forward on all of its many fronts, for its strength lies in its diversity.

The Production of New Mathematics

It is enlightening to note how so many of the research topics mentioned here and in Appendix B—for instance, the developments in partial differential equations, vortices, aircraft design, physiology, and global change—have developed out of the mathematical research described in the 1984 Report, both in its body and in Arthur Jaffe's appendix, "Ordering the Universe: The Role of Mathematics." The recent developments in number theory and geometry follow naturally from the Mordell conjecture, which was featured prominently in the 1984 Report. One can likewise see in the report of five years ago the roots of the recent developments in topology and noncommutative geometry. Although wavelet analysis was not mentioned in the earlier report, its roots in Fourier analysis were discussed. Similarly, the development of new algorithms was a prominent topic in the 1984 discussion, although the particular algorithms featured in Appendix B were not available then. These examples dramatically illustrate both continuity and innovation in mathematics.

It should be noted that much of the work discussed in Appendix B is the product of individual investigators. Mathematics is still very much "small science," with a tradition of individuals pursuing independent research. This is a strength because it allows the total enterprise to span a great many topics, remain flexible, and be responsive to the rest of science. However, the breadth required for many investigations calls for more collaborative work, which is practicable for mathematicians regardless of distance but is hindered in practice by the absence of adequate support for the occasional travel that is required. The recent innovations by the NSF (research institutes and science and technology centers) and the DOD (university research initiatives) provide valuable alternatives, both for established investigators and postdoctorals.

The continued production of valuable new mathematics requires not only that the number of individual investigators be increased as recommended in the 1984 National Plan, but also that the entire field reach out to the rest of the scientific world. Collaborating with researchers in other fields and making an effort to understand applications and improve the mathematical sophistication of others help the mathematical sciences become increasingly robust and valuable. The potential demand—in terms of the number of possible applications—for mathematics research is great, but the actual demand may be limited by failure of the mathematics community to communicate with others. Mathematics educators must design courses that meet the needs of the many students from other disciplines. Likewise, mathematical science researchers must write reviews and textbooks that are accessible to nonmathematicians. More of them need to make the extra effort to read journals and attend conferences outside their fields, to learn how to communicate fluently with potential users and collaborators, and to actively seek new opportunities for their work.

Finally, it is important to reemphasize that the research achievements and opportunities mentioned here and in Appendix B were selected from among a number of possibilities to illustrate the vigor and breadth of the mathematical sciences. This compilation is not intended to be comprehensive, nor is it intended to be a research agenda for the future. Many excellent new ideas and proposals will come to the fore as part of the natural development of the discipline, and these can and will compete for the attention of active researchers. The prospects are indeed bright.

Notes

[1]See, for example, *Mathematical Sciences: Some Research Trends*, Board on Mathematical Sciences (National Academy Press, Washington, D. C., 1988) for a very different set of topics. Other recent, more specialized reports also list significant research opportunities. These include the BMS advisory panel reports (to the Air Force in 1987 and the Navy in 1987 and 1990) mentioned in Chapter 2; the American Statistical Association report *Challenges for the '90s*, listed in Chapter 2; and *Operations Research: The Next Decade* ("CONDOR report"), *Operations Research*, vol. 36, No. 4 (July-August 1988), pp. 619–637.

[2]The NRC Board on Mathematical Sciences is producing a series of cross-disciplinary reports to foster this trend. The Institute for Mathematical Statistics has also addressed the trend in its report *Cross-Disciplinary Research in the Statistical Sciences* (Institute for Mathematical Statistics, Haywood, Calif., 1988).

4. The Problem of Renewal

The key problem facing the mathematical sciences today remains what it was in 1984: renewal. The pressing concerns of renewal are, Where will the mathematical talent come from? How can young talent be attracted to and retained in the career path? How can researchers be helped to remain active and be encouraged to serve as mentors for the next generation? The problem of renewal is crucial because of the increasing demand for mathematical scientists as educators and researchers.

Demand for Mathematical Scientists

Mathematics and familiarity with mathematical modes of thought are the foundations on which are built education in other scientific disciplines, and increasingly education in various areas of business, economics, and social science. Mathematical scientists are needed as educators to satisfy this growing demand, as well as to provide the increasingly sophisticated training of new mathematical scientists needed in increasing numbers by many quantitative areas of our complex society. United States Ph.D. production (supplemented by a large influx of foreigners) is at present barely sufficient to meet the current needs of our educational institutions, and demographers warn that faculties will need to grow after the year 2000 as the children of the baby-boom generation reach college age.[1]

Mathematical scientists are necessary also as researchers, because the expanding use of mathematics in all quantitative fields, the heightened mathematical sophistication of users, and the explosive growth in computer modeling are all fueling the demand for mathematics research.[2] Since World War II the trend toward quantification has affected not only traditionally quantitative areas but also such fields as biology, business, and economics. This trend seems to be continuing and even to be increasing, and it may be regarded as a natural phase of development that follows after observation, classification, and other qualitative methods alone become inadequate. Mathematics is vital to this progression because it is the language in which fundamental concepts and relationships can be precisely specified, manipulated, and extended for greater understanding. The spread of computer modeling has also generated a commensurate demand for mathematical expertise: mathematical scientists often provide critical steps in the process of developing computer models and algorithms, and they also address issues such as convergence criteria, error bounds, and expected asymptotic behavior, which are important for purposes of validation and control. Mathematicians need broad training in order to be responsive in this research environment.

Thus, to avoid serious declines in scientific and technological education, as well as shortages of urgently needed mathematical scientists at all levels, mathematical sciences Ph.D. production will likely have to increase in the near future. Assuring that the profession can attract bright young people is a goal to be addressed now, before large incremental demands for additional faculty and new mathematics strike.

Shortfall in Supply

The 1989 book *Prospects for Faculty in the Arts & Sciences*[3], by W. G. Bowen and J. A. Sosa, warns of near-term faculty shortfalls in U. S. colleges and universities. For instance, the authors project 9300 faculty openings in mathematics and the physical sciences in the period 1997 to 2002, but fewer than 7500 candidates, with the result that a maximum of only 80% of available faculty slots will be filled, assuming current student to faculty ratios. Bowen and Sosa project a very flat supply of mathematics Ph.D. degree holders seeking U.S. academic employment over the next 15 years, averaging just 356 annually.

Doctoral degree production in the mathematical sciences declined steadily over many years, falling from a peak of 1281 in 1972 to a low of 688 in 1985. During recent years the percentage of U.S. citizens receiving a Ph.D. in the mathematical sciences has dipped below 50%. Some evidence, albeit inconclusive, suggests that the increase in support given to graduate students and postdoctoral researchers since the early 1980s is beginning to have an effect. After three years of essentially flat Ph.D. production, data from the spring and summer of 1989 show that the total number of Ph.D.s awarded had increased by 12% over the previous year, to equal approximately the level of production in 1978. In addition, women constituted a record 24% of the U. S. citizen doctoral degree recipients. Whether or not these changes mark the beginning of a bona fide turnaround, the rate of influx of talent into the field will remain a high-priority concern for a number of years.

Reasons for the Shortfall

Changing Demographics. The problem of renewal is made more difficult by the shifting demographics of the United States. The report *Workforce 2000* (Hudson Institute, Indianapolis, Ind., 1987) has brought to public attention the dramatic changes occurring in the U. S. population and in the work force on which the economy depends. Its message that only 15% of net entrants to the work force between 1985 and the year 2000 will be native-born white males has surprised many people, driving home the point that in the future groups other than white males will provide much of the new talent for the nation.

This is a major issue in all the sciences, which are now so heavily dominated by white males. Science cannot continue to depend on the brain power of white males; their participation rate in the sciences would have to increase greatly to offset their declining numbers among work force entrants. Therefore, all branches of science must greatly increase efforts to attract and cultivate women and minorities. In mathematics, where women hold less than one Ph.D. in five and the numbers of blacks and Hispanics are almost vanishingly small, such efforts will need to be very intensive. The issues were vividly portrayed in the human resources chapter of the recent NRC report *Everybody Counts.*[4]

Cultural and Educational Problems. The problem of renewal in the mathematical sciences, exacerbated by changing demographics, must be seen and attacked in a broader context than that of graduate student recruitment and support. Attention must be paid to the entire mathematical pipeline, a requirement emphasized in *Everybody Counts*:

> The underrepresentation of minorities and women in scientific careers is well documented and widely known. Less widely known is the general underrepresentation of American students in all mathematically based graduate programs. Evidence of disinterest in mathematics permeates all racial, socio-economic, and educational categories, although the level of disinterest varies greatly among different groups. Young Americans' avoidance of mathematics courses and careers arises from immersion in a culture that provides more alternatives than stimulants to the study of mathematics. Without motivation and effective opportunity to learn, few students of any background are likely to persevere in the study of mathematics. ...
>
> Developing more mathematical talent for the nation will require fundamental change in education. Our national problem is not only how to nurture talent once it surfaces, but also how to make more talent rise to the surface. Although more must be done, the United States is reasonably successful in tapping and channeling the highly visible talent springs which develop without special support from formal schooling. But these sources are inadequate to our national need. We must, in addition, raise the entire water table.[5]

The forthcoming final report of the MS 2000 project will detail many crucial recruitment and educational reforms needed into the twenty-first century. All will require substantial input from the mathematics profession for planning and implementation.

What Discourages Talent. How do young people choose a career in the mathematical sciences? A very few young people with mathematical talent come into contact with interesting aspects of the subject and become committed to mathematics at an early age, but this is very much the exception. Most young people who decide to study mathematics make the commitment much later, balancing their aptitudes against the possible disciplines to pursue while weighing the quality of life offered in each profession. Obtaining information about mathematical careers is often difficult for the prospective mathematics major, because most teachers and other students are poorly informed about the possibilities. An unusually enthusiastic high school teacher, a professor in the early years of college, or some family friend or relative in the profession is the usual adviser. The picture they convey to the young student necessarily contrasts the joy of doing mathematics with the difficulty of obtaining support for graduate and postdoctoral studies, the heavy teaching loads even in the predoctoral years, and, after becoming established in research, the sudden decrease in the midyears in the ability to obtain research support. All this is in sharp contrast to career opportunities in the other sciences and in engineering.

The Leaky Pipeline. The mathematical sciences career path includes education from secondary school through the completion of the Ph.D., and professional development beyond that. In assessing the career path, this committee considered the quality of undergraduate and graduate education, the efficacy and efficiency of the process by which students become researchers and teachers, and the opportunities for continued professional growth throughout a mathematician's career. Renewal efforts critically depend on what takes place in doctorate-granting departments, and that is the milieu this committee addresses. Although problems exist throughout the career path, this discussion focuses on those that directly affect the production of research and researchers.

On a national level, evidence such as that shown in Figure 4.1 documents the leaky educational pipeline in mathematics. About half the students in the mathematics pipeline are lost each year. (Only U. S. citizen Ph.D.s are shown in Figure 4.1 because the chart represents the flow of U. S. students through the mathematics pipeline.) In high school and college, mathematics acts as a filter rather than as a pump; students are deterred, and mathematical talent is not identified and encouraged. As for graduate studies, the ratio of doctoral degree recipients to bachelor's degree recipients is lower in the mathematical sciences than in many other fields: over the period from 1971 to 1985, this ratio averaged 4% for the mathematical sciences, whereas it was 6% for engineering, 8% for life sciences, and 15% for the physical sciences.[6] Clearly, talent and productivity are being lost throughout the mathematics pipeline.

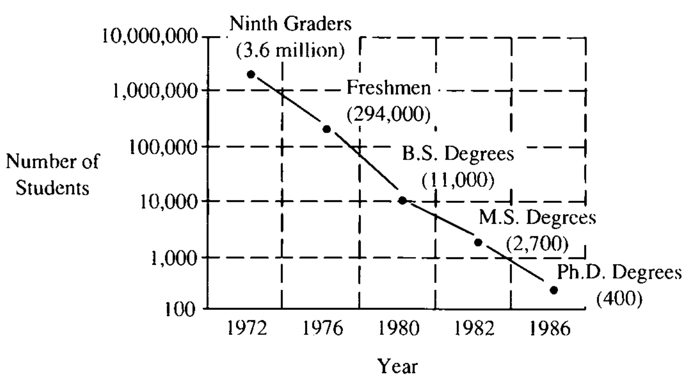

FIGURE 4.1. U.S. students in the mathematics pipeline.
SOURCE: From Mathematical Sciences in the Year 2000 project, reprinted from National Research Council, *A Challenge of Numbers: People in the Mathematical Sciences* (National Academy Press, Washington, D.C., 1990), p. 36.

Many career path shortcomings affect the production of Ph.D. mathematicians. In graduate school, only 18% of mathematical sciences students receive research funds to support themselves, compared to 28% in the social sciences, 45% in engineering, and 50% in the physical sciences (see Table 2.4). Upon receipt of a doctorate, the neophyte mathematical scientist does not generally have the benefit of postdoctoral research training, but moves directly into an assistant professorship. Only 21% of mathematical sciences junior faculty (assistant professors and instructors) active in R&D received federal support in 1987, compared with 53% in chemistry and 67% in physics and astronomy.[7] Further along the pipeline, only 18% of Ph.D. mathematical scientists in four-year colleges and universities surveyed in 1985 could call research their primary activity, as compared to 33% of chemists and 42% of physicists and astronomers.[8] The correlation between research funding for junior researchers and research activity in later years is striking. In addition, with the current reward structure, it appears that 82% of mathematical scientists who consider something other than research their primary activity are undervalued.

Mathematical sciences departments have adapted to these conditions but are unable to overcome them. While preparing this report, the committee asked four department chairs to write essays giving anecdotal accounts of problems and solutions. The problems described often stemmed from the fact that departments in the mathematical sciences have the broadest mission in the university, comprising research and graduate education, undergraduate education, upper- and lower-division service, and community outreach and education. Partial solutions often came from cooperation between departments and their administrations in choosing priorities among these missions and setting mutually satisfying goals.

How an increase in funding—in this case, from the university—can lead to marked improvements in overall departmental quality is reflected in one department chair's statement:

> Impending shortages of mathematicians and resulting increased competition between universities have made it more vital than ever to establish a first-class senior faculty ... [This] enabled us to argue for and achieve a general increase in salary levels ... In several cases research activity has improved as a result of the new climate in the department. Indeed, in some instances this has resulted in federal funding for those who had been off the rolls for some time. Faculty improvement has begun to have an effect on our resources for the future, especially with regard to the quality of our graduate students ... we now find a small group worthy of any institution.

The Reward Structure. Another chair's essay pointed out a problem with the academic reward structure: "A number of faculty develop instructional material, textbooks, and software [yet they] receive little recognition for these efforts, and a portion of the faculty attach negative weight to these activities. With our many missions, we have a responsibility to reward excellence in a broad range of activities." Another stated that "promotion or tenure without grant support is extremely difficult." Later, the same writer noted, "The implementation of [better courses for elementary and secondary school teachers] will require the participation of active mathematicians, although this is not always easily achievable because of the possible detrimental effects on one's career."

The current reward structure may be inferred from the results (Table 4.1) of a 1985 Conference Board for the Mathematical Sciences (CBMS) survey, which asked university department chairs to rate the importance of various professional activities to promotion or salary decisions.

Addressing the Shortfall

Recruitment. Recruitment requires an active effort on three fronts: improving the quality of the career path within mathematics, improving the external appeal of the profession, and performing recruiting drives. The first two lay the groundwork to maximize the effectiveness of the third, which is not discussed here. The quality of the mathematical sciences career path must be improved in order for recruitment efforts to suceed. Bowen and Sosa state:

> While many variables affect decisions to pursue graduate study, students are surely more likely to seek Ph.D.'s and to think seriously about teaching and research vocations, when employment opportunities in academia are attractive. The historical record offers strong support for this simple line of reasoning... [T]he number of newly awarded doctorates in almost every field increased dramatically in the 1960s. It is no coincidence that those were also the years when the number of academic appointments was growing rapidly, faculty salaries were rising, and financial aid for graduate study was widely available. Subsequently, the grim academic labor markets of the 1970s were accompanied by a sharp decline in the number of new doctorates earned, especially by U.S. residents.[9]

Table 4.1 Department Chair's Valuation of Professional Activities, 1985

	Valuation by Department (Percent)			
	Mathematics		Statistics	
Professional Activity	High*	Low*	High*	Low*
Published research	96	0	100	0
Talks at professional meetings	42	5	25	11
Supervision of graduate students	34	7	81	0
Classroom teaching performance	70	3	71	6
Undergraduate/graduate advising	9	22	21	21
Service to dept., coll., or univ.	31	5	31	11
Activities in professional societies or public service	22	8	31	6
Expository or popular articles	22	13	14	19
Textbook writing	9	35	12	50

* "High" means 4 or 5 on a scale of importance running from 0 to 5; "Low" means 0 or 1.

SOURCE: Adapted from National Research Council, *A Challenge of Numbers: People in the Mathematical Sciences* (National Academy Press, Washington, D.C., 1990).

It is reasonable that, in the absence of strong counter-influences, these same correlations hold for individual fields. A career in the mathematical sciences suffers by comparison with those in other fields, due to long-term effects of funding imbalances, so that recruiting efforts in mathematics are hindered. The 1984 National Plan and this committee's updated recommendations address precisely these problems.

Equal in importance to the effort to improve the career path is the need to improve the external appeal of the profession. The mathematics profession must reach out to students and the general public to show the value and accessibility of mathematics; the image of rigid, unquestionable theorems should be complemented by that of excited, creative, and inspired people developing *new* mathematics. This is part of the role of the Board on Mathematical Sciences, the Joint Policy Board for Mathematics, and the professional societies, but is also a challenge for individuals throughout the mathematical sciences community. The beauty, history, and excitement of mathematics are seldom conveyed to students; in fact, too often they receive the impression that mathematics is all 150 years old and stagnant, and that individuals cannot contribute except in limited and long-term ways. Thus the field appears uninteresting and intimidating.

Mathematics educators at all levels can reverse these negative images. Students who see computer-oriented work as glamorous need to learn that, without mathematics, the power of computers could not be applied to many real-world problems. Mathematical work crucial to global warming studies, aircraft design, or medical imaging devices should capture the attention of students who think that mathematics is irrelevant to modern developments. Two high school student winners of the 1988 Westinghouse Science Talent Search carried out new mathematics work, exemplifying the fact that newcomers can contribute. Advances such as wavelets and Karmarkar's algorithm show that it need not take decades for research to bear fruit. Finally, students should know that some 525,000 persons have received some mathematical sciences degree in the United States in the last 40 years. Most are still in the work force, yet three-fourths of them are working in areas other than the mathematical sciences. Clearly, a mathematical sciences degree provides a flexible foundation.

Many parts of the 1984 National Plan would aid recruitment by improving the career path to bring it more in line with those of other sciences, by increasing the attractiveness of a life in mathematical research, and by increasing the cadre of active, enthusiastic researchers, who serve as recruiters as well as mentors and positive role models.

Replenishment. Recruitment is just the start of renewal. If renewal is to be achieved, young people who choose to specialize in the mathematical sciences must first be well trained and then must be encouraged to remain active throughout their careers. The 1984 National Plan addresses both of these goals. The former can be accomplished by providing more research time for graduate students and postdoctorals, and by ensuring support for established researchers who will act as mentors. The latter can be attained by supplying a sufficient number of grants to encourage continued active research and professional development.

The laboratory sciences generally provide longer periods of direct interaction with faculty mentors than do the mathematical sciences: close contact in a research context begins early in a graduate student's career and extends beyond the doctorate for additional training. Beginning graduate students in the laboratory sciences may learn as much from advanced graduate students and postdoctorals as they do from the principal investigator—the group provides a mutually supportive and nurturing learning environment for all. The challenge for the mathematical sciences is to create an analogous environment for their own graduate students and postdoctorals.

The 1984 National Plan stipulates financial support for graduate student and postdoctoral research training, and, by recommending an increase in the number of established, funded investigators, provides for an environment that fosters mentor-apprentice interaction. Professors with good abilities and track records as mentors should be encouraged by, for example, being provided with their own postdoctoral funds, either individually or in groups.

An apprenticeship period is particularly important now because breadth is becoming vital to research in the mathematical sciences. Researchers have become more problem oriented, and so each investigator must be familiar with a wide variety of mathematical tools: unification of the field relies on, and demands, broader experience. Many mathematical scientists must also be adept in areas of engineering, biology, management science, or other disciplines. This breadth is apparent in much of the work profiled in Appendix B. The mathematical sophistication of researchers in many fields is increasing, with the result that mathematical sciences research problems are appearing more frequently in a nonmathematical context. The graduate student and postdoctoral research time stipulated in the 1984 National Plan would provide the quality training needed to renew the intellectual base of mathematics.

Unless its members possess diverse skills and interests, the field will not be able to respond to the demand for new mathematics arising in novel areas. The scientific and technological competitiveness of the United States is ever more dependent on our national ability to respond quickly to new developments, with minimal time to intellectually "retool." Unifying the mathematical sciences and linking them more strongly with other quantitative fields are important goals in today's globally competitive environment.

Replenishment of the field also demands that the potential of well-trained Ph.D. degree holders be realized. This can be fostered in part by supporting a larger cadre of individual investigators, including young investigators, as recommended in the 1984 National Plan. Research funding can also enable travel and workshop attendance, which expose researchers to new ideas, quicken their response to new research directions, and provide intellectual invigoration that can improve their ability to act as mentors. The availability of summer support would encourage a larger cadre of university mathematical sciences faculty to remain active in research. Although not all of these faculty members will carry on research throughout their careers, far too many currently cease such efforts within the first few years after receipt of the Ph.D.

Broadening the Reward Structure. The multiple roles played by mathematical sciences departments—providing general and specialized education for a large fraction of the college and university population, influencing society's mathematical knowledge through elementary and secondary school teacher training and expository writing, and developing new mathematics and future mathematicians—are all essential. Therefore, a corresponding reward structure is needed, so that people are encouraged to devote their energies to whichever of these valuable tasks best suit them. This change would make more efficient use of the human resources in the field. A revamped structure should include rewards for the following activities:

- *Teaching*—particularly conscientious and effective teaching at all levels, including the lower-division service courses and courses for prospective teachers. Tailoring courses for nonmajors, directing and improving the teaching abilities of graduate student instructors, and designing computer-oriented classes and their software are activities that must be encouraged.
- *Mentoring*—guiding and enhancing the education of undergraduate majors, graduate students, and postdoctorals. Good mentors devote time and energy to this process, honing their methods and maintaining broader interests than those necessary to do research alone, so as to give their apprentices the breadth and depth required of today's mathematicians.
- *Outreach*—collaborating with people in other fields, recruiting good students, particularly from among women and minorities, and communicating with local education professionals and with industry. Since the long-term health of mathematics depends on maintaining strong ties with the other sciences, recruiting top-quality people, and satisfying the mathematical needs of society and industry, departments and universities should encourage—and reserve funds for—all of these outreach efforts.

In short, there should be a broader spectrum of respectable careers available to people educated in the mathematical sciences.

Notes

[1]Current mathematics faculties cannot accommodate this growth. The number of full-time mathematics faculty at research universities actually decreased by 14% over the period 1970 to 1985; the simultaneous 60% increase in course enrollment was handled by tripling the number of part-time faculty.

[2]The demand for nonresearch mathematical scientists is also growing. The number of secondary school mathematics students will rise before the college population does, requiring more

mathematics teachers. And the projected demand for mathematical scientists at all levels is expected to increase by 29% between 1986 and 2000, compared to a 19% growth in overall employment. Many of these people will be employed in science and engineering. Considering all degree levels, the employment of mathematical scientists has already tripled over the period from 1976 to 1986, showing a 10% annual growth rate second only to that for computer specialists among the science and engineering fields.

[3]Bowen, W. G., and Sosa, J. A., *Prospects for Faculty in the Arts & Sciences*, (Princeton University Press, Princeton, N.J., 1989).

[4]National Research Council, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Academy Press, Washington, D.C., 1989).

[5]National Research Council, *Everybody Counts*, 1989, pp. 17-18.

[6]Data from Table 2.1, National Research Council, *A Challenge of Numbers: People in the Mathematical Sciences* (National Academy Press, Washington, D.C., 1990).

[7]Data from the Survey of Doctoral Recipients project office, National Research Council (personal communication).

[8]*Doctoral Scientists and Engineers: A Decade of Change*, NSF 88-302 (National Science Foundation, Washington, D.C., 1988).

[9]Bowen, W. G., and Sosa J. A., *Prospects for Faculty in the Arts & Sciences*, p. 162.

5. Recommendations

The 1984 Report described serious deficiencies in the situation of the mathematical sciences (see Appendix A). These shortcomings were reflected in the inability of the mathematical sciences research community to renew itself by attracting a suitably large and talented cohort of students, and they suggested the prospect of declining productivity in research activities. The 1984 Report recommended a plan for renewal, the National Plan for Graduate and Postdoctoral Education in the Mathematical Sciences, which called for mathematical sciences funding to balance that in the principal disciplines it supports, namely, the physical and life sciences and engineering. That 1984 National Plan has been only partially carried out: funding has risen to some $130 million per year, a figure that is about $100 million per year short of the 1984 plan's goal for 1989.

Primary Recommendations

The committee believes it is imperative to meet the goals set out in the 1984 National Plan, but the funding to meet those goals should be increased to $250 million per year, $225 million to cover the present cost of the 1984 National Plan, plus $25 million to support coherent programs that can effectively address the career path problems. In the committee's judgment this funding level, if achieved within three to five years beginning in FY 1991, will result in a reasonably balanced situation, one that will allow the mathematical sciences community to replace retiring members and also supply the growing needs of industry and government. Note that the recent report by W. G. Bowen and J. A. Sosa[1] estimates that the supply to demand ratio for mathematics and physical sciences faculty in the 1990s will be only 0.8. This projection is doubly worrisome for the mathematical sciences with their existing renewal difficulties.

Increased research funding alone will not be adequate to assure the renewal of the mathematical sciences. Other serious deficiencies in the mathematical sciences career path make it less attractive to students than the paths in the other sciences and in engineering. These deficiencies include markedly less opportunity for faculty research, fewer graduate research postions with stipends, and fewer postdoctoral research positions. Then, too, students seem to perceive a sink-or-swim attitude among many mathematical sciences faculty members.[2] These deficiencies exist despite efforts to increase graduate student funding and postdoctoral opportunities over the past five years. The drop-out rate from the mathematics career pipeline (beginning at the undergraduate level and terminating at the doctoral level) averages 50% per year, which is markedly higher than the corresponding rates in the other sciences and engineering.

A significant part of any increased funding over the coming five years should be used for coherent programs operated by departments, faculty groups, or even individual faculty members to (1) improve recruiting of qualified students, particularly women and minority students, (2) keep students within the field by providing mentors at every educational level, (3) provide research opportunities at all stages of students' careers, and (4) provide improved research opportunities for junior faculty and better access to research facilities and collaborators for senior faculty. The reward structure for mathematicians should be modified to credit involvement in such activities. Comprehensive, integrated programs should be encouraged and even solicited by funding agencies as part of their mathematical sciences activities. The National Science Foundation has already taken steps in this direction.

Thus this committee's three primary recommendations are as follows:

I. Implement the 1984 National Plan, but increase the level of federal funding for the mathematical sciences to $250 million per year. (The 1984 plan's goal of $180 million per year has risen due to inflation to $225 million, to which this committee has added $25 million per year for implementing Recommendation II).

II. Improve the career path in the mathematical sciences to continue to attract sufficient numbers of talented people and to use the entire human resource

base more effectively. Implementation of the 1984 National Plan by itself would accomplish much toward this goal. The committee estimates that $25 million per year of the federal funds called for in Recommendation I will significantly augment the 1984 National Plan through the funding of coherent programs aimed at *directly* encouraging young people, especially women and minorities, to enter and remain in mathematical sciences careers. Mathematical sciences departments should give increased recognition to faculty who act as mentors, who contribute to education, and who interact with collaborators from other disciplines, while universities should do more to help their mathematical sciences departments meet their multifaceted missions; these actions would improve the career path and thereby *indirectly* encourage young people to enter and remain in mathematical sciences careers. Cooperation between university mathematical sciences departments and their administrations is critical for successful implementation of this recommendation.

III. Because a wealth of striking research problems—many with potential applications to modern science and technology—currently challenges mathematical scientists, and because added intellectual stimulation will contribute to the renewal of the field, increase to 2600 (the level recommended in the 1984 National Plan) the number of senior investigators supported annually. This goal is implicit in Recommendations I and II, but it demands clear emphasis.

Mathematical sciences research has been highly productive over the past five years. Furthermore, mathematicians have become increasingly interested in transferring new mathematics into applied fields and in working with users of mathematics. These trends are bringing core and applied mathematics closer together as well as integrating formerly distinct fields of mathematics. The resulting vigor has been augmented by the rise of computation as a tool in research. Indeed, the pace of research in the mathematical sciences is accelerating. Thus the increase in productivity from additional funding is likely to be disproportionately large. In the United States there are some 1900 federally supported senior investigators. The committee estimates that an additional 700 highly productive mathematical sciences researchers are not supported. These people, who represent an opportunity to sustain the vigor and productivity of the field, should be given adequate funding.

Finally, the committee emphasizes that a vigorous mathematical sciences enterprise in the United States is essential to addressing the educational shortfalls so widely perceived by the public and their representatives. Too few primary and secondary school teachers are qualified to teach mathematics. Yet it is at this level that students often decide that they can or cannot undertake careers in science or engineering. Mathematics is perceived as a barrier to students who might otherwise make ambitious career choices: this is especially true for women and minorities.

Mathematics faculties in colleges and universities directly and indirectly affect the quality of primary and secondary school mathematics teaching. Preparation and continuing education for these mathematics professors must be improved if the United States is to remain competitive in science and technology. Mathematics education is crucial to achieving international competitiveness in all the sciences. Major initiatives, as suggested above, are critical to any serious attempt to address the educational problems so often lamented publicly. The health and vigor of the mathematical sciences is a vital index in judging the prospects for national attempts to solve the science-based problems of U.S. society.

Directed Recommendations
Federal Agencies:

- *Agencies Collectively.* Continue to encourage the internal unification of the mathematical sciences and their outreach to other fields. Support efforts toward community-wide implementation of the career path improvements called for in Recommendation II. Continue to push for adequate funding for the mathematical sciences and especially for the support of significantly more senior investigators.
- *National Science Foundation.* Begin to increase the number of supported senior investigators in the mathematical sciences. Continue to increase the number of supported graduate student researchers and postdoctoral researchers. Work with national groups to address issues involving human resources.
- *Department of Defense.* Push for real growth in the mathematics budgets of the Air Force Office of Scientific Research, the Army Research Office, and the Office of Naval Research. Continue the progress of the DARPA and NSA programs. Persuade the leaders of Department of Defense agencies to appreciate the importance of the mathematical sciences for national defense and to understand that the long-range prospects for defense of the country must rest on a strong, continuing research base.
- *Department of Energy, National Institutes of Health, and National Aeronautics and Space Administration.* Reevaluate programs to take advantage of the role the mathematical sciences can and do play. Increase support for the mathematical sciences, which currently is concentrated too much in the NSF and DOD. This can have an adverse impact on the nation's total science, engineering, and technology research and education, especially if DOD funding of mathematics does not increase. Recognize that the future

quality of technology bases affecting agency missions is dependent on the mathematics being done now.

- *Office of Science and Technology Policy.* Send a clear message to the federal agencies that reversing past declines in the mathematical sciences is a continuing national priority.

Universities. Recognize the central importance of healthy mathematical sciences departments to any university. Conduct in-depth reviews of the circumstances of mathematical sciences departments and work with department chairs to develop and emphasize plans for departmental improvement. Discuss and clarify the department's mission and goals and the administration's expectations of faculty members. Plan coordinated action to address career-path and reward-structure issues and undergraduate and graduate education standards.

In addition, work as intermediaries between mathematical sciences departments and local government and industry. Apprise state technology offices of the importance of mathematics to the quality of education and to the local economy. Make industry aware of the contributions that mathematical scientists can make as both researchers and teachers.

Department Chairs and University Administrators. Make special efforts to recruit women and minorities. Reassess and broaden reward structures so that they reflect the broad missions of mathematical sciences departments: research, service teaching, undergraduate and graduate education, and contributions to the national precollege mathematics education effort. Reevaluate the use of graduate teaching assistantships, being mindful of the twin goals of high-quality undergraduate instruction and well-balanced Ph.D. training.

Mathematical Sciences Community. Maintain the tradition of first-class research. Focus more attention on career-path problems (Recommendation II). Offer better training, including a commitment to a system of mentors for graduate students and postdoctorals. Create programs that provide the breadth necessary for today's mathematics research and applications. Establish guidelines for evaluating and improving mathematical sciences Ph.D. programs. Recognize the breadth of the mathematical sciences academic mission.

Notes

[1]Bowen, W. G., and Sosa, J. A., *Prospects for Faculty in the Arts & Sciences* (Princeton University Press, Princeton, N.J., 1989).

[2]This observation has been made about faculty members in all of the sciences; see, for instance, Kenneth C. Green, "A Profile of Undergraduates in the Sciences," *American Scientist*, Vol 77, No. 5 (Sept.-Oct. 1989), p. 478.

Applying for NSF Support: Advice for Young Researchers

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When applying for a research grant, a young mathematical scientist faces keen competition for limited funds. The quality of the research proposed and the qualifications of the researcher are major criteria in evaluating a project for funding. However, chances for funding can be improved if the application is carefully written and is based upon an understanding of how it will be evaluated. In this article, the authors' discussion centers upon the National Science Foundation.

1. Introduction

This paper is written primarily for able young researchers in the mathematical sciences with limited experience in applying for research grants. Funds for research are available from a number of government agencies and private foundations. The discussion here will center upon the National Science Foundation (NSF), an especially important source of support for young researchers residing in the U.S.

The crucial ingredients of a successful grant application are some sound research problems (one or a few) together with realistic plans for pursuing their solutions and a convincing case that the proposer has had past success with problems of similar difficulty. No amount of "grantsmanship" can improve a mediocre project. However, in view of the keen competition for limited research funds, the success of a grant application or **proposal** often depends upon how effectively it presents the researcher's ideas. Particularly in the case of young investigators, an effective presentation of the problems and of their relevance will provide important evidence of ability to complete the project.

This paper contains our personal views on how young researchers can effectively approach NSF for funding. Our opinions are based on our experience as former NSF program directors, but this paper has no official standing.

Several NSF informational booklets [1-3], available free of charge, are required reading for mathematical scientists seeking NSF support. This paper assumes that you have access to them. Notational conventions: Numbers in brackets refer to publications listed in the references. Required sections of an NSF proposal, as specified in Part I of [1], appear in SMALL CAPITALS. Where NSF jargon must be used, it is introduced in **boldface**, e.g., the word **proposal** above.

2. Getting Started

It would not be inaccurate to view NSF as a complex government bureaucracy with hundreds of employees handling thousands of proposals a year, usually taking half a year to respond to any one of them. However, you will increase your chances for support if you focus upon the particular NSF program that matches your current research interests, deal with the relevant **program director** on a person-to-person basis, and understand what happens to a proposal after you submit it to NSF. To set the stage for the discussion on proposal preparation in Section 4, this section and the next give you an inside view of some aspects of NSF organization and procedures.

2.1. The Division of Mathematical Sciences

Theoretical research and some applied and methodological research in the mathematical sciences are supported by the Division of Mathematical Sciences (DMS). In seeking a home at NSF for your research, this is the logical place to start. See [2] for a list of programs within DMS and Appendix VII of [1] for telephone numbers. Information in [3] and a look at the titles of grants and the names of investigators listed in [4-12] will help you to learn what subject matter is covered by each of these programs. However, many research topics span more than one program, and programs have fuzzy boundaries. This is why the program directors will make the ultimate decision as to which program will "house" your proposal.

If your research deals mainly with applications to the physical, biological, social, behavioral or computer sciences, then [2] will help you to learn about other programs that may support your work. [18] offers advice for those contemplating a proposal to a program in the social or behavioral sciences.)

2.2. Personal Contact and Submission of Proposals

Program directors in DMS are either career NSF employees or faculty members who have taken leave from regular university positions to work at NSF for one or two years. In either case, you can expect a DMS program director to be a professional scientist knowledgeable about the general area of your work and about academic life.

If you decide to submit a proposal to a DMS program, you should call ahead, perhaps during the late Summer or early Autumn. Give a capsule description of the work you intend to do and ask to talk to the program director who will handle proposals in that area. This call will introduce you to the person at NSF who will be most directly involved with your proposal and allow him or her to better understand your project. This is also a chance for you to ask about any points of procedure that are unclear to you. However, do not expect program directors to act as your research consultants or your private tutors in grantsmanship.

Officially, proposals may be submitted to DMS programs at any time of the year, provided that you allow six months for NSF to process your proposal. However, in a typical year the programs are out of money between mid-May and mid-September, so the *best* time for most young investigators to submit a proposal to DMS is from mid-September to mid-November. (Some programs outside of DMS have firm deadline dates for proposal submission.)

You can help keep your proposal from being delayed in its early travels at NSF by listing the program of submission in the first box on the COVER PAGE, e.g., "DMS–Algebra and Number Theory." When it has been entered into the NSF computer system and assigned a proposal number, you will receive a postcard acknowledging its receipt; allow several weeks for this.

3. Proposal Evaluation

Crucial to writing an effective proposal is an understanding of how it will be evaluated once it reaches NSF.

3.1. The Merit Review System

NSF uses what is called the **merit review system** to evaluate proposals. Under this system, the primary information for evaluating your proposal comes from fellow scientists who perform their services without pay. They are asked to evaluate proposals according to the NSF criteria explained in Part II of [1], including assessments of the merit of your research idea and your competence to do the work. If the applicant has received previous NSF support, reviewers are also asked to comment on the results. (See [13] and its references for additional insight into the NSF review process.)

Shortly after your proposal arrives in its designated DMS program, your program director will scan it and select about five initial reviewers to evaluate it. As we see below, the choice of reviewers is subject to guidelines that help to ensure balance and objectivity. The DMS review process is generally conducted by mail. (Some specialized DMS programs and programs in divisions other than DMS use **panels** of reviewers, which meet as a group to evaluate large numbers of proposals at a time, often with the benefit of some previously solicited mail reviews.)

Often the program director must choose additional reviewers if not enough of those in the first group respond in a timely fashion or if differences of opinion arise in the early reviews that he or she wants clarified. Reviewers are a scarce resource to whom the mathematical community owes a great deal of gratitude. The sequential approach can be slow, but it uses reviewers efficiently.

3.2. How Reviewers are Chosen

Reviewers of your proposal are chosen to provide two kinds of assessments. Some of your reviewers will be experts in your subfield, selected for their ability to comment on the technical details of your proposal. Probably one or two will be chosen specifically because they can view your proposal in perspective, evaluating the importance of your work to the field as a whole. Often the same reviewer will give evaluations of both kinds.

Among those restricted from evaluating your proposal are people who would profit financially from its funding, colleagues at your campus, and your present and recent collaborators and teachers. For this reason, your BIOGRAPHICAL SKETCH must include a list of all colleagues with whom you have worked closely during the past four years. You should also show your thesis and give the name of your thesis advisor. If there is anyone else you feel may have a **conflict of interest**—positive or negative, personal or professional—in reviewing your proposal, you should let the program director know this in confidence.

Choosing reviewers is one of the program director's most intricate tasks. At any given time, the number of proposals in an area may be quite large and any one reviewer can be asked to evaluate only a few of them. Thus, the program director must consider dozens of potential reviewers with expertise in each of the relevant specialties and try to make the best choices from among them for each proposal.

You can help your program director to do this work efficiently. Take care that your abstract (PROJECT SUMMARY) is clear and well focused, ending it with a short list of key words. Reference to entries in recent issues of such bibliographic references as *Mathematical Reviews*, *Current Index to Statistics* and *Science Citation Index* may help the program director to narrow the field of potential reviewers to those who are especially well-qualified to comment on your proposal. Your BIBLIOGRAPHY may also be a source of possible reviewers for your proposal. Finally, a proposer may submit a list of a dozen or so possible reviewers, but young researchers may not yet know their colleagues well enough to use this option to their advantage.

3.3. The Decision

A review consists of two parts: a narrative commentary and a rating. In many cases reviewers' comments carry more weight than their ratings, but some explanation of how ratings are used may be useful. The rating scale is ordinal with official definitions of the categories Excellent, Very Good, Good, Fair, and Poor (abbreviated as E, VG, G, F, and P, respectively). Some reviewers treat the scale as continuous, giving ratings such as E-, E/VG, or G++.

Based on the reviews of your proposal, reviews of competing proposals, and the program budget, the program director makes a recommendation on funding your proposal. The ratings of each review are tempered in view of the substance of the reviewer's comments and in view of how his or her ratings of any past proposals compared with those of other reviewers. Program directors are also aware that dedicated researchers are understandably enthusiastic about the importance of their own philosophies or specialties and that this may cause biases in their reviews of your proposal. Finally, the program director must take into account such factors as the balance of funding among the various subfields within the program, the age distribution and geographical distribution of those supported, and the need to bring underrepresented groups into the mainstream of research funding.

The program director's recommendation and reasons for it carry heavy weight in determining how grants are made, but they are not final. Because program recommendations are reviewed at several higher administrative levels before a final decision is made, you cannot expect your program director to make promises or predictions about the outcome of your proposal.

3.4. Keen Competition

By the standards of the federal government, NSF is a small agency – its annual budget would keep the Department of Defense going for only two or three days. In round numbers, NSF spent about $2 billion in support of research in fiscal year 1990. Of this total, the DMS budget was about $70 million. Depending on exactly how one counts, this budget supported about 1500 researchers. Even though some funding for the mathematical sciences comes from other NSF programs and from other federal agencies, it is clear that there is keen competition for research funds. It has been reliably estimated [17] that only about 10% of college and university faculty working in the mathematical sciences receive federal funding. Even though many active researchers do not apply for funding every year, an increasing number of well-qualified young researchers must compete with each other and with established researchers for the limited funds available.

About 40% of the proposals to DMS for new projects were funded in 1989. Even though the program director's evaluation is a complex and subjective one based on much more than the ratings, it is fair to say that in recent years funding has gone to almost all proposals with average ratings nearer to E than VG, to much less than half of those averaging around VG, and to very few with lower average ratings. In our experience, most of the funded proposals in the VG range are from young investigators.

3.5. Useful Feedback

Whether or not your proposal is funded, you will receive copies of all the comments and ratings in your reviews, but you will not be told the names of the reviewers. (If your proposal is submitted jointly with other researchers, only the first-named **principal investigator** (PI) receives these copies.) You may find that some personal references have been edited out of your reviews to protect the privacy of others. Example: "This is a far more important proposal than the one by [ ] that you sent me in the same mailing, but somewhat less exciting than the [ ] proposal that I reviewed last year."

Read your reviews carefully and as objectively as possible. Young researchers in particular should not hesitate to call the program director to discuss reviews. Undoubtedly, some of the reviews weighed much more heavily than others in his or her recommendation on your proposal. Knowing the reviewers' identities, for example, the program director may know that one reviewer's "In over a decade of intensive work in this area ..." presages a lot less insight than another's modest "In the last few years, I have not kept up with this field as well as I would have liked, but ..."

Whether or not you receive an award, try to find out from your program director in rough qualitative terms whether your proposal was rated near the borderline, far above it or far below. This information, combined with comments in the most important reviews, can be particularly valuable to a young investigator in deciding how to allocate research efforts and how to improve future proposals.

If your proposal was **declined**, but came close to being funded, you should consider whether to submit another one next year based on similar research ideas. Think about how you could use reviewer feedback and your own evolving perspective on the idea to improve the currency, relevance, clarity, focus, depth, and/or breadth of your next proposal. It often takes young investigators several tries before the first success. But NSF will not review another proposal on the same topic unless you make substantial revisions.

4. Writing Your Proposal

A proposal to NSF may include the work of one or more researchers. For the present, let us assume that you plan to apply alone. Partly, the task of writing a proposal consists of following the instructions in Part I of [1]. This section looks beyond the instructions to some techniques of effective presentation.

The medium of technical writing most familiar to young scientists is the research paper. *A proposal is not a research paper.* A paper reports work you have done; a proposal outlines and seeks support for work you hope to do. A typical research paper is read by a sizable audience of people interested in its specialized topic; a good proposal is tailored to the diverse needs of the very few who will read it. Most papers are revised between submission and publication; the submitted version of a proposal is the only version that counts.

4.1. Your Best Ideas

Your PROJECT DESCRIPTION should make a convincing case that your ideas can lead to exciting new developments in your field—fundamental advances, insights that show new connections among important ideas in several areas, original results that others will seek to build upon in their work, or concepts that will lead to important new kinds of applications. For example, if you intend to fill in a gap in a program of research that an established researcher has pursued successfully for a number of years, you should explain why your topic could become a chapter heading rather than a footnote in The Book about this area. Reviewers will be especially dubious if it appears that you are proposing to embellish your thesis to produce results that are of limited interest, even if they are technically difficult.

Remembering that the program director and perhaps one or two of your reviewers may not be specialists in your subfield, you should begin with a brief history or survey of recent developments surrounding your research. Show how your idea fits in and why it is important. If you are aware of connections to theoretical ideas in other fields or of potential applications, you should mention them and say whether you propose to explore them. Of course, you must also include enough technical detail that specialists in your area can understand the precise nature of your project.

Your BIBLIOGRAPHY can be an effective way to communicate with your reviewers. Include all of the papers upon which your work is based. Some reviewers may welcome a reference to a relevant survey paper, if one is available. The ones who are technical experts will expect to see references to their own work on closely related problems, even if your methods do not build on their results. This is not just a matter of ego: the best way for reviewers to think about your problem is to see how it relates to ones they already understand well. Thus, short bibliographies that include mainly references to your own work are not recommended.

4.2. Method, Time, and Money

Your PROJECT DESCRIPTION should include a research plan, in which you discuss how you intend to attack the problems you propose to solve. It is not expected that you will be able to predict exactly the path that your research will take or that you can foresee what results you will obtain. But it is important to show that you understand what you are up against and that you have some reasonable methods of attack in mind. This part of the proposal is *crucial* for young investigators (and often treated too lightly by more established ones).

You should tell what mathematical techniques you intend to use. If you have some preliminary results, you should indicate how you got them and say whether you expect the same methods to work more generally. If you have decided that the methods other researchers have used for related problems will not work for your problem, you should explain—tactfully—why not. Unless it is crucial to your exposition, you should avoid negative comments on the work of other mathematicians.

Another important part of your proposal is a realistic assessment of the time, money, and other resources you will need in order to do your research. The basic annual BUDGET for a grant in the mathematical sciences consists of money for two months of salary (usually used during the summer); any necessary money for computing; a $2500 (the 1990 figure) allowance towards travel, publication charges, secretarial help, etc.; plus university overhead charges. Most grants to young investigators are limited to one, two, or possibly three years of support at this spartan level. With strong justification, a grant might also include funds for items such as computing equipment or programming assistance. Money for assistance necessitated by a physical handicap should be requested.

It is most unlikely that a grant for a young investigator will include graduate assistants, postdoctoral associates, additional paid research time during the regular academic year, etc. (Grants to established researchers sometimes carry a commitment for three years of support, subject to annual progress reports and updated research plans. They sometimes include limited funds for graduate students and postdocs; but they rarely exceed the $2500 annual allowance per investigator.)

There are signs that grants in the mathematical sciences are gradually emerging from the "one man and his blackboard" view of funding. Using the information in the last paragraph as a realistic base, you should request what you really need in order to do efficient research for one or two years. You will not get more than you ask for and a **properly defended** request for more than the basic amount will not diminish your chances of getting a grant. (An outrageous request may draw the wrath of reviewers.) If your proposal is favorably reviewed, the worst that can happen is that your budget will be cut.

4.3. Your Credibility

An important question in the evaluation of your proposal is whether you have the required technical expertise, vitality, and self-discipline to carry out your research plan. For an established scientist, his or her history of published research on related topics, detailed in the BIOGRAPHICAL SKETCH, provides a strong indication of the performance that can be expected. As a young researcher you may not have had time to establish such a "track record." Furthermore, as we have already seen, some of the people who know you best are prohibited from reviewing your proposal. Thus, you must take full advantage of the opportunities that you *do* have to establish your credentials to perform.

As this is written, the rules are that your BIOGRAPHICAL SKETCH may list up to five of your papers relevant to your proposal and up to five additional papers, but this recently instituted format may be subject to change.* In any case, make sure that the most important work you have done is listed and accessible. If you have finished a paper that shows your abilities to good effect, list it in your vita (and also in your BIBLIOGRAPHY, if appropriate) and attach a preprint or reprint as an appendix to your proposal. This is particularly important for young researchers and for relevant papers not yet published. However, your PROJECT DESCRIPTION must stand on its own; it should not require reviewers to look at the appendix.

*[Editor's note: This ruling has been suspended. See "NSF Proposal Format Changes–Update" on page 687 of the 1990 July/August issue of *Notices*.]

4.4. Unofficial Pre-reviewers

Start work on your proposal early enough that you can develop it through several drafts and still submit it by the desired date. During this process, try to get a variety of colleagues to read your emerging proposal and to offer constructive criticism. Preferably these should include at least one technical expert in the area of your work, an experienced researcher who has written successful proposals, and someone a bit outside your area of specialization who can judge whether you have made a generally persuasive case for the importance of your project.

It is easy to get so involved in writing about your own research work that you become a poor judge of what others will see in your proposal. If you find yourself having to clarify, explain or amplify some parts of your proposal for these "pre-reviewers," then you probably need to do another draft. The finished version must speak clearly and convincingly for itself.

Finally, proofread your finished proposal carefully before you submit it. Serious grammatical and typographical errors can obscure your meaning and make you look foolish. To some reviewers minor errors are merely distractions; sterner reviewers take them to be evidence of sloth or incompetence.

4.5. Various Opportunities

Applying on your own for a standard research grant puts you into direct competition with other researchers of all ages and levels of past accomplishment. Even though it is a competition judged with sensitivity to the needs of young investigators, it is the least sheltered of the ways you can seek NSF support.

You may want to consider a joint proposal with others who share your research interests – at your university or elsewhere. This can be a particularly attractive option if one member of the group is a senior researcher who has experience in writing proposals. If not all members of the group are at the same university, read about subcontracts in Part I of [1] and Research Opportunity Awards in Chapter 7 of [2] and talk to your program director about your plans. If you received your Ph.D. less than five years ago, the PI of a proposal or of an ongoing grant may request you as a postdoctoral researcher on his or her project.

See [2], [3], [14], [15], and [16] for discussions of Mathematical Sciences Postdoctoral Research Fellowships, NSF-NATO Postdoctoral Fellowships in Science and Engineering, and Presidential Young Investigator Awards. All three involve keen competition among candidates from diverse disciplines, are evaluated by specially chosen panels of scientists, rely heavily on letters of recommendation for evaluation, and especially encourage applications from women and minority researchers. (The two postdoctoral programs listed above are quite different from postdoctoral support under someone else's grant.)

NSF has a variety of programs for members of groups that have not historically received their share of research support: persons employed at predominantly undergraduate institutions, women, minorities, and the handicapped. If you are a member of one of these groups, you should look at Chapters 6 and 7 of [2], request additional information brochures where available, and consult your program director to see whether you are eligible for one or more of these programs. If so, you should strongly consider applying.

5. Concluding Remarks

We want to end this discussion with a few words of caution, hope, and thanks.

By definition, official documents such as [1] are applicable to all cases. They can be difficult to read because, in order to be universal, they must use specialized terminology and state general principles that apply across the full range of disciplines supported. Here we have tried to use official jargon sparingly and to be specific about how the general principles apply to mathematical scientists. We hope the result is readable and useful, but the disadvantage is that there will certainly be exceptions to what we have written.

In this paper we have taken the pragmatic approach of describing the funding picture for young investigators as we believe it to be. This should not be taken as a defense of the *status quo*. Clearly, NSF has given considerable attention to the special needs of young researchers. Even so, the current picture is a patchwork of exceptions and special programs - some of them quite effective, some not. It is time to establish a coherent, adequately-funded plan for the identification, development, and support of outstanding young scientists that starts at the undergraduate level and continues for several years after the doctorate.

Acknowledgment

This paper is largely based upon B. E. Trumbo's, How to get your first research grant, *Statistical Science*, **4**, 121-150 (1989), which was addressed to an audience of young statisticians and was written while Trumbo was on sabbatical leave from California State University, Hayward. Among others too numerous to mention, Ingram Olkin, Nancy Flournoy, Paul Shaman, Judith Sunley, Murray Aborn, and the late Morris DeGroot made contributions to that paper which carry over to the present one. This abridged version, written for a general audience of young mathematical scientists, also benefits from the comments that accompanied [19]. See that paper, its references, and the accompanying commentaries for more information.

References

[1] *Grants for Research and Education in Science and Engineering* (NSF 83-57).

[2] *Guide to Programs* (NSF 89-63).

[3] *Opportunities in the Mathematical Sciences* (NSF 89-111).

[4-12] *Division of Mathematical Sciences - Summary of Awards* [Nine individual publications, one for each DMS program.]

[13] *Proposal Review at NSF: Perceptions of Principal Investigators (Report of a Survey by NSF's Program Evaluation Staff)* (NSF 88-4), February 1988.

[14] *Mathematical Sciences Postdoctoral Research Fellowships (with Research Instructorship Option)* (NSF 87-59).

[15] *NSF-NATO Postdoctoral Fellowships in Science and Engineering* (NSF 87-50).

[16] *Presidential Young Investigator Awards* (NSF 86-22).

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[18] Levine, Felice J. (1986). Social and Behavioral Science Support at NSF: An Insider's View. *Guide to Federal Funding for Social Scientists* (Ed.: Quarter, Susan D.) 46-63, Russell Sage Foundation, New York.

[19] Trumbo, B. E. (1989). How to get your first research grant. *Statistical Science*, **4**, 121-150.

(References [1-16] are publications of the National Science Foundation. Single copies of these publications are available free of charge from DMS or from Forms and Publications, NSF, Washington, DC 20550. Order by title and number. Publication dates are not given for booklets that are revised regularly.)

Mathematical Education

William P. Thurston

William P. Thurston is professor of mathematics at Princeton University. A Fields medalist and internationally-known researcher in topology and geometry, he has in recent years also become interested in issues in mathematics education. He currently serves on the Mathematical Sciences Education Board of the National Research Council and on the Executive Committee of the AMS Council. Thurston has been a judge in the Westinghouse Science Talent Search, and, in June of this year, he made a presentation at a workshop organized by the Mathematicians and Education Reform Network. He also serves as mathematics editor-in-chief for *Quantum*, a mathematics and science magazine for young people. Thurston says: "The [following] essay was stimulated by a study on the teaching scholarship connection, sponsored by the Pew Charitable trusts, on how graduate education and junior faculty 'apprenticeship' does or doesn't prepare us to be teacher-scholars. I was the mathematician on the panel, and the contrast between the different fields was brought home to me."

Mathematics education is in an unacceptable state. Despite much popular attention to this fact, real change is slow.

Policymakers often do not comprehend the nature of mathematics or of mathematics education. The 'reforms' being implemented in different school systems are often in opposite directions. This phenomenon is a sign that what we need is a better understanding of the problems, not just the recognition that they exist and that they are important.

I am optimistic that our nation will find solutions to these problems. Problems arising from failure of understanding are curable. We do not lack for dedication, resources, or intelligence: we lack direction.

Symptoms

There are many symptoms of the problems in mathematics education. The number of undergraduate mathematics majors is about half what it was 15 years ago. The number of U.S. graduate students is less than half what it was 15 years ago, although foreign students have taken up some of the slack. The performance of our students at all levels, as measured by standardized tests, is below that of other industrialized countries.

The typical response of American adults, on meeting a mathematician, is one of dismay. They apologetically recall the last mathematics course they took, which is usually the one where they lost their grip on the subject matter.

Many companies recognize lack of mathematical competence as a major problem in their workforce. Technology has removed the need for elementary mathematical facility in a few jobs, such as ringing up hamburger orders, but it has also eliminated many unskilled jobs, such as assembly-line work, while creating many others requiring considerable mathematical sophistication.

Students in college mathematics courses are unresponsive. They are afraid to speculate and afraid to reach into themselves for ideas. When one visits classrooms at different grade levels, one sees a dramatic decline in liveliness and spontaneity with age. One gets the impression that the natural interest and curiosity of young children in mathematics has been weeded out.

In most places, it is harder to get students to do homework or to study outside the classroom than it was twenty years ago.

Even those college students who have been successful in the high school mathematics curriculum, including calculus, have a narrow base of knowledge of mathematics.

Stratification and Compartmentalization

A major source of problems, and a major barrier to solutions of the problems, is the stratification and compartmentalization of the immense mathematical education enterprise, from kindergarten through graduate school. In particular, there is very little communication between high school and college teachers of mathematics. There is also less than optimal communication between the people who are involved with curricular reform at the college level and research mathematicians. This splintering partly results from the existence of several different professional associations, including the American Mathematical Society (AMS), which primarily represents mathematical research; the Mathematical Association of America (MAA), which primarily represents undergraduate mathematics; and the National Council of Teachers of Mathematics (NCTM), which primarily represents the most committed high school mathematics teachers. Additional organizations represent two-year colleges, applied mathematics, statistics, and operations research, as well as computer science.

The membership of the AMS and the MAA overlap by only about 1/3. Most members of the AMS are not even aware of the existence of the NCTM. Conversely, few members of the NCTM are aware of the AMS. Very few academic mathematicians have any contact with school mathematics teachers except through their children. Most teachers are trained at institutions with few if any research mathematicians. A number of universities are strong both in mathematical research and teacher training, but, even at those universities, most research mathematicians are not involved in teacher training.

Even more severe is the compartmentalization due to the division of primary and secondary education into many individual school districts and schools where the real decisions are made, and the division of college education into many different academic departments where the real decisions are made. Many people are thinking about the problems and making individual efforts to solve them. Many of these local efforts are quite successful. Unfortunately, there is far too little coordination and sharing of the insights gained.

Mathematics is a Tall Subject

One feature of mathematics which requires special care in education is its 'height,' that is, the extent to which concepts build on previous concepts. Reasoning in mathematics can be very clear and certain, and, once a principle is established, it can be relied on. This means it is possible to build conceptual structures which are at once very tall, very reliable, and extremely powerful.

The structure is not like a tree, but more like a scaffolding, with many interconnected supports. Once the scaffolding is solidly in place, it is not hard to build it higher, but it is impossible to build a layer before previous layers are in place.

Difficulties arise because students taking a particular course are in different stages of mastery of the earlier learning. They also tend to be secretive about exactly what they know and what they don't know. For instance, many calculus students don't correctly add fractions, at least not in symbolic form: the typical mistake is that

$$\frac{a}{b}+\frac{c}{d}=\frac{a+c}{b+d} \quad \left(\text{much simpler than } \frac{ad+cb}{bd}\right).$$

However, students feel guilty that they are shaky on addition of fractions and are slow to admit it and ask how and why it works, even to themselves.

Addition of fractions is a very boring topic to someone who already knows it, but it is an essential skill for algebra, which in turn is essential for calculus. It is not so hard, when talking with students individually, to find out what parts of the structure need shoring up and to deal with those parts individually. But it is quite difficult to find a level of teaching which is comprehensible and at the same time interesting to an entire class with heterogeneous background.

Mathematics is a Broad Subject

Mathematics is also very broad. There are many subjects that are never discussed in the mainline curriculum which culminates in calculus. The subjects that are discussed have many interesting side-branches that are never explored.

In my parents' generation (during the 1940s), the standard first college mathematics course was college algebra. Soon afterward, the standard first college course was calculus, until the early 1960s, when calculus became standard for the best high school mathematics students. By now first year calculus has largely migrated to high school in affluent school districts, so that most of the better mathematics and science students at our best universities have already taken calculus before they arrive. At Princeton, for instance, two-thirds of entering students placed out of at least one semester of calculus last year.

For instance, two-thirds of students entering Princeton last year placed out of at least one semester of calculus.

The acceleration of the curriculum has had its cost: there has been an accompanying trend to prune away side topics. When I was in high school, for instance, it was standard to study solid geometry and spherical geometry along with plane geometry. These topics have long been abandoned. The shape of the mathematics education of a typical student is tall and spindly. It reaches a certain height above which its base can support no more growth, and there it halts or fails.

These two trends (lengthening and narrowing of school mathematics) have been hastened by the growing reliance on standardized tests. Standardized tests are designed to cover topics on the most standard curriculum: if only half the students study some topic, it is unfair to ask about it on a standardized test. This is not so bad as long as tests are used in a disinterested way as one of several *devices for measurement*. Instead, higher test scores are often treated as the *goal*. Legislators, newspapers and parents put superintendents and school boards under pressure, superintendents and school boards put principals under pressure, principals put teachers under pressure; and teachers put students under pressure to raise scores. The sad result is that many mathematics courses are specifically designed to raise scores on some standardized test.

We don't diagnose pneumonia with only a thermometer, and we don't attempt to cure it by putting ice in a patient's mouth. We should take a similarly enlightened attitude toward testing in mathematics education.

The long-range objectives of mathematics education would be better served if the tall shape of mathematics were de-emphasized, by moving away from a standard sequence to a more diversified curriculum with more topics that start closer to the ground. There have been some trends in this direction, such as courses in finite mathematics and in probability, but there is room for much more.

Mathematics is Intuitive and Real

Students commonly lose touch with the reality and the intuitive nature of mathematics. From kindergarten through high school, they often have teachers who are uncomfortable with anything off the beaten path. Young children come up with many ingenious devices to work out mathematical questions, but teachers usually discourage any nonconventional approach—partly because it is not easy to understand what a child is thinking or trying to say, and the teachers don't catch on, partly because the teachers think it's not okay to use an alternative method or explanation.

By the time students are in college, they are inhibited from thinking for themselves and from admitting out loud what they are thinking. Instead, they try to figure out what routines they are supposed to learn. When there is any departure in class from the syllabus or the text, someone invariably asks whether it's going to be on the test.

Unless mathematics makes a real connection to people, they are unlikely ever to think about it or use it once they have completed a course.

Precocity and Competition

Along with the emphasis on tests has come an emphasis on precocity and acceleration in mathematics. It is relatively easy for a bright student to work through the mathematics curriculum far more quickly than the usual pace.

There are several problems associated with precocity. People who skip ahead in the curriculum often have gaps in their background which only show up later. At that point, the person may be too embarrassed to admit the gap and tries to fake understanding. This regularly leads to disastrous results.

Another problem is that precocious students get the idea that the reward is in being 'ahead' of others in the same age group, rather than in the quality of learning and thinking. With a lifetime to learn, this is a shortsighted attitude. By the time they are 25 or 30, they are judged not by precociousness but on the quality of work. It is often a big letdown to precocious students when others who are talented but not so precocious catch up, and they become one among many. The problem is compounded by parents in affluent school districts who often push their children to advance as quickly as possible through the curriculum, before they are really ready.

A third problem associated with precociousness is the social problem. Younger students are often well able to handle mathematics classes intellectually without being able to fit in socially with the group of students taking them.

Related to precociousness is the popular tendency to think of mathematics as a race or as an athletic competition. There are widespread high school math leagues: teams from regional high schools meet periodically and are given several problems, with an hour or so to solve them.

There are also state, national and international competitions. These competitions are fun, interesting, and educationally effective for the people who are successful in them. But they also have a downside. The competitions reinforce the notion that either you 'have good math genes', or you do not. They put an emphasis on being quick, at the expense of being deep and thoughtful. They emphasize questions which are puzzles with some hidden trick, rather than more realistic problems where a systematic and persistent approach is important.

This discourages many people who are not as quick or as practiced, but might be good at working through problems when they have the time to think through them. Some of the best performers on the contests do become good mathematicians, but there are also many top mathematicians who were not so good on contest math. Quickness is helpful in mathematics, but it is only one of the qualities which is helpful. For people who do not become mathematicians, the skills of contest math are probably even less relevant.

These contests are a bit like spelling bees. There is some connection between good spelling and good writing, but the winner of the state spelling bee does not necessarily have the talent to become a good writer, and some fine writers are not good spellers. If there was a popular confusion between good spelling and good writing, many potential writers would be unnecessarily discouraged.

I think the answer to these problems is to build a system which exploits the breadth of mathematics, by allowing quicker students to work through the material in greater depth and to take excursions into related topics, before racing ahead of their age group.

Mystery and Mastery

Mathematics is amazingly compressible: you may struggle a long time, step by step, to work through some process or idea from several approaches. But once you really understand it and have the mental perspective to see it as a whole, there is often a tremendous mental compression. You can file it away, recall it quickly and completely when you need it, and use it as just one step in some other mental process. The insight that goes with this compression is one of the real joys of mathematics.

After mastering mathematical concepts, even after great effort, it becomes very hard to put oneself back in the frame of mind of someone to whom they are mysterious.

I remember as a child, in fifth grade, coming to the amazing (to me) realization that the answer to 134 divided by 29 is 134/29 (and so forth). What a tremendous labor-saving device! To me, '134 divided by 29' meant a certain tedious chore, while 134/29 was an object with no implicit work. I went excitedly to my father to explain my major discovery. He told me that of course this is so, a/b and a divided by b are just synonyms. To him it was just a small variation in notation.

One of my students wrote about visiting an elementary school and being asked to tutor a child in subtracting fractions. He was startled and sobered to see how much is involved in learning this skill for the first time, a skill which had condensed to a triviality in his mind.

Mathematics is full of this kind of thing, on all levels. It never stops.

The hard-earned and powerful tools which are available almost unconsciously to mathematicians, but not to students, make it hard for mathematicians to learn from their students. This puts a psychological barrier in the way of listening fully to students.

It is important in teaching mathematics to work hard to overcome this barrier and to get out of the way enough to give students the chance to work things out for themselves.

Competence and Intimidation

Similarly, students at more advanced levels know many things which less advanced students don't yet know. It is very intimidating to hear others casually toss around words and phrases as if any educated person should know them, when you haven't the foggiest idea what they're talking about. Less advanced students have trouble realizing that they will (or would) also learn these theories and their associated vocabulary readily when the time comes and afterwards use them casually and naturally. I remember many occasions when I felt intimidated by mathematical words and concepts before I understood them: negative, decimal, long division, infinity, algebra, variable, equation, calculus, integration, differentiation, manifold, vector, tensor, sheaf, spectrum, *etc.* It took me a long time before I caught on to the pattern and developed some immunity.

Teachers also are frequently intimidated about mathematics. High school teachers are often timid about approaching college and university teachers. They also question, with some justice, whether university professors are in touch with the problems they have to deal with. There is so little general contact between those who teach mathematics in high schools, colleges, and universities that few professors know much about the educational problems in high school or elementary school. Elementary school teachers are often quite insecure about their grasp of mathematics and timid about approaching anyone.

The Problems and Solutions are the Same

There is much in common about the problems—and the solutions—of mathematics education at different levels, from kindergarten through graduate school. The failure to communicate is a real loss, and the potential gain from opening of two-way communications is great.

Over the past two years, I have met many people involved in mathematical education at all levels, partly as a member of the MSEB (Mathematical Sciences Education Board), a national board for mathematics education, composed of people from diverse backgrounds in mathematics and education, including a number of teachers. I have learned a lot.

During the spring semester of 1990, John Conway, Peter Doyle, and I organized a new course ('Geometry and the Imagination') at Princeton which borrowed a good deal from the ideas I learned. We taught as a team, shunning lectures and emphasizing group discussions among students. We emphasized manipulables, cooperative learning, and problem solving. We asked students to keep journals and to write out their ideas in good and complete English. Each student did a major project for the course. These ideas are all borrowed from ideas current in K-12 mathematics education, focused in the NCTM curriculum standards.

To culminate, we held a 'geometry fair': like a science fair but with a popcorn machine and without prizes. It was great fun.

The course came alive, qualitatively more than any course we had taught before. Students learned a lot of mathematics and solved problems we wouldn't have dared ask in a conventional college class.

One topic we discussed was mathematical education. Students were given an earlier draft of this essay and wrote 70 thoughtful essays based on their own experiences. This essay has benefitted considerably from their comments.

Socially Excluded Groups

Why do so few women become mathematicians, and so few of the non-Asian minorities?

I am convinced that the poverty of the school mathematics teaching and curriculum has a lot to do with it. The way mathematics is taught in school does not address the real goals of a mathematical education. It is very hard to get a sense of the depth, liveliness, power, and breadth of mathematics from any ordinary experience with mathematics in school. I believe that most students who really master the subject matter, and eventually become scientists, mathematicians, computer programmers, *etc.*, are those who have some other channel for learning mathematics, outside the classroom. Sometimes it is the home, sometimes it is books, sometimes it is an unusual teacher, but often it is the 'nerd' social subgroup in school. When I was in high school, I certainly belonged to this subgroup (although the name 'nerd' was not yet current), and I appreciated it very much. However, it is a very different matter for white and Asian males to join this social subgroup than for women, Hispanics or blacks.

Since channels of learning outside the classroom are currently dominant in mathematics education for the top group of students, improvement of the general quality of mathematics within the classroom therefore should act as an equalizer, particularly helping blacks, Hispanics, and women. For people who are not already tuned in to the mathematical style of discourse, it is especially important to teach in a way that is not watered down, but that begins from a person's real experience.

Intimidation also has a lot to do with it. The emphasis on precocity, high test scores, and competition work to amplify the small differences which arise from other sources.

Goals and Standardized Tests

What is mathematics education good for?

Mathematics in life

First, mathematics is a basic tool of everyday life. When coffee comes in 13 oz. packages and 16 oz. cans, can you take that information in stride (walking slowly by the shelf), along with the prices and the prominent signs claiming 'contains 23% more' on the cans, to help decide which you'd prefer to buy? In buying a new car with various gimmicks in financing, rebates, and features, do you understand what is going on? If most people did, the gimmicks would be pointless.

Second, mathematical reasoning is an important part of informed citizenship. Can you understand the reasoning behind studies of health risks from various substances, and can you judge how important they are? When listening to politicians, can you and do you use your reckoning powers to help decide how important some statistic is, and what it means? Can you measure and calculate adequately for simple sewing and carpentry? Can you plan a budget? When you see graphs in newspapers and magazines, do you understand what they mean, and are you aware of the several devices frequently used either to dramatize or to play down a certain trend?

Third, mathematics is a tool needed for many jobs in the infrastructure of our increasingly complex and technological society. These uses are pervasive and varied. The dental technician, the fax repairperson, the fast food manager, the real estate agent, the computer consultant, the bookkeeper and the banker, the nurse and the lawyer, all need a certain proficiency with mathematics in their jobs.

Fourth, mathematics is intensively used (and sometimes abused) in most branches of science. Much of theoretical science really *is* mathematics. Statistics is one of the most common uses of mathematics. Many scientists use the widespread computerized statistical packages, which alleviate the need for computation. However, people who use statistical packages are often shaky in their understanding of the basic principles involved and often apply statistical tests or graphical displays inappropriately.

Mathematics is alive

To me, these utilitarian goals are important, but secondary. Mathematics has a remarkable beauty, power, and coherence, more than we could have ever expected. It is always changing, as we turn new corners and discover new delights and unexpected connections with old familiar grounds. The changes are rapid, because of the solidity of the kind of reasoning involved in mathematics.

Mathematics is like a flight of fancy, but one in which the fanciful turns out to be real and to have been present all along. Doing mathematics has the feel of fanciful invention, but it is really a process of sharpening our perception so that we discover patterns that are everywhere around. In his famous apology for mathematics, G.H. Hardy praised number theory for its purity, its abstraction, and the self-evident impossibility of ever putting it to practical use. Now this very subject is applied very widely, particularly for encoding and decoding communications.

My experience as a mathematician has convinced me that the aesthetic goals and the utilitarian goals for mathematics turn out, in the end, to be quite close. Our aesthetic instincts draw us to mathematics of a certain depth and connectivity. The very depth and beauty of the patterns makes them likely to be manifested, in unexpected ways, in other parts of mathematics, science, and the world.

To share in the delight and the intellectual experience of mathematics—to fly where before we walked—that is the goal of a mathematical education.

Testing and "accountability"

Unfortunately the goals of school mathematics have become incredibly narrow, much narrower even than the first set of utilitarian goals listed above, let alone the others. It is popular lately for politicians and the public to demand "accountability" from the school systems. This would be great, except that educational accounting is usually based on narrowly-focused multiple-choice tests.

It is as if students were considered to have mastered Shakespeare if they could pass a timed vocabulary test in Elizabethan English, or that they had learned to write when they could correctly choose the grammatical form of a sentence from four possibilities.

The state and regional boards of education these days hand out a laundry list of skills which students are supposed to know at a certain age, rather than a curriculum: horizontal addition versus vertical addition, addition of 2 digit numbers to 2 digit numbers with a 2 digit answer versus addition of 2 digit numbers to 2 digit numbers with a 3 digit answer, *etc.*

A front-page article in the New York Times Metropolitan section of July 24, 1990 contrasted the elementary schools in two similar difficult neighborhoods of Brooklyn. The first was a 'successful' school, with two reading lessons a day, the second lesson in 'test-taking skills' and practice for the standardized reading test. In this school, 80.5% scored at or above grade level. The other school was an 'unsuccessful' school where they prepare for the test for 'only' 3 months. In that school, 36.4% score at or above grade level.

The reporter cited an example of how the principal sets the tone in the 'successful' school:

> She is not satisfied with just the right answers; she wants the right steps along the way. In one fourth-grade class, she noticed that pigtailed Keanda Snagg had made a wild, though accurate, stab at a problem requiring her to average which of two stores had lower prices.
>
> "It looks like you were going to do it without doing the work," she told Keanda.
>
> As she watched Keanda go through the calculations, she stressed fundamentals beyond arithmetic, like putting numbers in clearly ordered columns.

I can't tell which school is actually more successful without seeing them for myself, but one thing I know: neither the test scores nor the cited incident are demonstrations of greater success.

Thinking and Rote

Narrow goals are stultifying.

People are much smarter when they can use their full intellect and when they can relate what they are learning to situations or phenomena which are real to them.

The natural reaction, when someone is having trouble understanding what you are explaining, is to break up the explanation into smaller pieces and explain the pieces one by one. This tends not to work, so you back up even further and fill in even more details.

But human minds do not work like computers: it is harder, not easier, to understand something broken down into all the precise little rules than to grasp it as a whole. It is very hard for a person to read a computer assembly language program and figure out what it is about. A computer reads and executes it in the blink of an eye. But the most powerful computer in the world is not clever enough to drive a car safely, or control a stroll along the sidewalk, or come up with an interesting mathematical discovery.

Studying mathematics one rule at a time is like studying a language by first memorizing the vocabulary and the detailed linguistic rules, then building phrases and sentences, and only afterwards learning to read, write, and converse. Native speakers of a language are not aware of the linguistic rules: they assimilate the language by focusing on a higher level, and absorbing the rules and patterns subconsciously. The rules and patterns are much harder for people to learn explicitly than is the language itself. In fact, the tremendous and so far unsuccessful attempts to teach languages to computers demonstrate that nobody can yet describe a language adequately by precise rules.

It is better not to teach a topic at all than to attempt teaching it in tiny rules and bits.

Answers and Questions

People appreciate and catch on to a mathematical theory much better after they have first grappled for themselves with the questions the theory is designed to answer.

There is a natural tendency, in teaching mathematics, to use the logical order and to explain all the techniques and answers before bringing up the examples and the questions, on the supposition that the students will be equipped with all the techniques necessary to answer them when they arise.

It is better to keep interesting unanswered questions and unexplained examples in the air, whether or not the students, the teachers, or anybody is yet ready to answer them. The best psychological order for a subject in mathematics is often quite different from the most efficient logical order.

As mathematicians, we know that there will never be an end to unanswered questions. In contrast, students generally perceive mathematics as something which is already cut and dried—they have just not gotten very far in digesting it.

We should present mathematics to our students in a way which is at once more interesting and more like the real situations where students will encounter it in their lives—with no guaranteed answer.

What Can We Do?

This depends on who we are.

In our compartmentalized system, it is hard for a single organization or individual to do very much to affect the overall system directly. But addressing the local situation will indirectly influence the global situation. I will address the question from the point of view of college and university mathematicians.

First, college and university mathematics departments should develop courses which can give students a fresh chance in mathematics. Remedial courses are widespread, but their success is limited: going over the same material one more time is tedious and boring, whether you understood it the first time or you didn't. There is a built in handicap to enthusiasm and spontaneity.

Instead, there should be more courses available to freshmen and nonmajors which exploit some of the breadth of mathematics, to permit starting near the ground level without a lot of repetition of topics that students have already heard. For instance, elementary courses in topology, number theory, symmetry and group theory, probability, finite mathematics, algebraic geometry, dynamical systems (chaos), computer graphics and linear algebra, projective geometry and perspective drawing, hyperbolic geometry, and mathematical logic can meet this criterion.

Second, we should work to create better channels of communication between the compartments of the educational system. We need to find devices so that the educational accomplishments of professors are visible within the profession, not merely within the classroom or within the department. We need to find vehicles for exchange of interesting ideas between different departments: for instance, exchange visits between directors of undergraduate studies and chairs of departments. We should visit each other's classrooms. We need more talks and special sessions related to education at our professional meetings, and more prizes for educational accomplishments.

The newsletter, *Undergraduate Mathematics Education Trends*, and the MAA newsletter, *Focus*, are two such vehicles, and there are several other publications which carry articles on undergraduate education. The annual chairman's coloquium organized by the Board on Mathematical Sciences of the National Research Council is another vehicle of communication, although it has a broader agenda than education. Still, these existing channels are very small compared with what we could establish.

Even more important and more difficult is the creation of channels for communication between the strata: most important for colleges and universities is communication between high school, college and university mathematics departments. This communication must be two-way: college and university professors can learn a lot about how to teach from school teachers. The MSEB is one such channel, along with the state mathematics coalitions that they have helped to stimulate, but what we need is a much more massive exchange.

How can the senior professors, who are at the top of a system which is clearly not doing such a great job, presume to teach their juniors how to do better? The graduate students and the junior faculty often do a better job at teaching mathematics than the senior faculty, who have sometimes become resigned to the dismal situation, settled into a routine, and given up on trying any new initiatives. Even when they do a pretty good job in their own classrooms, against the odds, they do not usually get involved in improving the overall system.

Often other professors are suspicious of the professor who does take an interest in education. They tend to assume that research is the only activity which really matters and that turning to education is a sign of failure in research. Senior professors sometimes explicitly advise junior faculty not to waste too much energy on teaching, or they will never be promoted.

We must recognize that there are many different ways that we can make important contributions to society and to our institutions. It is dumb to measure mathematicians against the single scale of research. Education is an important and challenging endeavor, which many people engage in by choice, not necessity. We should judge them by what they accomplish, not by what they might have accomplished if they spent their time and energy elsewhere.

What urgently needs to change is the system of professional rewards. We need something better than the current situation within university mathematics departments where there is lip service to the importance of teaching, but, when it comes to the crunch of hiring and tenure decisions, teaching and service count only in the marginal cases where the candidates cannot be differentiated by the quality of research.

People are socially motivated. As we discuss education with each other, we put more energy into it, and it becomes more important to us. The academic culture *can* change, and it has changed. The process of change is mostly an informal one (what you talk about at lunch), not controlled by organizational decisions. But when the time is ripe, as I believe it is now for mathematical education, a little nudging by organizations can help stimulate a huge change.

The needed reforms will take place through collegial, cooperative efforts. Good mathematical ideas spread very rapidly through informal channels in the mathematical community. As we turn more of our attention to education, good educational ideas will also spread rapidly.

Serving at the NSF

Mathematical Sciences Rotators Tell What it's Like

Although the mathematical sciences community has great respect (some would say outright reverence) for the National Science Foundation (NSF), few mathematical scientists seriously consider going to work for a period at the NSF. Year after year, the Foundation has difficulty recruiting mathematicians and statisticians to serve as visiting scientists (that's official lingo for "rotators"), even though almost all who have spent time at the NSF say they benefited from the experience. Interviews with the mathematical sciences staff now completing "tours of duty" at the NSF reveal that all found the experience worthwhile and enriching.

"I came to the NSF out of a sense of duty to the mathematical community, but I quickly signed on for a second year," says Jonathan Lubin of Brown University, who served as a program director in Algebra and Number Theory in the Division of Mathematical Sciences (DMS). "There is really a wonderful work environment here." Carroll Wilde of the Naval Postgraduate School in Monterey, California served as a program director in Teacher Enhancement in NSF's education directorate. "There's a professional environment, a collegiality stronger than I have found anywhere in my entire professional career," he says.

A Paper-Shuffling Bureaucracy?

But isn't NSF just a big, paper-shuffling bureaucracy? Some program directors interviewed remarked on the amount of "paper pushing" at NSF, but evidently the quantity of paper pushed does not produce a stultified staff. "I expected some federal bureaucratic torpor," says Lubin, "but I am really impressed with the dedication of the staff at all levels of NSF, not just within DMS, but in the other divisions as well. The program directors in DMS and other divisions, as well as the support staff, are very dedicated." Mary Ellen Bock of Purdue University, who served for two years in the Probability and Statistics program, says NSF is in some ways less bureacratic than academia. "As a matter of fact," she says, "I thought people [at NSF] are more open-minded than in a typical university department, where people sort of draw their lines of turf."

Gerald Chachere of Howard University spent a year in the Special Projects program. "Before I came here, the NSF appeared to me to be a monolithic structure, but it's really made up of people who have been faculty in colleges and universities," he says. "Many people don't know that, and it's very helpful for the mathematical community at large to realize that the staff here is made up of people much like themselves."

The NSF workload is such that program directors usually must set aside their own research for a while. But the tradeoff is a new perspective on that research. "It's really super to get this close-up view of interesting aspects of what's going on," says Bock. "If you're a researcher, when you leave here, your research is just inevitably changed. You get more of a sense of the big picture. You can never look at your own research in isolation. If I were a researcher who wanted to take a fresh look at my area or switch areas, this is the place I would come."

Science Policy Discussions

Program directors at the NSF become involved in a range of science policy issues that affect the entire mathematical sciences community. Many rotators find this aspect of their job to be a fascinating change from the more provincial institutional viewpoint. "Coming from a small school, I liked being at the center of where things are happening, being more in contact, hearing about what's going on," states Russell Walker of the Montana State University, who served two years as program director for Geometric Analysis. "I liked a lot of the science policy discussions. I actually *liked* staff meetings!" Learning about the funding situation in the DMS changed some of his perceptions of how the NSF interacts with the mathematical sciences community. "At small schools, there's a certain perception that the DMS is not being fair to them, or that equal people at small schools aren't getting funded," he notes. However, he says, the NSF tries to spread funds to smaller schools, but funding is so tight that "just because you're doing consistent research and publishing in top journals does not mean you will get funded. ... The cutoff level [for awarding grants] is just a lot higher than I thought, and that's the main explanation for everything."

In the interest of stretching NSF dollars, Walker strongly supports a salary cap on NSF grants. "I don't think people fully understand that when they get an NSF grant, they tend to get a salary raise," he noted. "Next time they come back [to the NSF for funding], their salaries are 20% higher. And then they wonder why we can't fund more people." Lubin agrees that the NSF needs to increase the number of principal investigators funded, "but unless Congress gives us more money, it's going to be difficult. There's no way we can stretch our funds further unless there is a change in the structure of individual grants, such as through salary caps. The fact that there has been a salary cap the last two years has had a small but noticeable change and has permitted us to fund a few more people."

Tight funding means fierce competition not only for individual grants but also for the various priorities that DMS has set for itself, such as addressing human resource issues. "I'm happy that DMS is making a serious effort to bring in underrepresented minorities as reviewers, panelists, and principal investigators," says Chachere, but he fears that allocations for programs addressing such issues might be decreased if predictions of declining budgets become reality. "In DMS, human resources, as other non-research issues, probably have a priority lower than that of research, and that is as it should be."

The currently tight budget climate throughout the federal government means that increases for the NSF for fiscal year 1991 will be hard to come by. DMS staff say they could fund twice as many investigators with no drop in quality, but simply do not have the funds to do so. When program directors are making difficult decisions from among many excellent proposals and must balance competing priorities, it is all the more important to have a highly qualified staff with a broad knowledge of their fields and a wide perspective on the roles and responsibilities of the mathematical sciences community.

Mathematicians in Education Programs

The largest concentration of mathematical scientists is in the DMS, but several also work in various divisions in the Education and Human Resources (EHR) directorate (until recently called Science and Engineering Education, or SEE). Thomas Berger of the University of Minnesota served two years at the NSF, first in the Teacher Enhancement program and then in Materials Development. "Generally, the mathematicians who come [to the education directorate] love it," he notes. "Even for a very 'pure' research person, this experience so broadens a person's horizons that it turns out to be of value not only in what that person can do in the community, but in what it does for that person's view of mathematics and their own research." Many more mathematical scientists, and particularly those who are prominent in the research scene, should consider working in the NSF educational programs, Berger says, for "the quality of scientists who come to the NSF directly influences the quality of programs and awards that NSF makes."

However, Berger notes that many mathematicians assume they can instantly understand all the problems of education. "A person who's an expert in PDEs would not think of talking about algebraic geometry as an expert," he notes. "But, by golly, they know everything there is to know about mathematics education. But really they know less about it than they know about algebraic geometry." It's also important that rotators come to the NSF with a willingness to learn because it's difficult to know which ideas will work and which won't. "My idea was to come here with as many ideas as possible and watch for more while I was here, and then to push those that had a chance of success and drop the ones that weren't going to succeed," he says. "You can't dictate to the community, you can only flow with the community. But through your activities you can have influence on the community. And I think most program officers find that very exciting."

Wilde of the Teacher Enhancement program says that working in education at the NSF has underscored for him the importance of college and university faculty working on precollege education. "I've become more and more convinced of the need for the higher education community to become involved in precollege schooling," he says. "It's extremely important to the well-being of our colleges and universities that we assume our share of the responsibility for bringing to the doors of the colleges and universities the people who are going to be the next generation of scientists and engineers."

Faculty sometimes find that their institutions are less than enthusiastic about their serving at the NSF—sometimes tenure at the NSF is seen simply as a temporary loss of a member of the teaching faculty, without any benefit to the institution. Negotiations about salary and benefits can also be complicated, and many faculty are reluctant to leave their research to come to the NSF. The NSF is aware of such problems and is working to make it easier for faculty members to serve at the NSF. For example, acting on a suggestion of the DMS Advisory Committee, the NSF is looking into the possibility of providing released time for faculty after they leave NSF, in order to help them get back into research.

Despite these difficulties, the mathematical sciences rotators at the NSF are enthusiastic about their experience. "I'd encourage people to come here," says Walker. "There's nobody who doesn't like it, everyone seems to like it, though they have their doubts at first!"

Allyn Jackson
Staff Writer

Forum

The Forum section publishes short articles on issues that are of interest to the mathematical community. Articles should be between 1000 and 2500 words long. Readers are invited to submit articles for possible inclusion in Forum to:

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American Mathematics and the Rest of the World

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The American school of mathematics is clearly the first in the world. After the tremendous contribution made by refugees from Europe in the thirties and the forties, generations of American mathematicians came of age in the fifties and the sixties and made mathematics departments in the U.S. what they are now. But today, the domination of the United States seems to depend heavily, once again, on its capacity to attract foreign mathematicians from all over the world. My purpose in this *Forum* article is to discuss various negative aspects of this brain drain and to call for a greater concern on the part of American mathematicians for the welfare of schools of mathematics outside of the U.S.

$1 + (-1) = 0$

When a distinguished colleague leaves his or her home country to take a position in the U.S. and bring to some American department competence and energy, it means that there is somewhere a tremendous loss of that same competence and energy. His/her former colleagues and students who might have benefited from his/her scientific influence won't be given that chance. And the loss is more than just scientific. Everywhere, institutions of higher learning are apt to go through crises: an indifferent administration, an incompetent chairman, momentarily adverse economic conditions... . In such a circumstance, the loss of a colleague who chooses to leave is the loss of a *voice for change*. In a huge country like the U.S., one can always go to some other American department. But in a smaller country, where there may be very few employment possibilities, the decision to leave means to *leave the country*.

Of course, on the other hand, for the *individual concerned* the decision might have a positive effect, allowing him or her to find a decent working environment.

Can arithmetic reflect the bottom line? If so, my bet is that it should not be $1+(-1) = 0$ but rather $1+(-1) < 0$, at least in the long run, because the loss for the original country is far greater than the gain in the U.S.

After pointing out these negative aspects, I want to make it clear that I consider the freedom to choose where one wants to live and work fundamental. Before or during the Second World War, lives were at stake, and the world is grateful that the U.S. should have existed and have been willing to welcome many refugees.[2,3] More recently, for instance in the U.S.S.R. or in China, the limits to intellectual freedom have made it impossible for intellectual life to thrive, and many found no other solution than leaving their country. In my view, *whatever the reasons*, there should be no restriction on the freedom of circulation.[4]

The law of supply and demand

To go any further, one must analyze the international academic job market on both sides: the supply side and the demand side.

On the supply side, there are three (not necessarily disjoint) reasons pushing mathematicians and other academics away from the countries where they grew up and were trained. The first one is political persecution. A second cause for the emigration of scientists is the deterioration of the job market, of funding, and/or of the university environment: this is the case in several rich countries of Europe, for instance Great Britain, Germany, or to a lesser extent my own country, France. A third case is that of scientists from developing countries or from Eastern Europe where an acceptable working and/or living environment might not be available.

This accounts roughly for the factors leading people to *leave*. But it is only one aspect. For one thing, the American job market is wide open because it cannot provide enough "home-trained" mathematicians. American departments are seeking foreign graduate students as desperately as foreign faculty. (This would be very obvious in the—completely hypothetical—situation where suddenly no foreign graduate student joined a mathematics graduate program for five years, and, say, during the same period no new foreign faculty member arrived in the U.S.)

It is in my view quite hypocritical to see the present flow into the U.S. solely as a consequence of the poor conditions in other countries pushing people *away*. The flow is just as much caused by the demand of the job market in the U.S.[5] If there were now, as in the sixties and the early seventies, nearly one thousand new American Ph.D.'s in mathematics every year, covering all needs and beyond, and still all these offers to foreign mathematicians were made, the situation could be interpreted quite differently... The perspective of the job market for the 1990s in mathematics in the U.S. shows that things are going to become worse with the wave of retirements that will occur.[6]

An article in the *New York Times* (May 8, 1990) about the arrival of Soviet scientists quoted several mathematicians: Ronald Graham of AT&T-Bell labs and Rutgers: "[it is] a tremendous opportunity for the U.S."; Melvyn Nathanson of CUNY: "[the Soviets] replenish the mathematical juices of the U.S."; and Mark Ablowitz of the University of Colorado: "[this influx] helps us going through some rough periods".

Reading these remarks, one might think that the U.S. has just been through a terrible war or perhaps a tremendous economic crisis, so that it needs all the mathematical help it can get through some international marshall plan! But it is of course hardly so. The disaster, if any, is that the richest country in the world doesn't want to pay for a decent pre-college education![7]

Education

To be sure, there has been a lot of interest in the U.S. about educational matters. We in France have been following quite closely some of the initiatives that have been taken (MS 2000, 2061, etc.)[8], and have learned from them. And we too are quite worried about our capacity to train enough scientists, engineers, and mathematics and science teachers in the years to come. But we, as is perhaps the case in most developed countries, still seem to fare much better in our secondary education, in part of course because we allocate more money to it.

But education requires more than money; it requires will[9], by all parties involved: political institutions, parents, teachers *and the academic community*. For instance, university mathematicians in France[10] are very directly involved in the training and certification of teachers; actually the training of teachers is one of the main tasks of mathematics departments.

I will state my argument in a blunt way: *If Americans spent more money for education, if they cared more for schools, the U.S. probably wouldn't need to import so many mathematicians (and scientists and engineers ...); and it might not have so much money available to lure foreigners away from their country.*

But of course we are in the realm of politics, and, in a way, the question is not whether a policy is "good," but whether it is effective. And indeed, in some way, the American choice is rational: *why bother about making education better, when we can import all the qualified manpower, all the scientists and engineers we need, completely trained and ready to work?* The United States prefers to rely, or so it seems, on the educational performance of other countries, cashing in on the finished product without paying for the cost. Is it not ironic that all other countries, including poor countries like India or China should be *subsidizing* the mighty and generous United States?

Fight back

Clearly there is an international competition for the most able, and one may argue that this competition should have a positive effect. The problem, in both cases, is that the academic job market is international, while salaries and working conditions are determined by national conditions.

To be sure, industrialized countries, even though they are not as rich as the U.S., can fight back. In fact, the emigration of scientists can sometimes be used rather effectively as an argument to persuade governments to change their policies—although the example of Great Britain shows that the effectiveness is not guaranteed.

But is it really fair to say that poorer countries, if they want to retain their top scientists, need only match what American departments can offer?

Soviet Union

The changes in Eastern Europe and in the Soviet Union pose the most pressing problems of today. We all share a great feeling of elation to see at last our Soviet colleagues free to come and go as they wish. But the legitimate fear that they have of the instability of the sytem, and in particular of the rising wave of anti-semitism, pushes them to leave their country and to seek jobs in the U.S. *It is their decision and we must respect it.* But I have the uneasy feeling, confirmed by the comments that I quoted earlier, that this situation is perceived by many American departments as a bonanza. With absolutely no concern for the survival of the fantastic Soviet school of mathematics, each university wants to have its share of the spoils.

At the very least, mathematicians in the United States should ask themselves what can be done to help Soviet mathematicians who stay. Several things can be done to make the flow go in both directions: the most important is the development of short and long scientific visits to the U.S.S.R. *with American funds.*[11] And since Soviet mathematicians are coming out of their relative isolation, Soviet journals should be added on the list of journals where one can submit papers for publication.

The questions I have discussed in this article are complicated, and there is no simple answer. I do not call for restrictions on freedom of movement; on the contrary, I think that we must help, whenever it is necessary, colleagues who feel threatened. But we also have a collective responsibilty to maintain and develop mathematics all over the world. Like the ozone layer, mathematics is fragile, and all mathematicians should do their share to preserve it. This should especially be true of American mathematicians, who, because they belong to the largest scientific community have a special responsibility in this matter.

[1]I have enjoyed, as a visitor for the past two years, the hospitality of the Mathematics Department of Rutgers University in New Brunswick. I wish to take this opportunity to thank my hosts for offering such excellent working conditions.

[2]Among them my parents and grand parents—I know what this is about ...

[3]See the moving testimonial of Lipman Bers in *One Century of American Mathematics*, AMS (1988).

[4]I fully support the AMS Committee on Human Rights, the Association of Concerned Scientists, and other such organizations for their tremendous role in helping individuals whose human rights are denied.

[5]It is very much to the moral credit of American mathematicians to give a priority to hiring better foreign mathematicians at the expense of their own fellow citizens. But this is bound to reinforce the present trend of a small flow of American graduate students going into mathematics and therefore the global imbalance of the world market for mathematicians.

[6]The new David report "Renewing U.S. Mathematics: A Plan for the 1990's" contains a detailed analysis of the "problem of renewal": "United States Ph.D. production (supplemented by a large influx of foreigners) is at present barely sufficient to meet the currents needs ... ". The problems that this "*large influx of foreigners*" might induce in their home countries is unfortunately not even mentioned in the report.

[7]The U.S. president's words : "read my lips: no new taxes" affects the whole world in more than one way.

[8]La *Gazette des Mathematiciens*, published by the *Société mathématique de France* contains regular informations from other countries *besides France*, as well as book reviews and survey articles. I have not yet found any mathematics library in the U.S. which subscribes ...

[9]One instance of lack of political will is the constant rejection of a national curriculum. In a very perceptive article in the May 1990 issue of *Physics Today*, the physicist Chiara Nappi shows the role the national curriculum has played and is still playing in Italy to reduce inequalities—and also to attract students from both sexes into scientific studies.

[10]I am far from considering that the situation in France is ideal. As a matter of fact, I believe that we have a lot to learn from the U.S., just as the Americans would very much benefit from our (and other's) educational experiences and philosophies. *Notices* could be an ideal medium for international informations on mathematical education and research.

[11]For instance the French Ministry for Research has recently announced a contigency plan for scientific cooperation with the Soviet Union and Eastern European countries, including a number of fellowships and grants to travel to those countries.

"Everybody Counts" - Another Point of View

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Edward G. Effros is unhappy with the emphasis that the National Council of Teachers of Mathematics (NCTM) "Standards" and the National Research Council (NRC) reports "Everybody Counts" and "Reshaping School Mathematics" place on computers and calculators. He argues that these "curricular changes" will make the problem of innumeracy (a new term that refers to the condition of not being able to calculate 9×7 in your head) worse than it already is and that they do not put the problems of mathematics education in the more general context of general educational decline.

The emphasis that the NCTM and NRC put on technology is *not* calls for curricular change. Instead, these recommendations are part of a demand that we change the way our students *learn* and *do* mathematics.

Indeed, the "Standards" outlines a curriculum that is topically quite conservative. If the "Standards" are implemented in schools, students will continue to study algebra, geometry, elementary functions, and perhaps calculus. There will be an infusion of mathematical induction, some combinatorics and probability, and a few topics from discrete mathematics, but these are not fundamental changes. There are no calls for courses in linear algebra, number theory, or logic, even though these topics are within reach for many high school students. I've talked with many high school teachers about the proposed curricular changes, and none of them feel that the suggested curriculum is a radical departure from the high school curriculum of 1990. What *is* different, and what almost every high school teacher feels will be an extremely difficult change, is the emphasis that the NCTM and NRC places on having students construct mathematics for themselves.

The new reports are constuctivist documents. They call for a decreased attention to the rote memorization of facts, the active involvement of students in the construction of mental models for mathematical abstractions, and the change in role for the teacher from one of transmitter of knowledge to one of intellectual coach. It is becoming clear that the traditional mathematics classroom, in which a teacher explains some mechanical algorithm and then has the students work a page of practice problems, just doesn't work. Effros wonders why his university students can't do even the simplest paper and pencil calculations. Does he honestly think that it's because they didn't practice the calculations *ad nauseam* in their school days?

Of course they practiced; some of them practiced the same kinds of drill for eight years. But all that drill didn't help them understand the underlying mathematics, and it didn't even help them remember how to do the calculations. Recently, I taught a semester course in "remedial" mathematics to high school students. I discovered early on that (with a simple example to jog their memory) the students could easily combine fractions, do long division, convert decimals to fractions, and the like. In fact, they fully expected that this course would be another five months of mindless drill, and they were perfectly willing to spend their time that way. Instead, I asked them to solve problems, very simple arithmetic problems about cost, pay, size, and distance. One of the problems was this:

> *In* 1978, 664 *families out of every thousand families had a color TV. How many families per thousand did not have color TVs in 1978?*

One student's answer was 1314. I asked to see her work, and my worst fears were confirmed: She had subtracted 664 from 1978.*

The argument, then, isn't about whether students should have paper and pencil skills or calculator skills. It isn't about whether students should draw pictures with a ruler and protractor or with a mouse. And it isn't about whether students should manipulate polynomials with a pencil or with a computer. The argument is about whether or not the kind of mathematics instruction that we all experienced in our school days, the mathematics instruction of drill and technical expertise, can help students *do* real mathematics. Effros describes banks that advertise for people who "know fractions". These banks probably couldn't care less about how people *manipulate* fractions; they want people who can apply arithmetic with rational numbers to the situations that come up in a bank, and it's not at all clear that proficiency in, say, "borrowing" in subtraction will help the tellers with what they need to know.

Perhaps Effros actually believes that drill and practice help people become mathematicians (or, at least, "numerate"). He says, "As in any other language, drill and practice remain the most important tools at our disposal for learning the first principles . . . ." That's not how most people become proficient in their native tongue, nor is it how people learn how to express themselves in a foreign language, in a programming language, or in mathematics. A new medium for expression is learned by *immersing* onself in the medium, and that's exactly what the NCTM and NRC are asking for in their recommendations about how mathematics instruction should change. They are asking us to create a *culture* of mathematics in schools, a culture in which students can have at their disposal high-powered tools (including pencils) for doing mathematical experiments, and a culture in which students can work together on problems that are developed in collaboration with their teachers.

The fact that Effros' criticism of the national reports centers around what he sees as the bad effects of calculators and computers is curious indeed. It is something like a criticism of miter boxes in cabinet making: the condemnation of a tool is as silly in mathematics as it is in carpentry. There are certain *uses* of tools that might be detrimental to students' mathematical development, but Effros never gets that specific. Is he opposed to the kind of activity that Muench describes in his review of *ISETL* in **[Mu]**? Is he opposed to using a computer to manage the very drill and practice exercises that he considers so important? How about using calculators as trigonometric tables? Using computers to graph equations? The point here is that computers (and to some extent calculators) are general purpose machines, and it's impossible to give a generic argument that shows how *all* uses are bad for *all* students.

To be sure, there are many issues that remain unresolved in the use of technology in mathematics education. Here are some that deserve the attention of the mathematical community:

1. Does the writing of computer programs in a programming language that is a close approximation to the language of mathematics help students build mental models for mathematical constructs? If so, why?

2. In spite of years of study in analytic geometry, many students do not understand the connections among the representations of a function as a process, an object, a graph, and a table. Can certain kinds of software help students use multiple representations for functions?

3. Can the computer modeling of recursively defined functions help students understand mathematical induction?

4. Most mathematicians believe that new results spring from capturing subtle patterns in many concrete calculations. Will such patterns be as easy to find if the calculations are carried out with a symbol manipulator?

5. One of the big differences between research mathematics and school mathematics is that the latter doesn't

*When I described this amazing incident to some middle school teachers, several of them wanted to know if my student did the subtraction correctly.

include experimentation as a primary focus. Will it be easier for students to do mathematical experiments if they use mathematical software? Exactly what kinds of uses will make experimentation easier? What kinds of experimental hueristics will students develop if they investigate mathematical phenomena in a computer environment? What kinds of phenomena can we ask them to investigate if a computer with appropriate software is in their repertoire of tools? Can technology help students make the leap from data-driven discovery to theoretical understanding? Using *Mathematica*, for example, it is fairly easy to develop a conjecture about which n have the property that $x^n - 1$ splits into exactly two factors over $\mathbb{Z}$. But what about a proof?

These are the kinds of questions we should be discussing. We should not be quibbling about non-issues like whether or not the advocates of the use of computers as mathematical tools think that young people should know their multiplication tables. *Everyone* agrees with Effros that high school graduates should be able to multiply 12 by 5, that they should be able to estimate half of 752, and that they should know that a difference of two squares is not irreducible. Some of us believe that technology will actually help students, not only with these low-level tasks, but with real mathematics as well.

Effros maintains that the reports he cites fail to put the problems of mathematics education in a societal context. I agree, but I don't agree with his assessment of this context or with his suggested remedies.

Are young people different from us? Of course they are. I'm different from my father, and he's different from my grandfather. Today's students look at mathematics through a different lens than the one we used in school. Young people will use existing tools in spite of us; it makes absolutely no sense to them when we prohibit them from using the machines they see all around them. If you ask a high school trigonometry class to give you the exact value of $\sin\frac{\pi}{3}$, many students will say that $\frac{\pi}{3}$ "equals" 60°, enter 60 on a calculator, hit the `sin` key, see .866, and know that the teacher must want $\frac{\sqrt{3}}{2}$ for an answer.

Are young people less capable at mathematics than us? Of course not. Because they have grown up with technology that was new in 1970, we can't expect students to respond to classroom methods from 1960. Sure, students become glassy-eyed when exposed to an hour lecture on mathematical dogma. But they respond very well in lab-like settings, or when they are asked to work on what seem like open ended problems. My experience is that today's best students are more creative, more eloquent, and more facile with abstraction that the best students of a decade ago.

What the NCTM and NRC do not address is the societal resistance to the teaching methods they propose. Already, we are hearing that making mathematics a subject in which students construct notions for themselves is too expensive. The kinds of activities required cannot take place in classes of 30 (or even 25) and the equipment involved is costly. The question, then, is whether or not people want to pay for a mathematics curriculum in which young people do more than memorize outdated algorithms. In Massachusetts, the answer is no. We are struggling here with tax-cap legislation that makes it impossible for schools to adequately fund their programs. So, while teaching loads should be decreasing so that teachers can study new mathematics or take on student apprentices, teachers are being laid off and class sizes are going up. Our school hasn't bought any new equipment since 1983. This complete lack of adequate funding is supported wholeheartedly by local business and industry; it makes one wonder about how much the banks want students to *really* know about fractions. From the beginning, public schools have been pulled in two directions. On one hand, working people see schools as institutions for social change, as places where their children can gain the insights they'll need to "move up the ladder". On the other hand, business and industry see schools as instruments for perpetrating inertia, as meta-factories for the production of workers. To the extent that workers today must know more about mathematics than their counterparts of a decade ago, schools will find support from the business establishment. But if a change in emphasis in mathematics education (or in any other field) threatens to put students in an environment where they are encouraged to question everything, we can expect little backing from those whose interest is served by the maintenance of the *status quo*. The NCTM "Standards" are asking schools to empower students in a way that will never find broad based support in the industrial complex. Effros' "simple ad campaigns" will have little effect on the way our schools are supported.

The "Standards" outlines a broad program for closing the gap between they way mathematicians and students of mathematics work. It remains to be seen whether or not the American public wants the gap closed, but clouding the waters with criticisms of a technology that will not go away contributes little to the debate.

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Computers and Mathematics

Edited by Jon Barwise

Editorial notes

After a month's hiatus, the column resumes with three articles. One is a comparative review of mathematics programs, by Barry Simon. Simon posed a series of mathematical problems to the developers of four all-purpose mathematics programs, and then compared the times their solutions took when run in the same environment. The result is an interesting indication of the comparative strengths and weaknesses of the programs reviewed. Another article, by William Dowling, discusses the fascinating topic of computer viruses, from a mathematical point of view. It shows how viruses are examples of well-known diagonalization techniques. Finally, we conclude with a review of *SOLVE1*, by Gustav Gripenberg.

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Computer Viruses: Diagonalization and Fixed Points

*William F. Dowling**

Abstract

Constructing computer viruses can be viewed as an exercise in applied recursive function theory, if one defines a virus as a program that "reproduces" itself. Here I give a construction for viruses that includes a proof of the Recursion theorem (or Fixed Point theorem) of recursive function theory. The intention is not to give cookbook instructions for ne'er-do-wells (the construction is impractical) but to present a *positive* result using diagonalization: a fixed point lemma, and its relation to viruses. To balance the discussion, I also present a more typical negative application of diagonalization showing that even if a very broad definition is given to "virus," one cannot guarantee a virus detection program is safe (non-virus-spreading).

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Introduction

Computer viruses have become a topic of popular news for two reasons. First, a widely publicized virus (the "internet worm") affected a large number of mid-sized computers on a national network in 1988. Second, quite a few viruses affecting personal computers, mainly IBM-type personal computers and Macintoshes, have become widespread on campuses and in university computing centers. Consequently, many people using personal computers have experienced exasperating performance degradation and wasted time cleaning up after viruses and have become suspicious of wide area network connections. The purpose of this article is to give a mathematical definition of *computer virus*: a program that "reproduces," and to show that the existence (in the mathematical sense) of viruses is an inevitable consequence of fundamental properties of any computing domain. If we use a more operational definition and say that a virus is a program that infects, or alters, the operating system under which it runs, then if an operating system is susceptible to any virus, then one cannot guarantee the safety of a putative virus detecting program. Warning: two distinct and non-equivalent definitions of "virus" are used!

The technique I shall use to construct a virus is not the most direct possible, but it is, I believe, fairly entertaining and requires no prerequisites. It is illustrative of uses of Kleene's Recursion theorem, and makes use of a positive form of a diagonalization argument. The ideas here are essentially Kleene's; the "Diagonal fixed point lemma" I learned in a course given by Scott Weinstein — it is due to Owings [2]. Self-reproducing machines and their relation to the Recursion theorem are described in a general setting in Rogers [3].

Notation

How can we formalize the notion "virus": a program that reproduces itself? Let us fix a programming domain, that is, a programming language and its (hardware and software) support processor. Say the language is Pascal and the support is your favorite compiler and hardware. The choice is not important. To avoid inessential details, we will assume that Pascal programs take their input from a file (string) of characters, and print a file of characters as a result. For now we ignore the interaction between Pascal programs and the chosen support processor—for example: attempted division by 0 yields a certain string in the output file, etc. However, it is possible that a program may loop endlessly; in this case the support processor will not interfere, and the program is said to return no result (even though it may have written a part of a file as output before it got caught in the loop.) The expression "P halts on input i" means that program P does not get caught in such an infinite loop while processing input i. Thus programs compute *partial functions* from character files to character files. Furthermore, some such programs represent functions on N (natural numbers), namely those that on input of a string of digits, return a string of digits.

Let $\mathcal{P}$ be the set of Pascal programs and note that $\mathcal{P}$ is countable since (the text of) each Pascal program is a finite string of characters drawn from a finite alphabet. If $\{P_0, P_1, \dots\}$ is an indexing of $\mathcal{P}$ then ϕ_i will denote the function (on character files) computed by program P_i. $P_i(y)$ denotes the result of running P on input y and is a representation of $\phi_i(y)$ when this exists, otherwise it is undefined. As remarked above, some ϕ's may be viewed as functions on N, so expressions like $\phi_{\phi_i(j)}$ are sometimes used. If $\phi_i(j)$ doesn't determine a natural number, then $\phi_{\phi_i(j)}$ is taken to refer to the totally undefined function, computed by a Pascal program that loops on every input.

We are not too concerned about the exact nature of the indexing, except that we require that it is such that the following functions can be computed by Pascal programs:

1. $Rep : i \mapsto P_i$;
2. $Comp : \mathbf{N} \times \mathbf{N} \to \mathbf{N}$. Given the indices of two programs P and Q, *Comp* computes the index of the composite of P and Q: that program which passes its input to Q, and when and if Q halts, runs P on the output from Q.
3. A Pascal emulator. This takes two arguments P and i as input; P is a (character string) representation of a Pascal program. The Pascal emulator returns the same result (or loops) as program P does on input i.

An alphabetical listing of all Pascal programs would satisfy these requirements (although one imagines that *Rep* and therefore *Comp* would be horrendously time-consuming to run.)

Given an indexing and a function *Rep*, we may formally state what it is to be a program that reproduces itself:

Definition: A *virus* is a program $P = P_m$ such that for every input y, $P(y) = Rep(m)$.

We now proceed to the construction of a virus.

Diagonalization and a fixed point result

To the extent that most mathematicians are familiar with diagonalization arguments, they are known as yielding negative results. Two results known as Cantor's theorem, proved by diagonalization, state "Not all reals in [0,1] appear in any enumeration of infinite binary sums $\sum_{i=1}^{\infty} b_i 2^{-i}$ ($b_i \in \{0,1\}$);" and "For no set S is the cardinality of S equal to the cardinality of the powerset of S." Another negative result proved by diagonalization is "There is no Pascal program which decides the membership question for the set $\{i \in \mathbf{N} \mid P_i \text{ haltsoninput } i\}$." The essence of the diagonalization argument is this: If M_{ij} is any square matrix (even infinite), then no row of M is distinct from the diagonal at every position, since row i matches the diagonal at position i. The negative results listed above are proven by showing that the contrary implies the existence of a square matrix with a row distinct from the diagonal at every position. "Paradoxes" arise this way too: if there is a barber b that shaves every man who does not shave himself, we may construct a matrix $M_{ij} = 1$ if i shaves j, 0 otherwise, and the row M_b is the negation of the diagonal in the sense that $\forall j$, $M_{bj} = 1 - M_{jj}$. That is, there is no such barber.

Diagonalization can be used in a positive way as well, to get a fixed point result (see Owings [2].) Let f be a function. A square matrix M is *row-wise closed under* f if every row is f-related to some row, that is, if $\forall i \exists k$ such that $\forall j, f(M_{ij}) = M_{kj}$. Further, M is *diagonally complete* if some row of M is equal to the diagonal. Amazingly, the existence of an M with this pair of properties ensures that f has a fixed point! To see this, suppose row M_i is equal to the diagonal, and row k is the f-image of row i. Then $f(M_{ik}) = M_{kk} = M_{ik}$. That is, M_{ik} is fixed under f. This result is the "Diagonal fixed-point lemma."

Now suppose $f : \mathbf{N} \to \mathbf{N}$ is a function, computed by some Pascal program, that respects our indexing of Pascal programs: $\phi_i = \phi_j \implies \phi_{f(i)} = \phi_{f(j)}$. In this case f is called "extensional." Since f is extensional, it determines an operator (also denoted f) on the functions ϕ: $f(\phi_l) = \phi_{f(l)}$. We shall show that there is an $n \in \mathbf{N}$ such that $\phi_n = \phi_{f(n)}$ by using the Diagonal fixed-point lemma. Let M be the infinite matrix of partial functions: $M_{ij} = \phi_{\phi_i(j)}$. Note that every entry M_{ij} can be computed by some Pascal program P_l; in fact such an l can be determined effectively from i and j. P_l is a program which 1) uses *Rep* to construct P_i; 2) uses a Pascal emulator subroutine to determine the action of P_i on input j; 3) when and if step 2 finishes, uses *Rep* again to construct $P_{\phi_i(j)}$; and 4) uses the Pascal emulator again to compute the action of the program constructed in step 3 on it's (P_l's) input.

We need to show that M is diagonally complete and closed under f. Let P be a Pascal program which on any input $j \in \mathbf{N}$, computes the same thing as $P_j(j)$. (As above, this simply requires a call to *Rep* and a call to the Pascal emulator.) Suppose k is the index of this P, then for all $j \in \mathbf{N}$ $\phi_k(j) = \phi_j(j)$ therefore $\phi_{\phi_k(j)} = \phi_{\phi_j(j)}$ and row k of M equals the diagonal. Now we show that M is closed under f. Let P be a Pascal program (depending on i) that takes an input j and does the following: 1) computes *Rep*(i); 2) uses the Pascal emulator to apply the result of step 1) to the input j; 3) when and if 2) finishes, computes f of the result of 2). Let $k = k(i)$ be the index of this P. Thus $\phi_k(j) = f(\phi_i(j))$ unless $\phi_i(j)$ loops, in which case both expressions are undefined. Then for any j

$$f(M_{ij}) = \phi_{f(\phi_i(j))} = \phi_{\phi_k(j)} = M_{kj}$$

That is, M is row-wise closed under f. The fact that f is Pascal-program computable was used in computing k; and the fact that f is extensional is needed so that the expression $f(M_{ij})$ makes sense. Under these conditions on f and our previous assumptions about the indexing, we may use the Diagonal fixed-point lemma to conclude a weakened form of the Recursion theorem: there exists $n \in \mathbf{N}$ such that $\phi_n = \phi_{f(n)}$. Observe that n is obtained entirely constructively from (a program for, or index of) f using only *Comp*, *Rep*, and the Pascal emulator.

The Recursion theorem can be strengthened so that the restriction that f be extensional can be removed. Let f be any Pascal computable function on $\mathbf{N}$. We will say ϕ_i and ϕ_j are $\overline{f}$-related if $\exists k$ such that $\phi_i = \phi_k$ and $\phi_j = \phi_{f(k)}$. Then the argument above will show that every row i of M is $\overline{f}$-related to some row k of M — the construction of k is the same. Since the diagonal is one of M's rows, some diagonal element M_{ii} is $\overline{f}$-related to itself. Thus there is a k such that $\phi_k = M_{ii} = \phi_{f(k)}$.

We now show how a virus, as defined above, may be constructed. Let r be an index for *Rep*, and let $f : \mathbf{N} \to \mathbf{N}$ be the function which, given an index x, returns the index of a Pascal program P which does the following: 1) computes *Comp*(r, x); 2) returns this number, independent of its (P's) input. (Thus f always returns the index of a program that computes a constant function, but which constant function depends on the value of x.) It is clear that f is computed by some Pascal program, given that *Comp* is. (Observe however that f is not extensional.) By the Recursion theorem there is an n such that $\phi_n = \phi_{f(n)}$ which is the function of y that returns $Comp(r, n)$. Therefore

$$\forall y \; Rep(\phi_n(y)) = Rep(Comp(r,n))$$
$$\forall y \; P_{Comp(r,n)}(y) = Rep(Comp(r,n))$$

The virus is the program with index *Comp*(r, n): on any input y its output is the character string representation of itself.

The entire process I have described is effective: in principle one can actually write a computer virus this way. This is not, of course, the way viruses are written in fact. But it does show that one can expect the universal existence of self-reproducing programs. The reason is that only very weak assumptions were made in showing the existence of a Pascal virus: any language in which it is possible to write an interpreter for that language, and to manipulate program representations (*Comp* and *Rep*) is susceptible. At the heart of the construction is a substitution function (f), whose fixed point is used to build the virus. Practical virus programs (see [4]) use a substitution function and a fixed point of it in exactly the way f and a fixed point for it were used here — but its construction can be made considerably simpler.

Virus detection: a negative diagonalization

We turn now to a slightly more realistic setting.* Programs running on modern computers, unlike those that have been described up to this point, run "in an environment." This is to say that when a program is executed, it is run as a subprogram of the logically independent program, the operating system, which is responsible for such bookkeeping chores as primary and secondary memory management, process management, recording statistics, and so on. For practical purposes, viruses as described above do their harm by "infecting the operating system." That is to say, they copy themselves into the operating system.

To reflect this malignancy, for the remainder of this paper, we shall use an updated definition of "virus:"

Definition: A *virus* is a program that, when run, alters the code of the operating system.

(When a new version of the operating system is written legitimately, it replaces, not alters, the former operating system.) Note that no particular behavior is required of the modified operating system: requirements on reproduction are unnecessary for the result we seek.

It would be nice if we could detect automatically which programs are viruses and which are not by submitting them to a filter program, thus avoiding the expense and inconvenience of unwittingly and possibly harmfully altering our operating system. We now show there can be no program that does this correctly for every

*The following material is drawn from Dowling [1].

possible input, while guaranteed not to spread a virus itself.

We begin by fixing an operating system OS, and making a definition.

Definition: Program P spreads a virus on input x if running P under operating system OS on input x alters OS. Otherwise it is safe on input x. A program is safe if it is safe for all inputs.

We also make the assumption that there exist viruses for OS, otherwise there would be no necessity for our test. Now for the sake of contradiction, let us assume there is some safe program *IS-SAFE* that decides the safety of running an arbitrary program P on arbitrary input x. Thus

$$\textit{IS-SAFE}\ (P,x) = \begin{cases} \text{yes} & \text{if } P \text{ is safe on input } x \\ \text{no} & \text{otherwise} \end{cases}$$

Given such a program and our assumption that there exist viruses, it is easy to write a program $D()$ of one argument that has the following behavior:

$$D(P) = \begin{cases} \text{Write "Have a nice day"} & \text{if } \textit{IS-SAFE}\ (\text{P,P}) = \text{no} \\ \text{alter OS} & \text{otherwise} \end{cases}$$

Loosely, D is different at every position from the diagonal of the matrix $M_{P,x} = \textit{IS-SAFE}\ (P,x)$.

We can now show that *IS-SAFE* cannot be both safe and correct by examining the behavior of D on input D. If D is safe on input D this can only be because it has not executed the otherwise clause, that is, because $\textit{IS-SAFE}(D,D)$ = "no", thus showing that *IS-SAFE* is not correct. On the other hand, if D alters OS on input D, there are two possibilities. On one hand, the call to $\textit{IS-SAFE}(D,D)$ may be returning "yes" so the otherwise clause in D is being executed, in which case *IS-SAFE* is not correct. On the other hand if *IS-SAFE* returns "no" (so D simply prints "Have a nice day") the assumption that D is unsafe on input D means that the call to *IS-SAFE* must be the culprit, that is, *IS-SAFE* is not safe. We conclude that the assumption of the existence of a safe, correct program that runs on OS and checks the safety of its input must be incorrect; there can be no such program *IS-SAFE*.

Our assumption of the existence of a virus for OS, while necessary for the proof of the non-existence of *IS-SAFE*, is by no means valid for every operating system. An operating system and even some programs it runs, may be stored in a non-writable area of computer memory. In this case, there can be no program whose execution causes the OS to be altered, so there is a safe program *IS-SAFE*: one which computes the constant function "yes." For example, some personal computers keep their OS in ROM (read only memory), and in embedded systems (for example the computers that control VCRs and automobile ignition systems) both OS and the programs it runs are in ROM. One might model such a situation by a program OS that maps triples to triples: $\langle P, x, OS\rangle \mapsto \langle P, P(x), OS\rangle$. OS not only computes $P(x)$, but also is responsible to return OS and P (unchanged). Considerations like those in the previous section lead to the existence of programs that compute such a function; by definition it would be uninfectable (as it returns OS, not some altered program OS′.)

For general purpose computers, however, both OS and P reside in the same physical area of the computer's storage, (virtual or actual) main memory, and this area is writable. The execution of P, even under the control of OS, may cause changes to the memory locations in which OS is stored. Furthermore, for practical reasons, operating systems do not in fact write themselves out on every execution of a program but rather only compute the second component of the triple above. This combination of factors leaves open the possibility of the existence of a virus — and justifies the assumption that leads to the result that *IS-SAFE* cannot exist.

References

[1] Dowling, William F., "There are no safe virus tests," *Am. Math. Monthly,* 96.9, pp. 835-6.

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[3] Rogers, H., *Theory of Recursive Functions and Effective Computability,* McGraw-Hill, 1967.

[4] I. Witten, Computer (in)security: infiltrating open systems, *Abacus* 4 (Summer 1987) 7-25.

Four Computer Mathematical Environments

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In the May 29, 1990 issue of *PC Magazine* (Volume 9, Number 10), I published an article ("The New World of Higher Math") comparing four general purpose mathematical programs which include symbolic manipulation: *Derive*, *Macsyma*, *Maple*, and *Mathematica.* I was reviewing the IBM PC versions although all of them but *Derive* run on multiple platforms.

As part of the preparation of the article, I developed a set of 20 trial problems that I sent to each vendor requesting them to supply solutions. In this way when I ran time tests, I would have what the vendor regarded as the optimal method for solving the problem. The article alluded to the problems and time tests but did not present them in detail because of space considerations and the feeling that they were too technical for the audience.

I've received many requests for details about these problems. Moreover, the solutions provided by the vendors present a fascinating introduction to the way these problems work. So here are the problems and solutions!

Timing (in secs)

	Derive	*Macsyma*	*Maple*	*Mathematica*
1	11	174	32	15
2	476	>600+	8	>600*
3	50	24	6	46
4	NA	57	22	NA (22**)
5	NA	>600+	21	36
6	NA	1	1	1
7	5	>600	12	20
8	3	>600	9	15
9	+++	355	6	1
10	25	++	18	223
11	NA	8	1	1
12	1	2	1	1
13	3	16	3	NA
14	3	10	2	NA
15	3	9	2	NA (12**)

* >600 is with the released vesion. An unreleased library (to be in the next release) reduces it to 36 secs.

** NA means 1.2 can't do it; times in () are with libraries not included in the current release but scheduled for 2.0.

\+ Actually, after about two minutes, the system spontaneously rebooted; I tried this 4 times!!

++ The other programs did this to high order real as I intended; *Macsyma* only provided a 6 digit real or exactly in terms of gamma functions at 2 secs and 113 secs so impossible to compare.

+++ Using special nature of equations and graphing with crosshairs to solve, this problem is doable!! But it is interactive so timing is impossible.

The tests used the version of these programs current at the time the review was written (January, 1990). *Mathematica* 2.0 which addresses some of the symbolic lacks in version 1.2 should be out around the time you read this. Similarly, *Maple* 4.4 which addresses some of the graphical lacks in version 4.2 is expected out and *Derive* 2.0 with a built-in programming language is coming out also.

Note that *Derive* is in a different category from the other three programs which are competitive with each other. The three M programs have all four of the essential elements of a mathematical environment: symbolics, numerics, graphics and programming. *Derive* is missing the programming language but it requires less in resources (e.g. it will run on an XT; the other programs require a 386) and money. It is an excellent choice for high schools and some college teaching but not so good as a serious research tool.

Problem 1. Hilbert Matrices

Invert the 20×20 Hilbert matrix.

Note: Numeric programs have severe round-off errors at about 12×12. This problem shows the advantages of exact rational arithmetic.

Derive:

```
HILBERT (n):= VECTOR (VECTOR (1/(i+j-1),j,1,n),i,1,n)
HILBERT (20)^-1
```

Macsyma:

```
(C1) hilbert [i, j]:= 1/(i+j+1)$
(C2) h20: genmatrix(hilbert, 20)$
(C3) h20i: h20^^(-1)$
```

Note: $ suppresses the output on the screen.

Maple:

```
with (linalg);
que := hilbert (20);
ans := inverse (que):
```

Note: Need to load the external linear algebra package.

Mathematica:

```
In[1] := hilbert = Table[1/(i+j+1),{i,20},{j,20}];
In[2] := inverse = inverse[hilbert];
```

Problem 2. Symbolic Sums and Factoring Polynomials

Factor (over the rationals) the sum from 1 to N of i^30 as a polynomial in N.

Derive:

```
Calculus/Sum i^30 i 1 n
Simplify (last)
```

Notes: Here and below we describe menu choices; so the first command is entered by hitting c then s then typing i^30 and hitting enter three times to get the defaults. Only *Derive* has the menu oriented approach as well as its author command. The *Derive* authors note that *Derive* was slow at the factoring, but much faster if one tried to factor out 2n+1 by hand.

Macsyma:

```
(C1) simpsum:true$
(C2) sum (i^30,i,1,n);
(C3) FACTOR(%);
```

Note: In *Macsyma*, % refers to the last answer.

Maple:

```
ans := factor (sum (i^30, i=1..N)):
```

Mathematica:

```
In [1]:=<< GosperSum.m
In [2]:= GosperSum [i^30, {i, 1, n}] // Factor
```

Notes: You have to load an external library. The calculation was much faster with a beta for the 2.0 version of GosperSum.m than with the one shipped with version 1.2.

Problem 3. Taylor Series and Padé Approximations

Find the [20,20] diagonal Padé (continued fraction) expansion of exp(x).

Derive:

Like the other programs, some external files are provided but they are more like little programs that you have to modify than external functions. While *Derive* has no programming (branching), it can do quite a bit by its ability to define functions:

```
CF(a,m,n) := VECTOR(VECTOR(ELEMENT (a,m-n+i+j),
j,1,n+1),i,1,n)
DV(a,m,n) := ELEMENT(ROW_REDUCE (CF((a,m,n)),n+1)
```

followed by five more formulae.

Macsyma:
(C1) taylor (exp(x), x, 0, 40)$
(C2) pade (%, 20, 20);
Maple:
que := taylor (exp(x), x, 41):
ans1 := convert (que, ratpoly):
ans2 := convert (que, confrac):
ans3 := convert (ans1, confrac, x):
Note: *Maple* provides three different ways to get the answer in differing forms including two as continued fractions.
Mathematica:
In [1] :=<< Numerical Math/Approximations.m
In [2] := Pade [Exp[x], {x,0,20,20}]
Note: Again an external set of routines is needed.

Problem 4. Symbolic Integration and Differentiation
Take the derivative of (x^10)*cos (x^5*ln(x)). Then take the integral of the result and simplify it.
Derive:
Author x^10cos(x^5 ln(x))
Calculus/Differentiate
Simplify
UNABLE TO DO THE RESULTING INDEFINITE INTEGRAL
Macsyma:
(C1) diff(x^10*cos(x^5*log(x)), x);
(C2) integrate (%,x);
Maple:
que := diff ((x^10)*cos(x^5ln(x)), x);
ans1 := int(que, x):
ans2 := evalc(ans1):
Mathematica:
In [1] := derivative =D[x^10Cos[x^5Log[x], x]
In [2] := Integrate [derivative, x]
UNABLE TO FIND ANSWER; however a module implementing the Risch algorithm while not in version 1.2 is slated to go in version 2.0 and it can do the calculation.
In [3] := << Risch.m
In [4] := Int [derivative, x]

Problem 5. Factoring in Several Variables
Factor the 6 × 6 van de Monde determinant.
Derive:
vars := [q, b, c, d, e, f, g]
vandem := VECTOR (VECTOR (ELEMENT (VARS, i)^, j, 0, n-1), i, 1, n)
det(vandem(5))
Factor/Rational (last)
Macsyma:
(C1) load(matfuncs)
(C2) vandermonde(6);
(C3) determinant(%)$
(C4) factor(%);
Maple:
que := vandermonde ([u, v, w, x, y, z]);
ans := factor(det(que)):
Note that Vandermonde is built in for *Macsyma* and *Maple*.
Mathematica:
In [1] := VandermondeMatrix [n_,z_]:=
Table [z[i]^(j-1),{j,n},{i,n}]
In [2] := VandermondeMatrix [6,x] // MatrixForm
In [3] := Det [%] // Factor

Problem 6. Total vs. Partial Derivative
Consider a function F(x,y) with y a function of x, y(x). Compute the total derivative DF/Dx and the partial derivative with respect to the first variable.
Derive:
DOES NOT DO PARTIAL DERIVATIVES; could handle total derivative.
Macsyma:
(C1) load(ndiff)$
(C2) depends(y, x)$
(C3) /*Total derivative */ diff(f(x, y), x);
(C4) /*Partial derivative */ pderivop(f, 1, 0)(x, y);
Maple:
tdiff := proc(f, y, x)diff(f, x)+diff(f, y)*diff(y(x), x) end:
ans1 := tdiff(f(x, y), y, x):
ans2 := diff(f(x, y), x):
Mathematica:
In [1] := Dt[f[x, y], x]
In [2] := D[f[x, y], x]

Problem 7. Prime Testing
Find the next prime after 10^64. There are prime tests based on Fermat's theorem, which are not rigorously correct but right "most of the time". All the programs but *Macsyma* have such a test implemented.
Derive:
Next_Prime (10^64)
Macsyma:
(C1) for n from 10^64+1 step 2 do
(if primep(n) then (print ("this is the answser"), return (n)) else print (n))$
"*PC MACSYMA* "finds" the prime 10^64+57, in the sense that it takes a very long time considering whether this number is prime; but is unable to prove it in an acceptable amount of time, due to the old factoring algorithm in the released version."
Maple:
ans := nextprime(10^64):
Mathematica:
Two solutions were provided, each programmed.

```
In [1] := NextPrime[n Integer] :=
Block [{i=n+Mod[n+1, 2]},
          While [! Prime Q[i], i+=2];
                    i
]
In [2] := NextPrime[10^64]
In [3] := NextPrimeFaster[n_ Integer] :=
Block [{i=n+Mod[n+1, 2]},
      prod = Times @@ Prime[Range[Floor[N[Log[n]]]]];
      While [True,
                If [GCD[i, prod]==1,
                If [PrimeQ[i], Break[]]];
                i+=2
      ];
             i
]
```

Note: The answer is
1000000000000000000000000000000000
0000000000000000000000000000057.

Problem 8. Integer Factoring
Factor(236789456789432678);
Derive:
Enter the number and choose Factor from the menu.
Macsyma:
(C1) factor(236789456789432678);
Maple:
que := 236789456789432678;
ans := ifactor(que):
Mathematica:
In [1] := FactorInteger[236789456789432678]

Problem 9. Solving Nonlinear Equations (from the Simon-Wilson Benchmarks)
Solve numerically the triple of nonlinear equations:

sin(x)+y^2+ln(z)=7
3*x+2^y−z^3=−1
x+y+z=5

Derive:
Derive only directly solves equations of one variable but an involved solution was provided using direct substitution, some graphical work to compute where curves cross and the fact that these equations aren't that complex.
Macsyma:
Provided a "by hand" solution much like *Derive* but more automated.
Maple:
```
que := {
        sin(x)+y^2+ln(z)=7,
        3*x+2^y−z^3=−1,
        x+y+z=5
};
ans := fsolve(que):
```
Mathematica:
In [1] := FindRoot [{Sin[x]+y^2+Log[z]==7,3x+2^y−z^3==1, x+y+z==5}, {x,1}, {y,1}, {z,1}]

Problem 10. Infinite Integrals and Sums
Compute the integral from zero to infinity of e(-x)/(1+x^4). Compute the sum from 1 to infinity of 1/n^4 either numerically or exactly.
Derive:
Calculus/Integrate Alt-e^-x/(1+x^4)×0 inf
approximate
Note: *Derive* does not directly do infinite sums but the sum from 1 to 16 plus an integral approximation from 16 to infinity gives the answer "to single precision".
Macsyma:
(C1) f1(x):=exp(-x)/(1+x^4);
(C2) quanc8(f1, 0, 20);
Note: The PC version couldn't get better accuracy than one in a million. By an involved sequence of preliminary reductions by hand, an exact antiderivative was found!
(C1) simpsum:true$
(C2) sum(1/n^4, n, 1, inf);
Note: This gave the exact answer: pi^4/90.
Maple:
que := exp(-x)/(1+x^4);
ans := evalf(Int(que, x=0..infinity)):
ans1 := sum(1/n^4, n=1..infinity):
Note: This gave the exact answer: pi^4/90.
Mathematica:
In [1] := NIntegrate[Exp[-x]/(1+x^4),{x, 0, Infinity}, WorkingPrecision ->40, Points ->20, AccuracyGoal ->30, Method -> DoubleExponential]
In[2] := NSum[1/n^4, {n, 1, infinity}]
Note: Could only force the exact answer for the sum by invoking the built in zeta function.

Problem 11. TEX conversion
Format the function
f(x) := (1+sin(x))/(exp(-tan(x))
in some version of TeX and/or some version of TROFF.
Derive:
"Derive has no TeX or TROFF interface"
Macsyma:
tex((1+sin(x))/exp(-tan(x)))$
Maple:
que := (1+sin(x))/exp(-tan(x));
readlib(latex):
latex(que);
readlib(eqn):
eqn(que);
Note: eqn is *Maple's* name for TROFF
Mathematica:
In [1] := f[x] == (1+Sin[x])/(Exp[-Tan[x]] // TeXForm

Problem 12. Language Translation
Generate a program to compute the function
f(x):=(1+sin(x))/(exp(-tan(x))
in Fortran, C and/or Pascal.
Derive:
Derive has a Transfer/Save/Fortran command on the menu tree.
Macsyma:
gentran(f(x):=(1+sin(x))/exp(-tan(x)))$
Maple:
```
readlib(fortran):
interface(echo=0):
lprint (      function f(x));
lprint (      real x);
fortran(que);
lprint (      end);
```
Mathematica:
In[1] := (1+Sin[x])/(Exp[-Tan[x]]) // CForm

Problem 13. Linear ODE Solutions
Solve the ODE y″+y=sin(x).
Derive:
An elaborate file was provided which stepped through a textbook solution with Wronskians.
Macsyma:
(C1) sol: ode2 ('diff(y, x, 2)+y=sin(x), y, x);

Maple:
que := diff(y(x), x$2)+y(x)=sin(x);
ans := dsolve(que,y(x)):
Mathematica:
In [1] := DSolve[y''[x]+y[x]==Sin[x], y[x], x]
doesn't work! An explicit textbook solution by computing Laplace transforms was presented.

Problem 14. Nonlinear ODEs

Solve the ODE x^2*dy/dx+2*x*y−y^3=0
Derive:
A partial solution going with a detailed analysis of the form of the equation was provided.
Macsyma:
(C1) sol: ode(x^2*diff(y, x)+2*x*y−y^3=0, y, x);
Maple:
que := x^2*diff(y(x), x)+2*x*y(x)−y(x)^3=0;
ans := dsolve(que, y(x)):
Mathematica:
A direct solution was not provided but the first five terms of a power series solution were found and solution via a clever change of variables provided a solution.

Problem 15. Solve the Recursion Relation s(n)= 3*s(n−1)−2*s(n−2); s(1)=1, s(2)=1

Derive:
No general solution was provided but a detailed analysis did get an answer.
Macsyma:
(C1) LOAD(DIFFER)
(C2) /* *MACSYMA* assumes that the recursion relation begins with s[0], instead of s[1]. */
difference(s[n+2]=-3*s[n+1]-2*s[n], s[n], [s[1]=1, s[0]=1]);
Maple:
que := {s(n)=-3*s(n-1)-2*s(n-2), s(1)=1, s(2)=1};
ans := rsolve(que,s(n)):
Mathematica:
Cannot be done with *Mathematica* 1.2 but 2.0 will include an Rsolve external file.
In [1] := << Rsolve.m
In [2] := Rsolve[{s[n+2]+3s[n+1]+2s[n]==0/; n>=0, s[1]==1, s[2]==1}, s[n], n]
The answer is
Out [93]={{(-2)^n-3(-1)^n}}

Problem 16. Graph the Polar Function r=sin(3*theta).

Graph the surface

z=x^2*y^2*cos(r) (r^2=x^2+y^2)

Print it on a laser jet. Graph the function sin(1/x) on the interval (-1,1).

Problem 16.1 Graph the polar function r=sin(3*theta).
Derive:
First author "sin(3*theta)", then use Options/Display to go to graphic mode, then Plot/Options/Type/Polar, then /Plot.
Macsyma:
plot(sin(3*theta), theta, 0, %pi, polar), plotnum=120$
Maple:
ans := plot([sin(3*theta), theta, 0..Pi],
x= −sx..sx, y=-1..9/16, coords=polar);
Mathematica:
In [1] := PolarPlot[r_,{t_, tmin_, tmax_}, opts_] :=
ParametricPlot[{r Cos[t], r Sin[t]},{t, tmin, tmax},opts,
AspectRatio -> Automatic]
In [2] := PolarPlot[Sin[3 theta],{theta, 0, 2Pi}]

Problem 16.2 Graph the surface z=x^2*y^2*cos(r), where (r^2=x^2+y^2).
Derive:
Using the author command, enter the function as a function of x and y and then shift to graphics mode with Options/Display and then Plot/Plot.
Macsyma:
plot3d(x^2*y^2*cos(sqrt(x^2*y^2)),x,-1,1,y,-1,1)$
Maple:
3D graphics not supported in version 4.2.
Mathematica:
In [1] := Plot 3D[x^2y^2Cos[(x^2+y^2)^(1/2)],{x,-4,4},{y,-4,4}]

16.3 Print it on a laser jet.
Derive:
Derive relies on you to have another program to do print-screens.
Macsyma:
"The method differs for different versions of *MACSYMA*. For *PC MACSYMA*, copy the plot to the MS_Paint window, then do a screen hardcopy. This method is due to be improved in the next version."
Maple:
Laser Jet printers not supported in version 4.2.
Mathematica:
Use the supplied hardcopy program which can be run from inside *Mathematica*. (See the example on page 869.)

Problem 16.4 Graph the function sin(1/x) on the interval (-1,1).
Derive: Author the function and choose Plot/Plot.
Macsyma:
(C1) equalscale: false$
(C2) adaplot2(sin(1/x), x, -1, 1, -1, 1)$
Maple:
ans := plot(sin(1/x),x=-1..1,y=-1..1, resolution =640,
style=LINE);
Mathematica:
In[1] := Plot[Sin[1/x],{x,-1,1}]

Problem 17. Write a program to generate the first n terms in the continued fraction expansion for the real x.

Derive:
While a program can't be given, you can compute these terms by a simple sequence of repeated keystrokes.
Macsyma:
my_cf(x,n):= block([cflength:n], cfdisrep(cf(x)))$
Maple:
This is built into *Maple* via convert(x,confrac,n) but a program was supplied for illustration purposes:

```
con_frac :=proc (f, maxit)
local nu,de,r,Q,pq,i,qmax,q0,q1,q2,j;
if type(f ,float) then nu :=op(1,f); de:= op(2,f);
if de<=0 then de:=10^(-de) else nu:=nu*10^de; de:=1; fi;
elif type(f, fraction) then nu:=op(1,f); de:=op(2,f);
elif type(f, integer) then nu:=f; de:=1;
```

```
else ERROR(invalid arguments)
fi;
if type(maxit,integer) then qmax:=maxit else ERROR (in-
valid arguments) fi;
q0:=1; q1:=0;
for i from 0 to qmax do
  pq:=iquo(nu,de,'r');
  if i=0 and r<0 then pq:=pq-1; r:=r+de; fi;
  q2:=pq*q1+q0; q0:=q1; q1:=q2;
  Q[i]:=pq;
  if (r=0) then qmax:=i; break fi;
  nu:=de; de:=r;
od;
[Q[j]$ j=0..qmax]
end:
```

Mathematica:

```
In [1] := ContinuedFraction[x_Real, n_Integer?Positive]:=
        Floor[NestList[1/(# - Floor [#])&, x, n-1]]
```

Problem 18. Write a program that accepts a permutation (of arbitrary size in any convenient format) and compute its cycle decomposition.

Derive:

No solution provided.

Macsyma:

```
PERMUTATION_DECOMP(permlist):=
block ([i,j, list_of_cycles, new_cycle, remaining_numbers],
 /* It might be desirable to add some error checking here to
 check that PERMLIST is a list of length N whose members
 are distinct integers from 1 to N. /*
list_of_cycles:[],
remaining numbers:copylist(permlist),
START_NEW_CYCLE,
i:first(remaining_numbers),
remaining_numbers:rest(remaining_numbers),
new_cycle:[i],
ADD_TO_CYCLE,
j:part(permlist, i),
if not member(j, new_cycle)
      then (new_cycle:endcons(j,new_cycle),
                  i:j,
                  go(add_to_cycle))
      else (list _of_cycles:cons(new_cycle,list_of_cycles),
remaining_numbers:complement
(new_cycle,remaining_numbers),
if length(remaining_numbers)>0
then go(start_new_cycle)),
list_of_cycles)$
```

Maple:

This is built into *Maple* with the following:

```
with(group);
convert(list_perm,disjcyc);
```

but a program was supplied for illustration purposes

```
list_to_cycle:=proc(p)
local z, cp, c, i, n, s;
   n:=nops(p);
if not type(p,list) or {op(p)}<>{1..n} then
      ERROR(not a permutation.);
fi;
   cp:=NULL; s:={};
   for i from 1 to n do
         if not member(i, s) then
               c := i;
               z := p[i];
               while z<>i do
                     c := c,z;
                     s := s union z;
                     z := p[z];
               od;
               if c<>i then cp := cp,[c] fi;
   fi;
   od;
   [cp];
end:
```

Mathematica:

```
In[1]:= ToCycles[perm_?PermutationQ] :=
Block[{p=perm, m, n, cycle, i},
      Select[
      Table[
               m=n=p[[i]];
         cycle = {};
         While[p[[n]]; !=0,
               AppendTo[cycle,m=n];
                     n=p[[n]];
                     p[[m]]=0
               ];
         cycle,{i,Length[p]}
      ],
      (#=!={})&
]
]
```

Problem 19. Write a program to list all the k element sets of {1,2, . . . ,N}

Derive:

(Not exactly a solution!)

"First we define the universe:"

ELEMENTS := ["1", "2", "3", "4", "5", "6", "7", "8", (up to N)]

"Next we define a generating function:"

SETS (k,n):=$[\sum_{j=1}^{n}$ ELEMENT (ELEMENTS, j)$]^k$

"Highlight the following then choose Expand:"

SETS (2, 3)

"The cofactors of the terms having exponents all 1 are the k-element sets of the first n natural numbers."

"1"^{2} + 2 "1" "2" + 2 "1" "3" + "2"^{2} + 2 "2" "3" + "3"^{2}

Macsyma:

```
(must replace N and k with explicit values)
sizesubset(x,k):=(powerset(x),
subset (%%,lambda([y],length(y)=k)))$
x:makelist(i,i,1,N);
sizesubset(x,k);
```

Maple:

This is built into *Maple* with the following:

```
with(combinat);
combine(6,4);
```

but a solution was provided for illustrative purposes.

```
k_subsets := proc(N,k)
```

```
        local i, j, m, r, c, d;
        if not (type(N, integer) and N>=0 and
        type(k, integer) and k>=0 and k<=N)
        then ERROR(invalid arguments) fi;
        if k=0 then lprint({}); RETURN() fi;
        for i to N do d[i]:=i od:
        r:=N;
        c[0]:=-1;
        for i to k do c[i]:=i od;
        j:=1;
        while j<>0 do
              lprint({d[c[m]]$ m=1..k});
              j:=k;
              while c[j]=r-k+j do j := j-1 od;
              c[j]:=c[j]+1;
              for i from j+1 to k do c[i]:=c[i-1]+1 od;
    od;
    NULL
  end:
```

Mathematica:

```
In[1]:=KSubsets[l_List, 0]:={ {} }
In[2]:=KSubsets[l_List, 1]:=Partition[l,1]
In[3]:=KSubsets[l_List, k_Integer?Positive]:=
{l}/;(k==Length[l])
In[4]:=KSubsets[l_List, k_Integer?Positive]:=
      Join[
         (Prepend[#,First[l]])&/@KSubsets[Rest[l],k-1],
         KSubsets[Rest[l],k]
         ]
```

Problem 20. Write a program that takes two polynomials P and Q with coefficients in a finite field (say of order p^n) and finds the quotient (in this field). The results may be expressed in terms of a generator of the field and the polynomial it obeys over the field of order p.

Derive:

No solution provided.

Macsyma:

You can tell *Macsyma* to work in a given finite field with a few commands.

Maple:

A built in library function evalfg will solve the problem but a program was provided for illustrative purposes.

```
quotient := proc(f, g, x, m, a, p)
local D, i, j, c, d, t, gx, s, Qd, qd, F, G, Q;
c:=coeffs(f,x,'t');
D:=degree(f,x);
for i from 0 to D do F[i]:=0; od;
for i to nops([t]) do F[degree(t[i],x)] := Rem(c[i],m,a)
mod p od;
c:=coeffs(g,x,'t');
d:=degree(g,x);
for i from 0 to d do G[i]:=0; od;
for i to nops([t]) do G[degree(t[i],x)] := Rem(c[i],m,a)
mod p od;
gx:=Gcdex(G[d], m, a, 's', 't') mod p;
if gx<>1 then ERROR(m, is reducible) fi;
Qd:=D-d; qd:=Qd;
for i from 0 to qd do Q[i]:=0; od;
while qd>=0 do
  Q[pd]:=Rem(expand(s*F[D]),m,a) mod p;
  for i from d by -1 to 0 do
  F[i+qd]:=Rem(F[i+qd]-expand(Q[qd]*G[i]),m,a)mod p;
  od;
  for i from D by -1 to 0 do if F[i]<>0 then D:=i;
  break fi; od;
  if i=-1 then D:=i fi;
  qd:=D-d;
od;
convert([Q[Qd-j]*x^(Qd-j)$ j=0..Qd], +);
end;
```

Mathematica:

A solution was provided using an external package not included with version 1.2 but to come with version 2.0.

```
In[121]:=<<FiniteFields.m
In[122]:=a=FiniteField[P(y), y, {p,n}]
In[123]:=b=FiniteField[Q(y), y, {p,n}]
In[124]:=c=a/b
```

In addition, you may supply any single programming example of less than 15 lines of code that you feel illustrates the power of your package.

Derive:

1: "The curvature of u(x) at the point x=a:"

2: CURVATURE (u,x,a):=$\lim_{x\to a}\{[d/dx]^2 u/[1+[du/dx]^2]^{3/2}\}$

3: "The parametric equations for the circle centered at x,y of radius r:"

4: CIRCLE (x, y, r, t):=[x+r COS(t), y+r SIN(t)]

5: "The parametric equations for the osculating circle of u(x) at x=a:"

6: "where the slope is s, the radius is r and the hypotenuse is h:"

7: K1(u,x,a,s,r,h):= CIRCLE [a–sr/h, ($\lim_{x\to a}$u)+r/h,r,x]

8: "K2 computes the radius and hypotenuse:"

9: K2(u,x,a,s):=K1[u,x,a,s, 1/CURVATURE (u,x,a), $\sqrt{(1+s^2)}$]

10: "KISS computes the slope, letting K2&K1 do the rest:"

11: KISS (u,x,a):=K2[u,x,a, $\lim_{x\to a}$du/dx]

12: "Choose Options Display and your graphics mode,"

13: "then highlight the following expression and choose Plot Plot:"

14: 2 COS(x)

15: "Highlight the following and choose approX to get 3 osculating circles:"

16: VECTOR (KISS (2COS(x),x,k),k, $-\pi, \pi, \pi$)

17: "Highlight the resulting matrix & Plot Plot to superimpose the circles:"

Macsyma:

```
(C1) /* DERIVE THE SCHWARZSCHILD BLACK HOLE
SOLUTION IN GENERAL RELATIVITY.
1. Load the CTENSOR package. */
(ratfac:true,load(ctensor))$
(C2) /* 2. Enter the general static spherically symmetric metric. */
(dim:4, omega:[r, th, ph, t], depends([a, d], r),
lg:matrix([a, 0, 0, 0], [0, r^2, 0, 0],
[0, 0, r^2*sin(th)^2, 0], [0, 0, 0, -d]));
```

(C3) /* 3. Compute metric inverse and Einstein curvature tensor. */
(cmetric(), ricci(false), einstein(true))$
(C7) /* 4. Make a list of the independent field equations. */
DE_LIST:FINDDE(EIN,2);
(C8) /* 5-6. Solve one field equation for A(R). */
ode(last(de_list),a,r);
(C9) sol_a: part(solve(map(exp,%),a),1);
(C10) /* 7. Cast the solution into standard form. */
sol_a: sol_a,exp(%c)=1/(2*m), factor;
(C11) /* 8-10. Now solve the equation EIN[4,4] = 0 for D(R)*/
ev(first(de_list), sol_a, diff, factor);
(C12) ode(num(%),d,r);
(C13) sol_d: ev(expand(radcan(%)),%c=1);
(C14) /* 11-12. Assemble the solution and check it. */
sol: [sol_a,sol_d];
(C15) ratsimp(ev(de_list,sol,diff));
(C16) /* EXAMINE THE SCHWARZSCHILD SOLUTION. 13. Enter the metric in standard coordinates. */
(clear_ctensor(), lg:matrix([1/(1-2*m/r),0,0,0],[0,r^2,0,0], [0,0,r^2*sin(th)^2,0],[0,0,0,-(1-2*m/r)]));
(C17) /* 14. Compute Christoffel symbols, Riemann and Einstein curvatures. */
(cmetric(),christof(mcs),lriemann(true),ricci(true))$
(C32) /* 15. Compute the geodesic equations. */
cgeodesic(true)$

Maple:

```
#Compute the hessian matrix of an expression and convert
# it to optimized fortran
que:=exp((sin(x)-1)*(x^2+y^2+z^2))*cos(y)+
sin(z+cos (x))*exp(-y);
hes := linalg[hessian](que,[x,y,z]);
readlib(fortran):
fortran(hes,optimized);
```

Mathematica:

Instead of a single problem, they supplied a bunch of "one-liners":

Draw a picture of the roots of a polynomial in the complex plane.

```
Root Plot [poly_,x_]:=
      block[{t},
            t=x/. Solve [N[poly==0], x];
            ListPlot[Transpose[{Re[t], Im[t]}],
            Prolog->PointSize [.04]
=>]
      ]
```

Generate an n-bit Gray code.

```
Gray [n_Integer]:=
Gray[n]=Flatten[{Gray[n-1], 2^(n-1)+Reverse[Gray[n-1]]}]
Gray[0]={0}
```

Find the variance of a list.

```
Mean[list_List]:= Apply[Plus,list] / Length[list]
Variance[list_List] := Mean[(list - Mean [list])^2]
```

Find a Jacobian.

```
Jacobian[funs_List, vars_List] := Outer [D, funs, vars]
```

Find the distinct elements in a list, and the frequencies with which they occur.

```
Frequencies [list_List] :=
Map [{#, Count[list, #]}&, Union[list] ]
```

Reviews of Mathematical Software

SOLVE1 — Vector and Matrix Units for Turbo Pascal

*Reviewed by Gustaf Gripenberg**

The software package *Solve1* consists of a number of Turbo Pascal procedures for doing vector and matrix calculations on IBM-PC and compatible computers. They are supplied in the form of different compiled units (TPUs) depending on the desired real data type (Single, Real, Double, or Extended) and also depending on the Turbo Pascal version used (4.0, 5.0, or 5.5). If no arithmetic co-processor is available, then only the Real data type can be used. The requirements on the computer are determined by the Turbo Pascal compiler.

The vector unit contains functions and procedures that calculate the scalar product of two vectors, the magnitude of a vector, the sum of two vectors, the difference of two vectors, the scalar multiple of a vector, and the normalization of a vector to unit length. The matrix unit contains procedures that initialize a matrix to a unit matrix, multiply a matrix by a scalar, vector, or another matrix, and that calculate the sum of two matrices, the LU factorization of a matrix, and the determinant of a matrix in LU form. Furthermore, there are procedures for doing Gaussian reduction with no pivoting, backsolving a triangular system and solving a system in LU form.

Several of these procedures are such that it would be quite easy for the user to write his or her own procedures on a few lines. The advantages of using the procedures in *Solve1* seem to be that they are faster and also that one does not have to worry about how one defines the array types. For vectors it suffices to give the length and for matrices the size of the matrix and the rowsize of the matrix of which it is a part.

One serious weakness is that the matrix additions and multiplications are restricted to square matrices. Furthermore, the LU factorization behaves erratically if the matrix is singular: in some cases no problems seem to appear, in some others there is a run time error that could be difficult to identify.

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Several demonstration programs with source code are included. These programs show how one can easily use the subroutines in the units to solve linear systems, inverting matrices, etc. They are useful additional building blocks for application programs.

The documentation is on the whole satisfactory, although one has to guess from the name what the output of the functions' subroutines are.

This package can be useful for people who write programs in Turbo Pascal and need to do matrix calculations. If the basic problem is to do matrix calculations, then this package is too restricted in scope to make Pascal the programming language of choice.

The price of the package is $35 and it is available from

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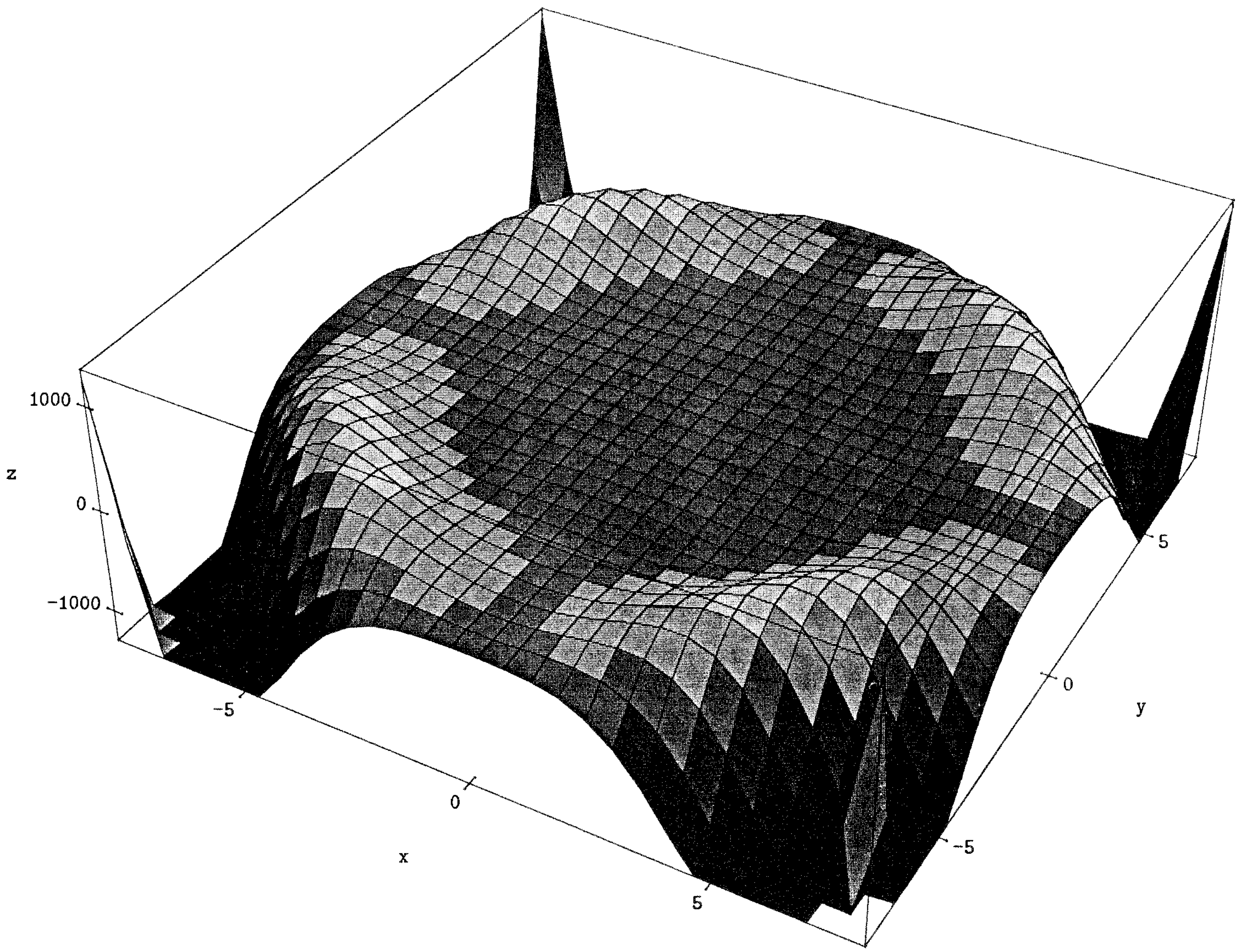
Gonzaga University
Spokane, Washington 99259

Graph of the Surface
z = x^2*y^2*cos(r) (r^2 = x^2 + y^2)
by *Mathematica.*



From Manuscript to Published Paper: How does it happen?

John A. Servideo
Manager of Editorial Services, AMS

Abstract

The purpose of this article is to outline and clarify what happens to a paper once it is sent to the Providence office for publication in an AMS book or journal. The production process is simplified and explained step-by-step for a typical paper. In general, publishing jargon has been avoided; but, in cases where its use is unavoidable, the various terms are highlighted in bold type and defined at the end of this article. Examples of signs used in correcting proof, marked proof, and the resulting corrected proof are illustrated.

Assumption: Let us assume that the paper to be published has been submitted to one of the appropriate journal editors. The editor will have had the paper reviewed and, if necessary, revised. In fact, the paper might have been reviewed and revised more than once. The Publication Division of the AMS has no control over this process and the time it requires. Production of the paper begins once the accepting editor has forwarded the paper to the Publication Division, specifically informing us that it has been accepted for publication in a particular journal.

1. Receipt of Manuscript in Providence

As soon as an accepted paper arrives in the Providence office, **a copyright transfer agreement** is sent to all authors. The paper is also assigned a code number. The code consists of two parts: the journal or book code and a sequential number. TRAN628 is an example of the code for paper number 628 accepted for publication in *Transactions*. The full title of the paper, the complete name of the author, the contact author in the case of multiple authors, the date received in Providence, the number of manuscript pages, the number of pieces of art in the paper, and the type of publication (author prepared or typeset) are examples of additional information entered into the **publications database**. If the manuscript is an electronic manuscript, this is also recorded.

2. The Role of the Production Editor

After the information needed for the database has been recorded, the manuscript is then forwarded to the **production editor** who will shepherd it through the production process to publication. The production editor plays a pivotal role in the publication process because it is this person's responsibility to coordinate all of the tasks and monitor the processes that the paper must undergo, all the while maintaining a schedule and assuring the quality of the published work.

3. Copy Editing and Type Marking

Although copy editing and type marking are two distinct processes, they can be done simultaneously or in tandem.

A manuscript must first be copy edited before it can be typeset. Copy editing can be done by the production editor, but more often than not it is done by a freelance copy editor. The copy editor is responsible for several important functions: the paper is read in its entirety and any typographical and grammatical errors are corrected; the manuscript is styled according to AMS guidelines and the style of the particular journal in which it will be published; and any ambiguous or unfamiliar mathematical notation is marked and identified for the typesetter.

The goal is to make the typesetting process as easy as possible by clarifying anything in the manuscript that might cause the typesetter to misunderstand what is wanted. At the AMS, all copy editing is done using red pencil. Copy editing changes are marked in situ; hence, the reason we ask that manuscripts be prepared using at least double line spacing and with ample margins. Figure 1 illustrates some of the most common signs used in copy editing manuscripts and correcting proofs.

It is important to keep in mind that the copy editor does not check the mathematical content of a manuscript.

We rely on the author, the accepting editor, and the review process to assure the integrity of the mathematics.

When copy editing is complete, the manuscript is type marked either by the production editor or the freelance copy editor. Type marking consists of assigning to each typographical element in the manuscript a mnemonic code that identifies that particular element for the typesetter. Two examples are **AH** for a first-level heading and **TM** for theorem text. The mnemonic codes are standard and generic, but the results are specific to a publication: **AH** used for *Proceedings* and *Transactions* will not necessarily produce the same typeset results. At the AMS, all type marking is done in blue pencil.

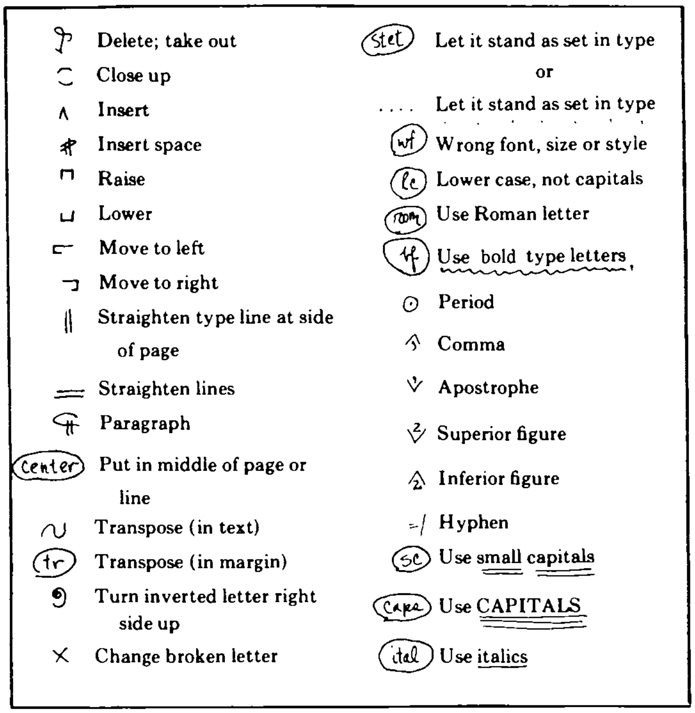


Figure 1. Signs used in correcting proofs.

4. Preparing Art

Anything in a manuscript that cannot be typeset falls into the category of art, which includes graphs, diagrams, photographs, and computer-generated images. Art is handled and produced in a process that is separate from the actual typesetting, so it requires special consideration.

When a manuscript contains art, we try to use the author's originals whenever possible. At the copyediting stage the production editor determines whether or not the art submitted with the manuscript can be reproduced well. Sometimes the art is redrawn for greater clarity or to obtain better copy from which to print.

While copy editing the manuscript, the production editor or the copy editor identifies any art that has to be rendered. The art is separated from the manuscript, copy edited, and type marked. Its desired placement in the manuscript and its size are indicated for the typesetter. (Placement of art is discussed in Section 9.)

5. Electronic Manuscripts

In recent years the AMS has encouraged authors to prepare and submit papers electronically. If the electronic files are prepared properly, the time from submission of a manuscript until publication can be shortened because we are able to capture the authors' keystrokes and avoid the time-consuming process of typing. An additional benefit to using an author-prepared electronic file is that the typesetter cannot inadvertently introduce errors.

At the beginning of the production process, electronic manuscripts are handled differently from the traditional, typed manuscript, so it will be helpful to explain those differences. When we receive an accepted paper that has been prepared using $\mathcal{A}_\mathcal{M}\mathcal{S}$-TEX, we request the electronic files from the author, if the files did not accompany the manuscript. Instructions are given for submission through electronic mail or on diskettes. When the electronic files are received the production editor orders a printout of the files, which are produced in a double-spaced format to allow room for copy editing and type marking. From this point on the files are treated the same way as files that are created by the AMS Composition Department.

6. Composition

Once the copy editing and type marking of the manuscript and the art have been completed, the manuscript is ready for **composition**. Depending on the length, initial composing time can take as little as two weeks. When the first round of typesetting is complete, the manuscript is returned to the production editor with first **galley proof** for proofreading. First proof of art usually appears at this time, if the art has to be redrawn.

7. Proofreading

Most proofreading of first galleys is done by freelance proofreaders who have received special training for dealing with high level mathematical content. Letter for letter, symbol for symbol, the proofreader reads the proof against the manuscript. Any corrections, whether they are oversights on the part of the copy editor or errors introduced during typesetting, are marked. Equations that do not fit the text width are marked for correct breaks and alignment. Overall format of the article is checked to make sure it follows the style and the design of the journal. Art is also proofread and marked for corrections at this time. Marked proof is then returned to the production editor, who checks it before returning it to the Composition Department for corrections. See Figure 2 (next page) for an example of proof marked for corrections and the resulting corrected proof.

EXAMPLE

THE USE OF PROOFREADING SIGNS

of B_1 and d_1d_p' divides d_1d_p' (+1) Hence B is reducible to the form (11.5) with diagonal terms $d_1, d_1d_2', \cdots, d_1d_p'$ which proves (11.4).

12. Groups with a finite number of generators. We shall discuss certain properties of these groups culminating in the basic product decomposition (12.5).

(12.1) DEFINITION. *Let* $B = \{g_1, \cdots, g_n\}$, $B' = \{g_1', \cdots g_n'\}$ *be two sets of elements of G containing the same number n of elements. By a unimodulaf transformation* $\tau: B \to B'$ *is meant a system of elations*

(12.2) $$g_i' = \sum a_{ij}g_j, \quad \|a_{ij}\| \text{ unimodular.}$$

The following proposition shows in how natural a manner unimodular transformations make their appearance in the theory of groups with finite bases.

(12.3) *Let G be a group with a finite base* $B = \{g_1, \cdots, g_n$ *In order that* $B' = \{g_1', \cdots, g_n\}$ *be a base for G it is necessary and sufficient that B' be obtainable from B by a unimodula r transformation.*

For any given set $B' = \{g_1', \cdots, g_n'\}$ of elements of G there exist relations

(12.4) $$g_i = \sum c_{ij}g_j, \quad C = \|c_{ij}\|$$

A necessary and sufficient condition ~~in order~~ that $\{g_i'\}$ be a base is that the G_j be expressible as linear combinations of the g_i', or that there exist relations

(12.5) $$g_i = \sum d_{ij}g_i', \quad D = \|d_{ij}\|.$$

From this follows

$$g_i = \sum d_{ij}c_{jk}g_{kj}$$

Hence since B is a base we must have $DC = 1$. This matrix relation yields $|D||C| = 1$, and since the determinants are integers we must have $|C| = \pm 1$. Thus in order that B' be a base C must be unimodular, or the condition of (12.3) must be fulfilled. Conversely, if it is fulfilled, C is unimodular and (12.5) holds with $D = C-1$ from which it follows readily that b' is a base.

THE PRECEDING PASSAGE PRINTED WITH ALL CORRECTIONS MADE

of B_1 and d_1d_p' divides d_1d_{p+1}'. Hence B is reducible to the form (11.5) with diagonal terms $d_1, d_1d_2', \ldots, d_1d_p'$ which proves (11.4).

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For any given set $B' = \{g_1', \ldots, g_n'\}$ of elements of G there exist relations.

(12.4) $$g_i' = \sum c_{ij}g_j, \quad C = \|c_{ij}\|.$$

A necessary and sufficient condition that $B' = \{g_i'\}$ be a base is that the g_i be expressible as linear combinations of the g_i', or that there exist relations

(12.5) $$g_i = \sum d_{ij}g_i', \quad D = \|d_{ij}\|.$$

From this follows

$$g_i = \sum d_{ij}c_{jk}g_k.$$

Hence since B is a base we must have $DC = 1$. This matrix relation yields $|D|\cdot|C| = 1$, and since the determinants are integers we must have $|C| = \pm 1$. Thus in order that B' be a base C must be unimodular, or the condition of (12.3) must be fulfilled. Conversely, if (12.3) is fulfilled, C is unimodular and (12.5) holds with $D = C^{-1}$, from which it follows readily that B' is a base.

Figure 2. An example of proof marked for corrections (bottom) and the same text after corrections have been made (top).

8. Author Proof

Corrected first proof is returned to the production editor who checks it thoroughly before sending it to the author. Along with the proof, the production editor includes a request for anything that is missing from the manuscript (for example, classification numbers and key words). The author also receives an offprint order form, which allows the author to order additional copies of the article and to provide an address to which the offprints can be sent. Also included in the package is the "Notice to Authors," which contains instructions for proofreading, examples of signs used in correcting proof, and mailing instructions.

We ask the author to proofread the galleys and return them marked with corrections within five days. In the case of multiple authors, unless instructed otherwise, proof is sent only to the author who has been designated as the contact author. Unfortunately, for reasons such as conflicting commitments, an unreported change of address, or excessive delays in mail delivery, proof copies are not always delivered and returned promptly. A delay at this stage of production often means that an article will be published later than was originally planned.

Having received from the author the proof marked for corrections, the production editor copy edits and type marks any new material that has been added and clarifies, when necessary, the corrections and changes that the author has requested. If all has gone as planned, the art will accompany the proof back into the Composition Department, where both will be corrected.

9. Making Up an Issue

At this stage, the production editor can request that an issue be made up. This means that, given the number of pages allotted to an issue, the production editor has enough articles ready to fill the issue. A list of articles in order of appearance is given to the Composition Department. In return, the production editor receives what we call the first issue file run. This set of proof resembles, as closely as possible, what the printed issue will look like. Usually, however, minor adjustments to the pages and some corrections are still necessary.

When checking the issue file, the production editor proofreads the corrections and the changes requested in the author's set of proof. End-of-line and bottom-of-page breaks are examined to make sure they are correct. The production editor also checks that enough space has been left for the art and that it has been placed appropriately. Whenever possible, we strive to place art where the author has indicated. Due to the number of pieces of art or the size of the art, it sometimes becomes impossible to do so. In such cases, we try to have the art appear on the page, or on the page spread, where it is first mentioned. Preferred placement is at the top or the bottom of a page. We avoid placing the art before it is mentioned. If the art cannot be placed on the spread where it is first mentioned, it is placed on the next page and a reference to that page is given.

Satisfied that all major corrections have been made and only a few minor corrections and page adjustments are necessary, the production editor then orders **camera copy**.

10. Preparing an Issue for the Printer

In addition to preparing the articles that comprise a journal issue, the production editor must coordinate the production of the covers, any front matter (title and copying information), and any back matter (cumulative index for a volume or procedures for submitting manuscripts). A request for the front cover is sent to the art editor along with changes that must be made. Tables of contents and cumulative indexes are now produced through automated procedures. However, they must be checked carefully for accuracy.

Camera copy of the covers (front, back, and insides), front matter, text, and back matter has to be checked to assure that final corrections have been made, that line and page breaks are acceptable, that art placement is optimum, and that the quality of the type meets the standards set for uniformity and reproduction. When the process is complete, the production editor then releases the issue for printing and binding.

Afterword

The average time required to produce a book or an issue of a journal is about eight months. About six weeks of manufacturing time is built into total production time. In the case of journals, a production editor usually has scores of papers in various stages of production to ensure that enough papers will be ready to fill an issue. Papers to be included in a book usually travel together through the production process. As I stated at the beginning, this article describes in simplified steps the production process for a typical paper. Due to space limitations, I did not address in depth exactly what happens to the paper during composition. That process is interesting and complicated enough to warrant a separate article.

For More Information

Authors who would like more detailed information on preparing and submitting electronic manuscripts can contact the Publication Department of the AMS, P. O. Box 6248, Providence, RI 02940-6248. Authors seeking information about papers in the process of production can contact the Editorial Department at the same address.

In early autumn of this year, two free publications, which contain more specific information on electronic manuscripts, will be available from the AMS. They are *A Manual for Authors of Mathematical Papers* and *Guidelines for Electronic Manuscripts*. Both publications can be requested from the Customer Services Department at the address given in the preceding paragraph.

Mathematics into Type, published by the AMS and available to members at a discount, is a valuable aid for anyone writing, formatting, or typing a mathematical paper.

Any of the above information may be requested electronically by using one of the email addresses in the following article in this section of *Notices*.

Definitions of Terms

Art. Anything in a manuscript that cannot be typeset is referred to as art. This includes computer-generated images, diagrams, drawings, graphs, and photographs. Art that must be enhanced or redrawn for publication is usually produced by a trained artist.

Camera copy. Final copy that is printed on opaque, glossy paper for the purpose of being photographed for the making of printing plates is called camera copy or camera-ready copy.

Composition. The complete processes of formatting a design, typesetting, producing and correcting the various stages of proof, rendering art, and making pages are grouped together under this term. At the AMS these functions are handled by the Composition Department, which includes typesetting, make up, and technical support sections.

Copyright transfer agreement. All authors whose work is published by the AMS are asked to assign copyright for the work to the AMS. This is done by means of the legal document known as the copyright transfer agreement. Transfer of copyright is a condition of publication.

Electronic manuscript. Any manuscript that has been prepared using a word processing program and that can be transferred through electronic mail or stored on diskette is considered an electronic manuscript.

Galley proof. The first proof produced after typesetting is referred to as galley proof. The term *galley* is a holdover from non-electronic typesetting systems when lines of type were cast in metal bars and the bars were held in a long tray called a galley. The difference between galley proof and page proof is that in the former, page breaks and page make up are not considered final; in the latter, pages more closely resemble the final product.

Production editor. The individual who coordinates the publishing process is called the production editor. Production editors have a wide variety of background experience. Some are mathematicians, but many are not. Others have expertise in Russian or another language. All production editors at the AMS must know how to mark up high-level mathematics for the purpose of typesetting.

Publications database. The publications database was created to serve as a tracking and monitoring system for all manuscripts received for publication. The system allows the user to check on the current status of any manuscript in the process of production. A typical database entry includes the manuscript code, full title, full authors' names, authors' addresses, date received, schedule of tasks started and completed, and date of publication.

AMS Electronic Mail Addresses

When the AMS was first connected to the Internet three years ago, an announcement appeared in *Notices* about a number of non-user-specific electronic addresses that could be used to contact Society staff. Since then, the number of such addresses has grown and some have been changed.

What follows is the current list of the non-user-specific addresses that may be used to contact the AMS and *Mathematical Reviews* staff, together with a description of the types of inquiries that should be made through each address.

EXDIR@MATH.AMS.COM
to contact the administrative offices in Providence.

MEET@MATH.AMS.COM
to send requests for general information about Society meetings and for submission of electronic preregistration for the annual and summer meetings.

AMSMEM@MATH.AMS.COM
to request information about individual or institutional membership in the AMS, about dues payment, about membership privileges, or to ask any general membership questions; may also be used to submit address changes.

CUST-SERV@MATH.AMS.COM
to send address changes, place credit card orders for AMS products, or conduct any general correspondence with the Society's Customer Services Department.

NOTICES@MATH.AMS.COM
to send correspondence to the Managing Editor of *Notices*, including letters to the editor, contributed articles, and information for the meetings and conferences listing.

SECRETARY@MATH.AMS.COM
to communicate with the Secretary of the Society.

e-MATH@MATH.AMS.COM
for information concerning the Society's new bulletin board service.

MATHREV@MATH.AMS.COM
to submit reviews to *Mathematical Reviews* and to send related correspondence.

MATHDOC@MATH.AMS.COM
for users of *Current Mathematical Publications*, *MR*, and *MathSci* who wish to order a copy of an original item from the MathDoc document delivery system.

GUIDE-ELEC@MATH.AMS.COM
to request a copy of the Society's *Guidelines for Preparing Electronic Manuscripts*. Please specify AMS-TeX or AMS-LaTeX version.

AMS-TEX@MATH.AMS.COM
to request an AMS-TeX style file for a particular AMS book series.*

AMS-LATEX@MATH.AMS.COM
to request the AMS-LaTeX style files.*

ABS-REQUEST@MATH.AMS.COM
to request style files for submission of abstracts for AMS meetings.*

ABS-SUBMIT@MATH.AMS.COM
to submit abstracts for AMS meetings.

PUB-SUBMIT@MATH.AMS.COM
to submit accepted manuscripts to AMS publications (other than *Abstracts*).

PUB@MATH.AMS.COM
to send correspondence to the AMS Publication Division.

TECH-SUPPORT@MATH.AMS.COM
to contact the Society's Typesetting Technical Support group.

*When requesting the files on diskette, please specify whether IBM or Macintosh diskettes are required and give a complete mailing address.

CALL FOR SUGGESTIONS

There will be a number of contested seats in the 1991 AMS elections.
Your suggestions are wanted by

THE NOMINATING COMMITTEE
for president-elect, vice-president, trustee, and five members-at-large of the council
and by

THE PRESIDENT
for three Nominating Committee members and two Editorial Boards Committee members

In Addition

THE EDITORIAL BOARDS COMMITTEE
requests suggestions for appointments to various editorial boards of Society publications.

Send your suggestions for any of the above to:

Robert M. Fossum, Secretary
American Mathematical Society
Department of Mathematics
University of Illinois
1409 West Green Street
Urbana, IL 61801

News and Announcements

Carroll Vincent Newsom 1904–1990

Carroll V. Newsom graduated from high school in Waxahachie, Texas in 1920 and from the College of Emporia in Emporia, Kansas in 1924. After teaching high school for two years in Cherryvale and one year in Salina, both in Kansas, and after attending graduate school at the University of Michigan during three summers and the academic year 1927-1928, Newsom was appointed instructor in mathematics at the University of New Mexico in 1928. A year's leave during 1930-1931 enabled him to receive his Ph.D. from Michigan in 1931; his thesis was supervised by W. B. Ford, and another favorite teacher was R. L. Wilder.

New Mexico, admitted to the Union as the 47th state in 1912, was a young state when Newsom arrived in 1928. The population consisted of English speaking Anglos, Spanish speaking descendants of the early Spanish settlers, and Native Americans (largely Pueblo Indians). The University had about 350 students, and Newsom and one professor constituted the Department of Mathematics. New Mexico provided an unusually wide variety of scientific, educational, and administrative experiences for Newsom. By September 1933 he had been promoted to Professor of Mathematics and Head of the Department. He has written as follows in his autobiography:

"My own experiences ... had convinced me that the common instructional program in mathematics ... of the nation was intolerably bad. ... I had an opportunity rarely granted ...; I was completely free to experiment ...; I was in charge. So I ... worked out a completely new program in college mathematics which would include new advanced courses and an utterly different kind of introductory course for many beginning students."

Newsom wrote books to support his program, and it quickly attracted national attention. Visitors such as R. G. D. Richardson and G. D. Birkhoff came to Albuquerque. Newsom accepted the invitation of Ralph Tyler, Dean of the School of Education at the University of Chicago, to participate in the "Eight Year Study", a national program of study and research supported by the Carnegie Foundation, which Tyler directed at Chicago.

Newsom organized the Southwestern Section of the Mathematical Association of America (MAA) in 1936. He was a member of the MAA's Committee to Review the Activities of the Association (the Langer Committee) and chairman of its Committee on the Slaught Memorial Papers. When war came, the Civil Aeronautics Administration asked him to write a textbook for a basic mathematics course to train flight crews, and he assisted in the design of a program to train meteorologists. The AMS and the MAA War Policy Committee appointed him a member of its Subcommittee on War Training Programs. Newsom edited the War Information section of the *American Mathematical Monthly*; he wrote one or more significant articles on some aspect of the war for this section in each number of the *Monthly*. Newsom was Editor of the *Monthly* during 1947-1951; Lester R. Ford, the Editor during 1942-1946, had been impressed by his performance as editor of the War Information section. After the war was over, Newsom was appointed a member of the Policy Committee (successor to the War Policy Committee). He and J. R. Kline made trips to Washington to promote the establishment of the National Science Foundation; on one occasion they talked to President Truman.

Newsom left New Mexico in 1944 and became Professor of Mathematics at Oberlin College. Next, Newsom served as Assistant Commissioner for Higher Education of the State of New York from 1948 to 1950, and he was Associate Commissioner for Higher and Professional Education from 1950 to 1955. He was Executive Vice President, 1955-1956, and President, 1956-1962, of New York University. After leaving NYU, Newsom held the following positions: Vice President and then President of Prentice-Hall, Inc., 1962-1965; Chairman of the Executive Committee and Director of Random House, 1967-1970; Educational Consultant, 1965-1966, and Vice President for Education of RCA, 1966-1969. He was active for many years in the development of educational television, and he made many trips to Africa and the East in connection with international education activities.

Carroll Newsom knew many of the great and the famous. He wrote fourteen books, and he was awarded twenty-four honorary degrees. He received the Pasteur Medal, and he was a Chevalier of the French Legion of Honor and a Benjamin Franklin Fellow of the Royal Society of Arts.

Carroll V. Newsom was born February 23, 1904 in Buckley, Illinois, and he died February 3, 1990 in Dublin, Ohio. He was buried in Gerow Cemetery in New Fairfield, Connecticut.

G. Baley Price
The University of Kansas

Presidential Young Investigator Awards Announced

The National Science Foundation (NSF) has announced the selection of 211 academic scientists and engineers to receive the Presidential Young Investigator (PYI) awards. The awards, which fund research by faculty members near the beginning of their careers, are intended to help universities attract and retain outstanding young Ph.D. scientists who might otherwise pursue careers outside teaching.

Each young investigator can receive up to $100,000 per year for five years in a combination of federal and matching private funds. The NSF provides base funding of $25,000 and will match private sector funding of up to $37,500.

Any U.S. institution that awards a baccalaureate, master's, or doctoral degree in a field supported by the NSF is eligible to participate in the program. Institutions may nominate faculty members who are holding or have been offered tenure-track positions.

The following lists the names, affiliations, and research areas of those PYI awardees chosen by the NSF's Division of Mathematical Sciences.

Sigurd B. Angenent, University of Wisconsin at Madison, classical analysis and applied mathematics; Bruce J. Bayly, University of Arizona, applied mathematics and geophysical fluid dynamics; Frederic V. Bien, Princeton University, algebraic geometry; Kevin Corlette, University of Chicago, geometric analysis; Daniel S. Freed, University of Texas at Austin, geometric analysis; John Grove, State University of New York at Buffalo, computational and applied mathematics; Matei Machedon, Princeton University, classical analysis; Jill C. Pipher, Brown University, classical analysis; John R. Stembridge, University of Michigan at Ann Arbor, algebraic combinatorics; Steven H. Strogatz, Massachusetts Institute of Technology, applied mathematics and biology; Erna B. Yackel, Purdue University—Calumet, mathematical education.

1990 LMS Prizes Awarded

The London Mathematical Society (LMS) has awarded several prizes for 1990. The Pólya Prize goes to G. B. Segal for his work on the interactions between mathematics and physics. The Senior Berwick Prize has been awarded to N. J. Hitchin for his paper, "The self-duality equations on a Riemann surface," (*Proceedings of the London Mathematical Society*, (3) 55 (1987) 59-126).

The Junior Whitehead Prizes were presented to M. T. Barlow for his work on probability theory and stochastic analysis, to R. L. Taylor for his work on l-adic representations for Hilbert modular forms, and to A.J. Wasserman for his work on operator algebras and related topics.

d'Alembert Prize Awarded

The Mathematical Society of France has announced that the 1990 d'Alembert Prize has been awarded to Michèle Chouchan for her radio broadcasts on mathematics and mathematicians. Chouchan is a radio producer on France Culture, Radio France.

Chouchan's broadcasts have spanned a number of different mathematical subjects. Some examples of titles of her broadcasts are "Bourbaki," "Who Are the Mathematicians?", "On Bourbaki in Industrial Mathematics," and "Mathematics Teaching." The prize jury judged her broadcasts to be excellent popularizations of mathematics, prepared with intelligence, as well as historical, sociological, cultural, and scientific interest.

The d'Alembert Prize was established by the Mathematical Society of France in 1985 to recognize an article, book, radio or television broadcast, film scene, or other project that enhances popular understanding of mathematics and its recent developments. The prize is awarded every two years.

AMS Awards Prizes at International Science & Engineering Fair

The American Mathematical Society presented seven Karl Menger Memorial prizes totaling $3,000 to seven outstanding high school students for projects presented at the 41st International Science and Engineering Fair held in Tulsa, Oklahoma on May 6-12, 1990. There were nearly 800 exhibits at the fair, including about 50 in the mathematics classification. The exhibitors qualified for this fair by winning prizes at regional fairs in the U.S. and abroad. A panel of eight judges representing the AMS examined all of the mathematics entries, as well as those entries in other classifications which had used mathematics in creative and original ways, and interviewed the student exhibitors. There were many excellent projects, and the judges had a difficult time selecting the winners from among them. All the judges came away impressed by the mathematical independence of the student exhibitors, by their willingness to tackle formidable mathematical questions, and by the ingenuity of their presentations.

Each prize winner receives a cash award and a certificate. The first prize carries a $1,000 award, the two second prizes a $500 award each, and the four third prizes a $250 award each.

First prize went to DANIEL K. DUGGER, 17, of Nova High School, Davie, FL, for "On homomorphisms between finite abelian groups". Second prizes went to JOSHUA ERLICH, 17, of Stuyvesant High School, New York, NY, for "Inconsistencies in the flat Freidmannian cosmologies"; and JOSHUA B. FISCHMAN, 17, of Montgomery Blair High School, Silver Spring, MD, for "*p*-adic continued fractions". Third prizes went to MIN-HORNG CHEN, 17, Taiwan Provincial First Taiching Boys Senior High School, Taiching, Taiwan, for "Envelopes developed from the partition lines of a triangle"; MATTHEW BAKER, 17, Oakland Mills High School, Columbia, MD, for "Analysis of a polynomial geometric series"; MICHAEL L. HARRISON, 17, Batesville Senior High School, Batesville, AR, for "Sums of reciprocals of least common multiples"; and VIRGINIA A. DIDOMIZIO, 15, Newton High School, Sandy Hook, CT, for "Chaos and the fractal geometry of regular polygons".

The judges representing AMS were Professors Jerry Bona, Ray Hamlett, Marvin Keener, Andy Magid, Darryl McCullough, Gus Pekara, Carol Wood, and John Woods.

Left to right: Min-Horng Chen, Matthew Baker, Virginia A. DiDomizio, Michael L. Harrison, Joshua Erlich, Joshua B. Fischman, Daniel K. Dugger, and Andy R. Magid. (Photo courtesy of FocusOne).

The Society's participation in the International Science and Engineering Fair is supported, in part, by income from the Karl Menger Fund, which was established by the family of the late Karl Menger. Individuals interested in making a donation to this fund may send their contributions to Karl Menger Fund, American Mathematical Society, P. O. Box 1571, Annex Station, Providence, RI 02901-1571.

Andy R. Magid
University of Oklahoma

American Team Places Third in Olympiad

A team of six American high school students placed third in the 31st International Mathematical Olympiad, held July 8-19 in Beijing, China. This was the nation's best showing in the annual competition since 1986.

The American team scored 174 out of a possible 252. Ahead of the Americans were teams from China (230) and the U.S.S.R. (193); Romania took fourth place and France fifth with scores of 171 and 168, respectively. Fifty-four countries sent a total of 308 students to the competition.

The judges also awarded individual first, second, and third prizes to deserving team members. KIRAN KEDLAYA of Silver Spring, MD and JEFFREY VANDERKAM of Raleigh, NC both received gold medals. Three other U.S. team members received second prize silver medals: ROYCE PENG of Rancho Palos Verdes, CA, AVINOAM FREEDMAN of Teaneck, NJ, and JOEL ROSENBERG of Hartford, CT. The team's sixth member, TIMOTHY KOKESH of Bartlesville, OK, narrowly missed receiving a bronze medal. Among all the participants, twenty-three gold, fifty-six silver, and seventy-six bronze medals were awarded.

The Olympiad teams competed by working on solutions to six challenging mathematical problems in two, 4 1/2-hour sessions. One problem from this year's contest asked for a proof that there is a convex polygon of 1990 sides with all angles equal and whose side lengths are the squares of the numbers 1, 2, 3,..., 1990, arranged in some order.

The U.S. Olympiad activities are sponsored by eight national organizations in the mathematical sciences, including the Mathematical Association of America and the AMS. Financial support is provided by IBM, the Army Research Office, the Office of Naval Research, Hewlett-Packard, and the Matilda R. Wilson Fund.

Mathematical Contest in Modeling

Six student teams from across the country have received awards for their outstanding solutions to the Mathematical Contest in Modeling (MCM), which gives students the opportunity to challenge their skills in solving real-world problems. The winning papers were chosen from among 235 entries.

Participation in the contest has grown rapidly since it was first instituted in 1985. The number of entries has increased more than 40% in the last three years. This year, the entries came from forty states and four countries, including the People's Republic of China and Hong Kong.

Each three-student team had a three-day weekend to produce an analysis of an open-ended modeling problem, using only inanimate resources. The contest gives the teams a choice of two problems. This year, the first problem concerned the shape and spatial distribution in the brain of a drug injected into a patient. The data provided in the problem gives the concentration of the drug in a collection of cylindrical tissue samples and asks for an estimation of the distribution in the region of the brain affected by the drug. The second problem presents a map of county roads that need to be plowed after a snowfall. The problem is to use two snowplows in an efficient way to plow the roads, which are not laid out in a grid-like way, but which twist and turn.

The judging panel for the MCM designated six of the papers as outstanding. For the brain drug problem, two papers were selected. The names of the team members, the faculty advisors, and the institutions were: Michael Kelleher, David Renshaw, Athan Spiros, Professor T. O'Neil, California Polytechnic State University; and Christopher Malone, Gian Pauletto, Jim Zoellick, Professor C. M. Biles, Humboldt State University.

For the snowplow problem, the four outstanding teams were: Chris Hartman, Kirk Hogenson, John Miller, Professor J. P. Lambert, University of Alaska, Fairbanks; Joel E. Atkins, Jeffrey S. Dierckman, Kevin O'Bryant, Professor A.W. Schurle, Rose-Hulman Institute of Technology; Ronald Chernak, Laura E. Kustiner, Larry Phillips, Professor K. R. Yates, Southern Oregon State University; and Scott G. Frickenstein, Lester S. Ogawa, Jonathan D. Robinson, Professor W. E. Skeith, United States Air Force Academy.

The MCM is administered by the Consortium of Mathematics and its Applications (COMAP), a Massachusetts-based organization that publishes a wide variety of innovative curricular materials. Solomon Garfunkel, Executive Director of COMAP, described the winning solution papers as "extraordinary." He commended all of the participants for their diligent work. "Many, I expect, will be among our premier mathematicians, engineers, and physicists." He also noted that the advisors of the students deserve credit. "Although they can't assist the teams with the solution papers, many of these professors prepare with their teams months in advance."

Sponsors of the MCM include the Society for Industrial and Applied Mathematics (SIAM), the Operations Research Society of America (ORSA), the Army Research Office, and Jose Ayala. In addition to making cash awards, SIAM and ORSA chose one winning team from each problem category and paid for the team members to attend the societies' meetings. ORSA chose the Humboldt State team for the brain drug problem and the University of Alaska team for the snowplow problem. SIAM selected the CalPoly team for the brain drug problem and the Rose-Hulman team for the snowplow problem.

Ben Fusaro of Salisbury State University is the founder and director of the MCM. The next MCM will be held in February, 1990. Those interested in further information can contact Fusaro at Department of Mathematics, Salisbury State University, Salisbury, MD 21801.

Putnam Exam Winners

The fiftieth annual William Lowell Putnam Mathematical Competition was held on December 2, 1989. Administered by the Mathematical Association of America, the prestigious competition drew 2,392 contestants from 373 institutions in the U.S. and Canada.

The competition consists of an examination, given in two three-hour sessions. Designed to test originality as well as technical competence, the examination covers undergraduate mathematics through differential equations. It also may include questions that cut across various disciplines, as well as self-contained questions that do not fit into the usual categories.

An institution with at least three registered participants obtains a team rank based on the rank of three designated individual contestants. However, each contestant works independently on the examination, even if designated as a team member.

The five winning teams are listed below, in order of their ranking. (In all of the lists that follow, contestants' names are in alphabetical order.) Harvard University: JEREMY A. KAHN, RAYMOND M. SIDNEY, ERIC K. WEPSIC; Princeton University: DAVID J. GRABINER, MATTHEW D. MULLIN, RAHUL V. PANDHARIPANDE; University of Waterloo: GRAYDEN HAZENBERG, STEPHEN M. SMITH, COLIN M. SPRINGER; Yale University: BRUCE E. KASKEL, ANDREW H. KRESCH, SIHAO WU; Rice University: HUBERT L. BRAY, JOHN W. MCINTOSH, DAVID S. METZLER.

The first place team receives an award of \$5,000 and each team member receives \$250. The awards for second place are \$2,500 and \$200; for third place \$1,500 and \$150; for fourth place \$1,000 and \$100; and for fifth place \$500 and \$50.

In addition, the six highest scoring individuals were named Putnam Fellows and each received a \$500 award. Their names and affiliations are: CHRISTOS ATHANASIADIS, Massachusetts Institute of Technology; WILLIAM P. CROSS, California Institute of Technology; ANDREW M. KRESCH, Yale University; COLIN M. SPRINGER, University of Waterloo; RAVI D. VAKIL, University of Toronto; SIHAO WU, Yale University.

William Lowell Putnam, a member of the Harvard class of 1882, began the competition that bears his name in 1938. The idea grew out of Putnam's profound belief in the value of organized team competition in college studies. In 1927, Putnam's wife created a trust fund to support such activities. The first competition was in the field of English, and, a few years later, a second competition was held in mathematics.

Janusz Named to *MR* Post

Gerald J. Janusz has been named Executive Editor of *Mathematical Reviews*. Janusz, a professor of mathematics at the University of Illinois, Urbana-Champaign, began his new position on August 21.

Janusz received his Ph.D. in 1965 from the University of Oregon under the direction of Charles W. Curtis. He received a National Science Foundation Postdoctoral Fellowship and was a member of the Institute for Advanced Study in Princeton (1965-1966). After serving as an instructor at the University of Chicago from 1966 to 1968, he moved to the University of Illinois, where he advanced to the rank of professor in 1974. He also held a visiting position at Yale University (1974-1975). He served on the AMS Committee on Employment and Educational Policy from 1984 to 1986.

Janusz's research has focused on group representation theory, finite dimensional division algebras, the Brauer group of fields, algebraic number theory, and the connections among these subjects. In recent years, he has developed an interest in the calculus reform movement and has undertaken to write an honors level calculus textbook. In addition, he has worked on the use of computers in classroom teaching and was a participant in two projects funded by the National Science Foundation to find alternate approaches to the teaching of calculus at the university level.

Professor Janusz has also had extensive experience in editing mathematical journals and writings. Since 1985 he has been associated with the *Illinois Journal of Mathematics*, first as an editor, and, since 1986, as managing editor, a position that involved overseeing the entire production of the journal, from assigning manuscripts to reviewers to budget planning. He has served as editor for the AMS book series *Contemporary Mathematics* since 1986, and from 1972 to 1981 he was on the editorial board of *Communications in Algebra*. He was also editor of a volume of selected works of Irving Reiner, which appeared in 1989.

Janusz replaces Robert G. Bartle, who served as Executive Editor of *MR* during 1976-1978 and since mid-1986. Bartle, who also was a professor at the University of Illinois, Urbana-Champaign for many years, has accepted a professorship at Eastern Michigan University.

Connors to Head JPBM Office

The Joint Policy Board for Mathematics (JPBM) has announced that Edward A. Connors of the University of Massachusetts at Amherst has been appointed Director of the JPBM Office of Governmental and Public Affairs (OGPA) in Washington, DC, beginning July 1, 1990. He will coordinate legislative and public affairs activities for JPBM's three member societies, the AMS, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics.

Notices readers will probably be most familiar with Connors for his work on the AMS-MAA Surveys that appear each fall and spring. For the past three years, he has served as chair of the AMS-MAA Data Committee that produces that report and he is also chair of the AMS-MAA Committee on Employment and Educational Policy.

An activist within the mathematical sciences community and in dealings with the general public, Connors is the author of numerous articles on educational and policy issues. He has written extensively in the popular press about the implications of the declining number of mathematics Ph.D.s going to U.S. citizens and was the impetus behind a number of other media pieces on this subject. Last year, an entry consisting of a collection of these writings made him co-recipient of a public service award from the Council for the Advancement and Support of Education.

Connors says that one of his priorities at OGPA will be to continue and expand the public information effort that has begun. "I think we have many opportunities to communicate to the public, through the media," he declared, noting that university and college media outlets are a resource that OGPA could utilize. "I firmly believe that we in mathematics have an image problem. It's not all our doing, but we can do a lot to overcome some of the negative images of the mathematical sciences." He says he sees part of his job as "bringing to the forefront those mathematicians who have a talent in exposition" to help communicate mathematical sciences research to the public. "We're going to be soliciting the help of mathematicians not only in academia, but in industry as well," he states.

In addition, Connors wants OGPA to increase communication with the members of the three JPBM societies. "I'd like to get more of the mathematical community involved in our effort here," he says. "I intend to work hard to make sure the mathematical sciences community feels it's being listened to. The communication aspect is very important to me, whether we're talking about communicating with the public, or whether we're talking about this office communicating with the societies' members."

William H. Jaco, Executive Director of the AMS and an AMS representative on JPBM, says the Board is pleased that Connors has accepted the position at OGPA. "He has broad experience with national issues on mathematics education and employment in the mathematical sciences," Jaco noted. "He is a recognized spokesman for mathematics and brings to the office a high level of energy and enthusiasm."

Connors' colleagues at Amherst were equally enthusiastic about his taking the position. "Professor Connors understands the important national issues and he represents mathematics and higher education with skill and humor," said University of Massachusetts President Joseph Duffey. "Higher education has added a persuasive and well-informed advocate in Washington."

Connors will be replacing Kenneth Hoffman, who left OGPA to become the Executive Director of the Mathematical Sciences Education Board of the National Research Council. Hoffman took that position in September 1989, and, in the interim, Alfred B. Willcox served on a temporary basis as head of OGPA. Willcox recently retired from his position as Executive Director of the Mathematical Association of America.

Connors received his Ph.D. in 1969 from the University of Notre

Dame. He was an instructor at Notre Dame during 1968-1969 before going to the University of Massachusetts at Amherst, where he has been ever since. He served as head of the Department of Mathematics and Statistics at Amherst from 1977 to 1982 and is currently on leave from his position as professor of mathematics, in order to take the JPBM position. Connors was a Visiting Scholar at Harvard University in 1983 and at the Institute of Systems Science at the Academia Sinica in 1985. His areas of research are quadratic forms, classical groups, and mathematical education.

Also joining the OGPA staff, as Assistant for Governmental Affairs, is Lisa A. Thompson, who most recently held a similar position with the Council of Scientific Society Presidents and has worked for the Office of Science and Technology Policy. Sonya Dixon will serve as OGPA's secretary.

The JPBM staff can be contacted at JPBM, 1529 18th Street, NW, Washington, DC 20036; telephone 202-234-9570. OGPA will continue putting out its weekly electronic newsletter, *Tidbits*. Those wishing to receive *Tidbits* can get more information by sending electronic mail to the JPBM office at jpbm@athena.umd.edu.

Isaac Newton Institute for Mathematical Sciences

The Isaac Newton Institute for Mathematical Sciences, to be established in 1992 at the University of Cambridge in England, will be a research institute comprising pure mathematics, applied mathematics, statistics, engineering, computer science, theoretical physics, and all other sciences in which mathematics is applied. Sir Michael Atiyah, who was recently named Master of Trinity College of Cambridge, has agreed to be the first director of the Institute.

The Institute, which will be similar to the Mathematical Sciences Research Institute at Berkeley, will primarily consist of visitor programs. Typically, there will be two six-month programs in progress, each with about twenty scientists in residence at any one time (and more during university vacations). In addition, there will be instructional courses and workshops. Mathematical scientists from all countries will be encouraged to participate in the Institute's activities.

The Institute will be housed in a purpose-designed building which is expected to be completed by July 1992, when the scientific work of the Institute is to begin. The building will contain seminar rooms, a library, and about thirty offices.

For more information about the Institute, write to: Dr. P. V. Landshoff, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Silver Street, Cambridge, England CB3 9EW. The Institute is inviting suggestions for topics for its programmes; details about the submission of proposals may be obtained from Dr. Landshoff.

News from the Mathematical Sciences Institute
Cornell University

Partial Differential Equations will be the theme of a special program of lectures, a graduate seminar, and two workshops to be hosted during the coming months by the Mathematical Sciences Institute (MSI).

Peter Constantin from the University of Chicago will be the first speaker in a special program of invited lectures on Partial Differential Equations and Fluid Mechanics. Constantin will visit Cornell from September 4 through 12 and will give three lectures: On the Motion of Interfaces in Pressure Fields, Dirichlet Quotients and Navier-Stokes Equations, and Areas of Interfaces in Turbulent Flow. Jean-Claude Saut from the Université Paris-XII and Paris-Sud will visit in March and April of 1991 and deliver a series of talks on Linear and Nonlinear Dispersive Waves. Finally, Ciprian I. Foias from Indiana University will speak on Navier-Stokes Equations during the summer of 1991. A graduate seminar will be run as a part of this special program. For more information, please contact either Philip Holmes or Edriss S. Titi at the MSI's new address given below.

Alfred Schatz and James Bramble have organized a workshop on Partial Differential Equations in honor of Professor Lawrence E. Payne. Topics to be addressed include ill-posed problems, isoparametric inequalities and special maximum principles, Saint-Verant type principles, energy stability in nonlinear systems, inverse problems, and bifurcation theory. The workshop will be held October 5-7, 1990. For information, contact A. Schatz at MSI; 607-255-2318; schatz@mssun7.msi.cornell.edu.

A second workshop on the Mathematics of Computation in Partial Differential Equations will celebrate the 60th birthday of James H. Bramble. Organized by Lars Wahlbin, Richard Falk, Vidar Thomée, and Alfred Schatz, this workshop will be held January 25-27, 1991. A broad range of topics related to the mathematical theory of numerical methods for partial differential equations will be discussed. For information, contact L. Wahlbin or A. Schatz at the MSI; 607-255-4013; wahlbin@mssun7.msi.cornell.edu or schatz@mssun7.msi.cornell.edu.

The MSI recently moved into new and expanded headquarters. To attend a workshop or for information on MSI activities, contact the MSI at their new address: 409 College Avenue, Ithaca, NY 14850-4697. Their telephone number remains 607-255-8005.

New Journal on Undergraduate Mathematics

PRIMUS (Problems, Resources, and Issues in Mathematics Undergraduate Studies) is a new journal for the exchange of ideas in mathematics education at the collegiate level. A refereed quarterly, *PRIMUS* provides a forum for exchanging problems, activities, and teaching ideas, as well as for sharing resources, reporting results and discussing curriculum movements and reform activities.

Brian J. Winkel of Rose-Hulman Institute of Technology will serve as the editor of *PRIMUS*. The first issue is slated to appear in March 1991. For more information, contact: *PRIMUS*, Department of Mathematics, Rose-Hulman Institute of Technology, Terre Haute, IN 47803.

New National Science Board Appointees

Two new appointments have been made for the National Science Board (NSB), the policy-making body of the National Science Foundation: Peter H. Raven, Director of the Missouri Botanical Garden, and Benjamin S. Shen, Professor of Astronomy and Astrophysics at the University of Pennsylvania. The terms of eight other NSB members expired in May 1990, but their replacements had not been appointed at the time of this writing.

Staff at the NSF's Division of Mathematical Sciences

Listed below are the Program Directors for the coming academic year in the Division of Mathematical Sciences (DMS) at the National Science Foundation.

Classical Analysis
202-357-3455
John V. Ryff

Modern Analysis
202-357-3697
Ira Herbst

Geometric Analysis
202-357-3451
Robert Molson

Topology and Foundations
202-357-3457
Ralph M. Krause

Algebra and Number Theory
202-357-3695
Ann K. Boyle
Gary Cornell

Applied Mathematics
202-357-3686
Alfonso Castro
Fred Howes

Computational Mathematics
202-357-3691
Michael Steuerwalt
Alvin Thaler

Statistics and Probability
202-357-3693
Peter W. Arzberger
Nell Sedransk

Special Projects
202-357-3453
Bernard R. McDonald (Head)
Deborah F. Lockhart
Ann Steiner

The administrative staff includes:

Division Director
Judith S. Sunley
202-357-9669

Deputy Division Director
Bernard R. McDonald
202-357-9669

Administrative Officer
Tyczer Henson
202-357-3683

The permanent staff consists of Arzberger, Boyle, Krause, McDonald, Ryff, Sunley, and Thaler. The incoming rotators are Gary Cornell of the University of Connecticut, Robert Molson of the University of Kentucky, Nell Sedransk of the State University of New York at Albany, Michael Steuerwalt of Los Alamos National Laboratory, and Ann Steiner of Iowa State University.

Many thanks to outgoing rotators Mary Ellen Bock of Purdue University, Gerald Chachere of Howard University, Jonathan Lubin of Brown University, and Russell Walker of Montana State University (see the article, "Serving at the NSF" in this issue of *Notices*).

A number of factors have made DMS staff arrangements somewhat complicated this year. Under present arrangements, Ryff will be on sabbatical most of the year, but he will continue to handle the Research Experience for Undergraduates activities. As a result, Howes and Castro will oversee a portion of the Classical Analysis program, and Steuerwalt will handle some parts of the Applied Mathematics program. In addition, Lockhart will move to the Mathematics and Physical Sciences Directorate office of NSF as a Staff Associate for Education and Human Resources, but she will continue to be affiliated with the DMS. Despite these complications, the DMS staff will do everything it can to insure that all the programs continue to run smoothly.

All NSF staff can be reached via electronic mail. To form an individual's address, take the first initial and last name, and append @note.nsf.gov for Internet, or @nsf for Bitnet. For example, to contact John Ryff through Internet, use the address jryff@note.nsf.gov. The mailing address is Division of Mathematical Sciences, Room 339, National Science Foundation, 1800 G Street, NW, Washington, DC 20550.

Staff at DoD Agencies

Five agencies of the Department of Defense fund research in the mathematical sciences: the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), the Defense Advanced Research Projects Agency (DARPA), the National Security Agency (NSA), and the Office of Naval Research (ONR). In order to facilitate contact with these agencies, the names, addresses, and telephone numbers of the staffs are provided below.

AFOSR, Directorate of Mathematical and Information Sciences
AFOSR/NM
Building 410
Bolling AFB DC 20332-6448
Charles J. Holland, Director,
202-767-5025

Optimization and Discrete Mathematics
Neal D. Glassman
202-767-5026

Physical Mathematics and Applied Analysis
Arje Nachman
202-767-4939

Artificial Intelligence
Abraham Waksman
202-767-5028

Probability, Statistics and Signal Processing
Jon Sjogren
202-767-4940

Computational Mathematics
Arje Nachman (acting)
202-767-4939

Computer Science
Charles Holland (acting)
202-767-5025

Mathematics of Dynamics and Control
Marc Jacobs
202-767-5027

Marc Jacobs and Jon Sjogren joined the AFOSR staff in the Mathematical and Information Sciences Directorate this year. Jacobs is on leave from his position at the University of Missouri, and Sjogren joined AFOSR from his previous position as a research scientist for NASA at Langley Air Force Base.

ARO, Mathematical Sciences Division
P.O. Box 12211
Research Triangle Park, NC 27709
Jagdish Chandra, Director
Gerald Andersen, Associate Director
919-549-0641
(Program managers may be contacted at the extensions listed below.)

Applied Analysis and Physical Mathematics
Julian Wu, ext. 332

Computer Science and AI
David Hislop, ext. 314

Infrastructure, Support Programs for Army High Performance Computing Center
Bruce Henriksen, ext. 255

Numerical Analysis, Scientific Computing, Optimization, and Symbolic Methods
Kenneth D. Clark, ext. 256

Probability and Statistics
Gerald Andersen, ext. 253

Systems and Control; Centers of Excellence
Jagdish Chandra, ext. 254

Workshops, Army-wide Conferences, Tutorials, and Special Projects
Francis Dressel, ext.324

New on the staff of the ARO Mathematical Sciences Division are Bruce Henriksen, formerly of Micom, and David Hislop, from the Electronics Division of ARO. Henriksen will be overseeing the ARO High Performance Computing Center at the University of Minnesota, which was established in 1989 (see "Computing Center Launched at University of Minnesota," *Notices*, December 1989, page 1369).

DARPA, Applied and Computational Mathematics Program
1400 Wilson Boulevard
Arlington, VA 22209
Louis Auslander, Program Manager, 202-694-3145

NSA, Mathematical Sciences Program
Attn: RMA
Ft. George G. Meade, MD 20755-6000
Marvin Wunderlich, Director, 301-859-6438

ONR, Mathematics Division
Code 1111
800 North Quincy Street
Arlington, VA 22217
Neil Gerr, Director, 202-696-4321

Signal Analysis
Neil Gerr, 202-696-4321

Operations Research
Don Wagner, 202-696-4313

Probability and Statistics
Julia Abrahams, 202-696-4320

Discrete Mathematics
Marc Lipman, 202-696-4310

Numerical Analysis
Richard Lau, 202-696-4316

Applied Analysis
John Lavery, 202-696-4314

There has been one change in the ONR staff since last year. Don Wagner of the School of Industrial Engineering at Purdue University joined the ONR Mathematics Program staff this year.

Scientific Visits to China

Recent issues of *Notices* (January, March, and April 1990) have carried letters to the editor about scientific visits to China. Because of the violence in Tienanmen Square in June 1989, deciding whether to visit China for research, lectures, or conferences has posed a personal dilemma for many mathematicians and scientists.

In response to requests for individual scientists wishing assistance in making decisions about visiting China, the National Academy of Sciences Committee on Human Rights has produced a five-page discussion paper. The paper presents a number of arguments for and against such trips and lists important questions that should be answered in advance.

Copies of the paper, "Considerations Regarding Individual Scientific Visits to the People's Republic of China," are available from the Committee on Human Rights, National Academy of Sciences, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-3043.

Funding Information for the Mathematical Sciences

Visiting Professorships for Women

The Visiting Professorships for Women program at the National Science Foundation (NSF) is designed to provide opportunities for women scientists, mathematicians, and engineers to advance their careers while enhancing their visibility in these professions. The program is open to women employed in industry, government, or academia.

The program allows participants to pursue advanced research at an academic institution. In addition, participants will conduct interactive activities—such as teaching, counseling, or mentoring—designed to increase the visibility of women in academia. These activities should also help to increase the awareness of students and faculty (both male and female) of the contributions of women to science, mathematics, and engineering, and to demonstrate to students (especially females) the opportunities for careers in these fields.

Applicants must hold a doctoral degree (or have equivalent experience) in a field normally supported by the NSF and must have independent research experience. The instruction and other activities may be directed to the undergraduate or graduate levels, or to the community at large. Proposals will be evaluated on the plans for such activities, as well as the scientific merit of the proposed research. The usual award will be for 12 months for a full- or part-time professorship, but awards for one academic semester or for 24 months will be considered.

Last year, out of a total of twenty-seven awards made in all disciplines supported by the NSF, seven went to women in the mathematical sciences (see "NSF Awards Visiting Professorships," *Notices*, September 1989, page 854).

The deadline for applications is **November 15, 1990**. For further information about guidelines and eligibility, contact Margrete Klein, Program Director, Visiting Professorships for Women, National Science Foundation, 1800 G Street, NW, Washington, DC 20550; telephone 202-357-7734.

MSEB Calls for State Coalition Proposals

The Mathematical Sciences Education Board (MSEB) of the National Research Council is accepting proposals from nonprofit organizations for the establishment of state coalitions designed to improve mathematics education. The coalitions will involve state leaders from education, corporate, and public-policy sectors who are committed to mathematics education reform.

The State Mathematics Coalitions Project was launched by the MSEB in 1989 with funding from the Exxon Education Foundation and the Carnegie Corporation of New York. Twenty-five states have started coalitions as part of this program. The coalitions will eventually form a nationwide network for generating and implementing changes in mathematics education.

The MSEB does not currently have funding to support the coalitions on a long-term basis, but it does have a program to assist coalitions in securing future funding. Moreover, once the coalitions are formed, the MSEB will maintain its involvement to provide coordinated, national leadership.

The one-year planning grants of \$5,000 to \$10,000 will support planning activities for the coalitions. Proposals will be accepted until **November 30, 1990**. For more information on the state coalitions and instructions on proposal submission, contact: Dr. Robert J. Kansky, Director, State Mathematics Coalitions Project, Mathematical Sciences Education Board, 818 Connecticut Avenue, NW, Suite 500, Washington, DC 20006; telephone 202-334-1486.

Acknowledgement of Contributions

The officers and the staff of the Society acknowledge with gratitude gifts and contributions received during the past year. Contributing members of the Society paid dues of $138 or more. In addition to contributions to the AMS Centennial Fellowship Fund, there were a number of unrestricted general contributions. Some of the contributors have asked to remain anonymous. All of these gifts provide important support for the Society's programs. Also listed this year are AMS members who contributed, thru the Society, to the International Mathematical Union's Special Development Fund for travel grants to young mathematicians from developing countries. The names listed below include those whose contributions were received during the year ending March 31, 1990.

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Abolt, James A.
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Abrahamson, Brian
Abram, Thomas Joseph
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Albright, Hugh N.
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Alexander, Roger K.
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Anderson, Chris R.
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Anderson, Glen D.
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Anderson, Mark Stanley
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*Anker, Jean-Philippe
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•Artin, Michael
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*Barsotti, Leo
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•Baruch, Herbert Mark, III
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*Beauzamy, Bernard M.
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*Beeson, Michael J.
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*Beissinger, Janet Simpson
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*Belair, Luc
*Belilgne, Atlaw
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Bell, Murray Gordon
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*Bernert, Jan
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*Berrick, A. J.
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•Blackett, Donald W.
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•Blair, William D.
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*Bloom, Thomas
*Bloom, Walter R.
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*Bogdan, Victor Michael
*Bogvad, J. Rikard
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Bolley, Don S.
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*Bond, Robert Joseph
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*Bonin, Joseph E.
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Boos, William
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*Brattstrom, Gudrun B.
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Camina, A. R.
Campanino, Massimo
Campbell, Harold E. A.
*Campbell, Jean
Campbell, L. Andrew
*Campbell, L. Lorne
Campbell, Paul J.
*Campbell, R. B.
Campillo, Antonio
Campiti, Michele
Campos, L. M. B. C.
*Candiotti, Alan
Candy, Gregory T.
Cannon, James W.
Cannon, John R.
Cantoni, Vittorio
Cantrell, James C.
*Cantrell, Robert S.
Cantwell, John C.

Cap, Clemens Heinrich
*Capasso, Vincenzo
Capozzi, Alberto
Capparelli, Stefano
Cappell, Sylvain E.
Capuzzo Dolcetta, Italo
Caranti, A. E.
Caravella, Sandra M.
Card, Edward Frank
*Carey, A. L.
*Cargo, Gerald T.
Caricato, Gaetano
Carleson, Lennart A. E.
Carlisle, Ronald L.
Carlson, Bengt G.
Carlson, Bille C.
Carlson, James W.
Carlson, John R.
Carlson, John W.
Carlson, Jon F.
Carlson, Kermit H.
Carlson, Robert C.
Carlson, Timothy J.
*Carlsson, Renate
Carman, Grace Adams
Carmichael, Richard D.
do Carmo, Manfredo P.
*Carothers, David C.
Carpenter, Sarah A.
Carr, Donna M.
Carr, Ralph W.
Carrie, Dennis
Carroll, Francis W.
Carroll, Jeffrey S.
Carroll, Robert W.
Carroll, Timothy B.
Carruth, James H.
Carson, Andrew B.
Cartan, Henri
Carter, David W.
Carter, Patricia Hawks
Carter, Thomas J.
Cartier, Pierre
Casazza, Peter G.
Case, Bettye Anne
Casey, Robert Francis
Casey, Stephen D.
Casler, Burtis G.
*Cassels, J. W. S.
Cassidy, Phyllis J.
Castagnoli, Erio A.
*Castelfranco, Ann M.
Castle, Richard Jay
Castore, Glen M.
*Catanese, Fabrizio M. E.
Cateforis, Vasily C.
Cater, Frank S.
Cato, Benjamin R., Jr.
Cavaretta, Alfred S.
Cavender, James A.
Cawley, Robert
Cazzaniga, Franco
Cecil, Thomas E.
Cegrell, Urban
*Cehelsky, Priscilla
Cerda, Joan
Cerruti, Umberto
Certain, Melinda W.
deCesare, Kenneth M.
Cesari, Lamberto
Chabert, J. L.
Chafee, Nathaniel
Chaffee, James W.
Chai, Winchung A.
Chaiken, Seth D.
Chakerian, Gulbank D.
Chalmers, Bruce L.
Chamberlin, Richard E.
*Chambers, Graham A., Jr.
Champagne, Carol Z.
Chan, Jack-Kang
Chan, Kit Chak
Chan, Su-Han
Chan, Tony F.
*Chan, Whei-Ching C.
Chan, Y. H.
Chan, Yun K.
Chandarana, Sharad
Chandler, Buel E.
Chandra, Jagdish
Chandrasekar, Srinivasan
Chandrasekharan, P. S.
Chang, Bomshik
Chang, Der-Chen Edward
Chang, Derek Kong
Chang, Eugene J.
Chang, Gerard J.
Chang, I-Chen
Chang, Jen-Tseh
Chang, Kun Soo
Chang, Ping-Tung
Chang, Shao-Chien
Chang, Shyang
Chang, Sun-Yung Alice
Chang, Weita
Chang, Yu
Chanillo, Sagun
*Chapin, Edward W.
Chapin, Steven Arthur
*Charalambous, Michael Georgiou
Charles, Josette
Charney, Ruth M.
Chatterji, Srishti D.
•Chauvin, Andre
Chavey, Darrah P.
Chawla, Lal M.
Cheah, Jan
Chee, Pak Soong
Cheeger, Jeff
Chein, Orin N.
Chen, Concordia C.
Chen, Daniel K. C.
Chen, Dayue
Chen, Gui-Qiang
Chen, Louis H. Y.
Chen, Peili
Chen, Shuxing
Chen, W. W. L.
Chen, Y. W.
Chen, Yi-Ying
Chen, Yongzhuo
Cheney, E. W.
Cheng, Jih-Hsin
Cheng, Kuo-Shung
Cheng, Raymond S.
Cheng, Zhao-Yang
Cheon, Seok-Hyeon
Chern, I-Liang
Chern, Shiing S.
Chern, T. Y. Peter
Cherniavsky, John C.
Chernoff, Herman
Chernoff, Paul R.
Cherny, Julius
Cherowitzo, William E.
•Cheung, B. K. S.
Cheung, Chi-Keung
Cheung, Maria L.
*Cheung, Wing-Sum
*Chi, Quoshin
*Chi, Wenchen
Chiarella, Carl
Chiarenza, Filippo
Chicks, Charles H.
Chicone, Carmen C.
Chidambaraswamy, Jayanthi
Chihara, Theodore S.
*Chikwendu, Sunday C.
Chillag, David
Chillak, Edward W.
*Chillingworth, David R. J.
Chinburg, Ted C.
Ching, Liann
•Ching, Wai-Sin
Chinn, William G.
*Chipot, Michel
Chiswell, Ian M.
*Cho, Chong-Man
Cho, Choong Yun
•Cho, Yong Seung
Choe, Geon Ho
Choe, Young Han
Choi, Kwok-Pui
Choi, Kyu Hyuck
*Choi, Un Haing
Choi, Yun Sung
Choksi, Jal R.
Chong, Chi Tat
Choquet, Gustave
Chouteau, Charles C.
Chover, Joshua
*Chow, Kwang-Nan
Chow, Pao-Liu
Chow, Tseng Yeh
Chow, Yuan S.
Chrestenson, Hubert E.
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Christensen, Chris
Christy, Joe
Chu, Chinku
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Chuang, Pi-Chun
Chung, Lung Ock
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Churchill, Edmund
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Ciarlet, Philippe G.
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*Cifuentes, Patricio
•Cima, Joseph A.
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Cipriani, Fabio
*Cirina, Marco
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Clare, Loren Paul
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Clark, Robert A.
Clark, Stephen L.
*Clark, W. Edwin
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*Clarke, Francis
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Clary, Stuart
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Close, Edward R.
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Cobb, John
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Cochran, James A.
•Cochran, Tim D.
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Coffey, John
Cogburn, Robert F.
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*Cogswell, Richard L.
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•Cohen, Arjeh M.
Cohen, Daniel I. A.
Cohen, Frederick R.
Cohen, Henry B.
*Cohen, Leon M.
Cohen, Martin J.
*Cohen, Michael P.
Cohen, Moses E.
Cohen, Regina B.
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*Cohn, Harry
Cohn, Harvey
Cohn, Richard M.
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Cole, Herman D.
•Cole, Nancy
Cole, Paul Dana
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*Colley, Susan Jane
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Conlon, Joseph G.
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Connelly, Robert
Connolly, Frank X.
•Connors, Edward A.
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Cook, Larry T.
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Cooke, Kenneth L.
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Cooley, Clifford R.
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Cooper, Hilda L.
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Cooper, Jeffery M.
Cooper, Leroy W.
Cooper, Mark A.
*Cooper, S. Barry
Cootz, Thomas A.
Cope, Davis K.
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Coppotelli, Fred
Coram, Donald S.
*Corazza, Paul J.
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•Cordes, Craig M.
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Corduneanu, Constantin
Corlette, Kevin David
Cornelis, Eric
Cornell, Gary
Cornette, James L.
Corona, Carlos M.
Correia, Frank B.
Corrigan, Thomas Carney
Corsi Tani, Gabriella
Corti, Alessio
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Cosner, George C.
Cossio, Jorge
*Costa, David G.
*Costa, Douglas L.
Costabel, Martin
Costenoble, Steven R.
Cote, Louis J.
Cotsaftis, Michel
Cotter, Christopher S.
Cotton, Robert M.
Couch, W. Eugene
Coulter, Malcolm A.
Countryman, William Mark
Courteau, Bernard
*Coury, Nicholas J.
Couty, R.
Covington, Jacinta Ann
Cowan, Jack D.
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Cowan, Richard E.
Cowdery, Michele E.
*Cowen, Carl C., Jr.
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*Cowles, John R.
*Cox, David A.
*Cox, Lawrence H.
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Coxeter, H. S. MacDonald
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Crapo, Henry H.
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Craven, Bruce D.
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Crone, Lawrence J.
Cronheim, Arno
Cronin, Bernard
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Cross, Ronald W.
Crossley, Sterling G.
*Crow, Edwin L.
*Crowell, Jack L.
Crowell, Richard H.
•Crumb, Cyndi A.
Crumley, George L.
Cruthirds, John E.
*Cryer, Colin W.
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Cumro, Dennis L.
Cunkle, Charles H.
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Cunningham, Frederic, Jr.
Cunningham, Joel L.
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Curlovic, Donald L.
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Curry, James H.
Curry, John D.
Curtis, Charles W.
Curtis, Herbert J.
Curtis, Philip C., Jr.
Curto, Raul E.
Cushing, Jim M.
Cusick, Larry William
•Cusick, Thomas W.
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Cutler, Colleen Diane
*Cutler, Doyle O.
Cutler, Janice Z.
Cutler, William H.
Cuttle, Yvonne H.
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Dadok, Jiri
*Dahari, A. Sh
Dahl, Erlend
*Dahl, William J.
Dai, Taen-Yu
Dalang, Robert C.
*Dale, Knut T.
Dales, H. Garth
*D'Alotto, Louis A.
•Daly, John F.
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D'Ambrosio, Ubiratan
Damiano, David B.
Damon, James Norman
Dana, Martin P.
*Dancis, Jerome
Daney, Charles G.
Dangello, Frank Ralph
D'Angelo, John P.
*Daniel, Klaus H.
Daniels, M. Peg M.
D'Antona, Ottavio
D'Aprile, Margherita
D'Archangelo, James Michael
D'Aristotle, Anthony J.
Dark, R. S.
*Darst, Richard B.
Das, Anadijiban
Das, P. K.
D'Atri, Joseph E.
Datskovsky, Boris A.
D'Attorre, Leonardo
*Dauben, Joseph W.
Davenport, Dennis E.
Daverman, Robert J.
David, Chantal
*Davidon, William C.
Davidson, James R.
*Davidson, Kenneth R.
Davidson, Mark G.
Davies, Morton J.
Davis, Chandler
Davis, James F.
Davis, James H.
Davis, Jon H.
*Davis, Linda M.
Davis, Martin D.
Davis, Paul L.
Davis, Paul W.
Davis, Richard L.
Davis, Robert L.
Davis, Ruth M.
Davis, William J.
Davitt, Harold H.
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Dawes, A. M.
Dawson, Donald A.
*Dawson, John W., Jr.
Day, Wayne
Daybell, Dorothy A.
Dayton, Barry H.
Dean, Carolyn A.
•Dean, James R.
Dean, Nathaniel
DeAngelis, Kathleen R.
DeBlassie, Richard Dante
Debnath, Lokenath
*De Bruin, Marcel G.
Debrunner, Hans E.
De Canniere, Jean
*Dechene, Lucy I.
*Decker, Robert James
Deckert, Kenneth L.
Decruyenaere, Fabien L.
*Dedecker, Paul
Deeb, Waleed M.
Deeter, Charles R.
DeFacio, Brian
DeFelica, Patricia Ann
De Figueiredo, Djairo G.
Defrancesco, Henry F.
DeGray, Ronald W.
Dehesa, Jesus Sanchez
Deheuvels, Paul
Deift, Percy Alec
De Iongh, Johan J.
Deiter, Daphne D.
Dejter, Italo J.
Dekker, Jacob C. E.
Dekleine, Herbert A.
DeKoninck, Jean Marie
Dekster, B. V.
Delahunty, Michael D.
Delaney, Matthew S.
Delange, Hubert
De Lange, Jan
Delanoe, Philippe
*De La Penha, Guilherme M.
Delbaen, Freddy
Delchamps, David F.
Deleanu, Aristide
DeLeon, Morris Jack
Dell'Antonio, Gianfausto
Della Riccia, Giacomo
Delporte, Jean
*Del Riego de Del Castillo, L.
Delver, Robert
•Delzell, Charles N.
Demana, Franklin D.
De Marr, Ralph E.
Demetrius, Lloyd A.
Demeyer, Frank R.
Deming, Robert W.
•Demko, Stephen
Demmel, James W.
Dencker, Nils
Dennin, Joseph B.
DePagter, Bernardus
De Pascale, Espedito
Deprima, Charles R.
*Deriggi, Dennis F.
Deruaz, Marcel A. F.
Derwent, John E.
Désarménien, Jacques
*Deshpande, Janardan V.
Desmond, James Eddy
De Snoo, Hendrik S. V.
•Desoer, Charles A.
Desquith, Etienne
DeTurck, Dennis
Deuber, Walter Alfred
*Deumens, Erik
Deutsch, Emeric
•Deutsch, Michael
Deutz, Andre H.
Devaney, Robert L.
Deveney, James K.
*Devinatz, Ethan S.
Devlin, Keith J.
DeVore, Ronald A.
Dewallens, Jean H.
*De Wilde, Philippe
Dezern, David H.
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Dhooghe, Paul F. J.
Diamond, Beverly E. J.
Diamond, Fred I.
Diamond, Jack
Dias Da Silva, J. A.
Diaz-Miranda, Antonio
Dickenstein, Alicia M.
Dickerson, Charles E.
Dickinson, Arthur F.
Dicks, Dwayne
Di Concilio, Anna
*Diederich, Klas
Diener, Karl-Heinz
Diestel, Joseph
Dieter, Ulrich
Dietz, David
Dieudonne, Jean A.
Dijksma, Aalt
Dikshit, G. D.
*Dilao, Rui
Dilcher, Karl H.
Dillon, Meighan Irene
Dillon, Richard T.
Di Maio, Giuseppe
Dimsdale, Bernard
Dion, Gloria S.
Dionne, Benoit
Di Paola, Jane W.
Dipper, Richard T.
Divis-Poracka, Zita M.
Dixon, Albert T.
*Dixon, John D.
*Dixon, Peter Grant
Dlab, Vlastimil
Dobbins, Robert R.
Dobrow, Robert P.
Dobson, David C.
Dodson, Christopher T. J.
Dodziuk, Jozef
Doerfler, Willibald
Doering, Boro
Dolan, James M.
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Dold, Albrecht E.
Doleh, Yaser K.
Dolgachev, Igor
Dollard, John D.
Dombrowski, Joanne M.
Dominguez, J. M.
Dominijanni, Roberto
Domokos, Gabor
*Donahue, Sister Gabriel Mary
*Donaldson, James A.
Donaly, James P.
*Dong, Rui-Tao
Donnelly, Rod
Donoho, David Leigh
Doob, Joseph L.
*Dooley, A. H.
Dooley, Thomas J.
Doppel, Karl
Doran, Robert S.
Dordal, Peter L.
Dorfmeister, Josef F.
Dorlas, Tony C.
Dorman, David R.
Dorner, Bryan C.
Dorroh, James R.
Dorsett, Charles I.
Dorwart, Harold L.
Dossey, John A.
Dostal, Milos A.
Dotzel, Ronald M.
Dou, Alberto M.
Douglas, Jim, Jr.
Douglas, Ronald G.
Douglis, Avron
*Doust, Ian R.
Dovermann, Karl Heinz
Dowd, Robert E.
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Dowers, J. F.
Dowlen, Mary M.
Dowling, Diane M.
Dowling, Michael L.
Dowling, Thomas A.
*Downey, Rodney G.
*Downing, J. Scott
Doyen, Jean
Doyle, John C.
*Doyle, Peter G.
Drager, Lance D.
Dragt, Alex J.
*Drake, David A.
Drake, Frank R.
*Drasin, David
Dray, Tevian
Drazin, Michael P.
Drbohlav, Karel
Dreben, Burton S.
*Dreseler, Bernd
Dressel, Francis G.
*Drew, Gerald C.
Dreyer, Thomas P.
Dribin, Daniel M.
Driver, Bruce K.
Drobot, Vladimir
*Drucker, Daniel S.
Druet, Robert L.
Drumm, Todd A.
*Dubejko, M.
Dubisch, Roy
•Dubois, Joseph J.
Dubson, Alberto S.
*Du Cloux, Fokko
Dudley, Richard M.
Dudziak, James J.
Duer, John L. L.
Duff, George F. D.
Dugas, Manfred H.
Duke, William D.
Dukelow, James S., Jr.
*Dunbar, Steven R.
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Duncan, Ann L.
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Duncan, Richard D.
Dunham, Douglas J.
Dunion, Thomas J.
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Dunwoody, Martin John
Dupont, Johan L.
Dupre, Arthur M.
Dupre, Maurice J.
Duran, Wilfred O.
Durand, Loyal
Durbin, John R.
Duren, Peter L.
Durfee, Alan H.
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*Durgun, Kanat
Durkin, Marilyn B.
*Durrett, Richard T.
Durumeric, Oguz C.
Durusau, Patrick L.
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Dutt, J. E.
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Eachus, J. J.
•Ealy, Clifton E., Jr.
Eames, William P.
Earle, Clifford J., Jr.
•Eaton, Timothy R.
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Edwards, David Albert
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•Fay, John C.
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Feeman, George F.
*Feeman, Timothy G.
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*Feichtinger, Hans Georg
Feigenbaum, Joan
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•Feissner, George F.
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Felland, Michael E.
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Fender, Timothy N.
•Fendrich, John W.
Fenley, John C.
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*Fennig, Joseph N.
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Ferri, Massimo
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*Feurzeig, Wallace
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*Fine, Jonathan
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Fisk, C. Yvette
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•Fitzpatrick, Ben, Jr.
Fitzpatrick, Ben G.
Fitzsimmons, Patrick J.
•Fixman, Uri
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*Flaminio, Livio
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*Flath, Dan
*Fleishman, Bernard A.
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*Francoise, J. P.
*Frangos, Nicholas Efstr
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Goto, Midori S.
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Gover, Eugene H.
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Grabner, Gary Clem
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*Gracia-Bondia, Jose M.
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•Graham, C. Robin
*Graham, Colin C.
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Graham, Ian
Graham, Sidney W.
Graham, Victor W.
Grainger, Arthur D.
Gramain, Andre
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Grannell, Michael John
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*Graves, Larry K.
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Gravesen, Jens
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*Gray, Jack D.
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Gray, John W.
Gray, Mary W.
Gray, Robert E.
Gray, Samuel Hutchison
Gray, Scott Steven
Grayson, Matthew A.
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Grecos, Alkis
*Greechie, Richard J.
*Green, Gary Brian
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Green, Mark L.
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Green, Ronald P.
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Greenspan, Bernard D.
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*Greever, John
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Gregory, David A.
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*Greim, P.
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Greller, Larry David
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Griffin, E. L., Jr.
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Griffin, William Gerald
Griffing, Gary R.
Griffiths, Phillip A.
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Grossman, Edward H.
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Haber, Seymour
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•Hagler, James N.
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•Haight, John A.
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Nakamura, Masahiro
Nakamura, Riichiro
Nakamura, Yoshimasa
Nakanishi, Yasutaka
Nakano, Kazumi
Nakata, Masaomi
Nakata, Mie
Nakauchi, Hiroshi
Nakos, George
Namba, Kanji
Nambooripad, K. S. S.
Namioka, Isaac
Namkoong, Kyu-Oh
Nance, Anthony C.
*Nandakumar, N. R.
Narang, Deborah Lynn
Narang, Kamal
Narayanaswami, P. P.
Narcowich, Francis J.
Narendra, K. S.
Nariboli, Gundo A.
Narushima, Hiroshi
Nash-Williams, Crispin St J. A.
*Nastold, Hans-Joachim
Nataro, Dean C.
Nath, Radha G.
Nathanson, Melvyn B.
Nation, James B.
Natsume, Toshikazu
Naugle, Norman Wakefield
Naumann, David A.
Navarro, Francisco J.
Navarro, Jorge E.
Naveira, Antonio Martinez
Navot, Israel
Nayar, Bhamini M.
Nayar, Brij M.
Nduka, A.
Nebres, Bienvenido F.
•Neeb, Donna M.
Neggers, Joseph
Negrepontis, Stylianos
Neher, Erhard
Nehs, Robert M.
Neidhardt, Arnold L.
Neidinger, Richard Dean
Nel, Louis D.
Nelligan, John D.
Nelson, David
Nelson, Edward
Nelson, Edward O.
Nelson, Guy
Nelson, Larry D.
•Nelson, Paul
Nelson, Robert R.
•Nelson, Roger B.
Nelson, Timothy L.
Nelson, William
Nemethi, Csaba
*Neri, Umberto
Nerode, Anil
Nesbitt, Cecil J.
Nesin, Ali H.
*Ness, Linda A.
Neswan, Oki
*Neubauer, Gerhard J.
Neuhauser, Claudia M.
Neumann, Bernhard H.
Neumann, Peter M.
•Neumann, Walter David
Neuwirth, Lee P.
Nevai, Paul
*Neves, Vitor M. C.
Neveu, Jacques
Neveu, Lawrence V.
*Neville, Charles W.
*Nevo, Amos
Newberger, Stuart M.
Newlander, August, Jr.
Newman, Morris
*Newstead, Peter E.
Newton, Mervin E.
Newton, Paul K.
Ney, Peter E.
*Ng, Boon-Yian
*Ng, Eugene Kwan Sang
Ng, Ho Kuen
*Ng, Sze-Kui
Ngai, Sze-man
Nguyen, Bao Gia
Nguyen, Dung X.
*Nguyen, Hieu D.
Nguyen-Huu-Bong
Nicholas, Joyce Shealy
Nichols, Edward
Nichols, Eugene D.
Nichols, Preston
Nicholson, Victor A.
*Nicholson, W. Keith
Nickel, James A.
Nicol, Charles A.
Nicol, Sherrie Jean
Nicolas, Jean-Louis
Nicolau, Monica
Niederhausen, Heinrich
Niedzwecki, G. P.
Niefield, Susan B.
Nielsen, Lance
Niessner, Herbert
*Niethammer, Wilhelm
Nievergelt, Yves
Niino, Kiyoshi
Nijenhuis, Albert
Niknam, A.
Nirenberg, Louis
Nishida, Takaaki
Nishikawa, Seiki
Nishimura, Yasuichiro
Nishiura, Togo
Nisnevich, Yevsey A.
Nissim, Leonard J.
Nitecki, Zbigniew H.
Nitsche, Johannes C. C.
*Nivat, Maurice P.
Njastad, Olav
Nkashama, Mubenga Ngandu
Nobusawa, Nobuo
Nocilla, S.
Noel, Guy G. J.
*Noguchi, Hiroshi
Noguchi, Junjiro
Noguchi, Mitsunori
Nogura, Tsugunori
Nohel, John A.
Nolan, John P.
Noll, Landon Curt
Noonburg, Virginia A.
*Norden, Jeffrey S.
Nordgren, Eric A.
Nordhaus, Edward A.
Norman, Francis Alexander
Norman, Peter
Norman, R. Daniel
Norman, Robert Z.
Norris, Douglas A.
Norris, Nancy Ellen
Northcutt, Robert A.
Notarnicola, Filippo
Nottrot, Roel
Novella, Joseph D.
Novikoff, Albert B.
•Novinger, William P.
Nucci, Maria-Clara
Nulton, James D.
Nussbaum, Roger D.
Nusse, Helena E.
Nutt, Michael D.
Nyman, Philip D.
Oakland, David O.
Oates-Williams, Sheila
Obaid, Samih A.
Obata, Morio
Oberguggenberger, Michael B.
Oberschelp, Walter
Obert, David G.
de las Obras, Carmen
Ochanine, Serge
Ochs, Robert L., Jr.
Ocone, Daniel L.
Oda, Tadao
Odendahl, William J., III
Odenthal, Charles J.
Odlyzko, Andrew M.
Odoni, R. W. K.
Oehmke, Robert H.
Oehrlein, Christopher D.
Oeljeklaus, E.
Ogawa, Hajimu
Ogg, Andrew P.
Ogielski, Andrew T.
Ogle, Crichton
Ogmen, Haluk
Oguchi, Kunio
Oh, Hi-Jun
*Oh, Yong-Geun
*O'Hara, Kathy M.
Oharu, Shinnosuke
Ohta, Haruto
Ohwaki, Shin-Ichi
Oikawa, Kotaro
Ojakian, Ronald S.
Okada, Ikutaro
Okada, Masami
•Okamoto, Kiyosato
Okayasu, Takateru
Okoh, Frank
*Oksendal, Bernt K.
Okumura, Haruhiko
Okuyama, Akihiro
Olafsson, Gestur
Oldham, Frank Ernest
O'Leary, Robbin Lerch
Oler, Norman
Olesen, Dorte Marianne
Olesen, Mogens Norgaard
Oliger, Joseph E.
Oliker, Vladimir I.
Olin, Robert F.
de Oliveira, Carlos S. S.
Oliver, Henry W.
Oliver, Kenneth S.
*Oliver, Robert A.
Olivier, Reinhard M.
Olkin, Julia
Olmstead, P. S.
Olmsted, John M. H.
Olsen, Martin
Olshen, A. C.
Olson, Dwight M.
Olson, Loren D.
Olson, Timothy E.
Olum, Paul
Olver, Frank W. J.
Olver, Peter J.
Oman, John Arthur
Oman, Mary Ellen
O'Meara, Kevin C.
O'Meara, O. Timothy
Omori, Hideki
Onat, Emin T.
*Önder, Turgut M.
O'Neill, Anne F.
O'Neill, Bernard V., Jr.
Onishi, Hironori
Ono, Takashi

AMS CENTENNIAL FELLOWSHIP CONTRIBUTION IN MEMORY OF HORACE Y. MOCHIZUKI
Kenneth C. Millett

Ono, Yoshie
*Onose, Hiroshi
Onstott, Edward D.
Oodaira, Hiroshi
*Ooms, Alfons I.
Oono, Yoshitsugu
Opfer, Gerhard H.
Oppenheimer, Seth F.
•Oprea, John F.
Ordman, Edward T.
Orellana, Chacin Mauricio
Orihuela, Jose
Orlik, Peter P.
Orloff, Leo N.
Ornelas, António
O'Rourke, Joseph
Orr, Kent Edward
Orr, Martin
Orr, Richard J.
Orsted, Bent
Ortiz-Quiñones, Carmen A.
*Orzech, Morris
Osborn, J. Marshall
Osborn, T. A.
Osborne, Mason S.
Osborne, William John D.
Ose, David T.
Osgood, Brad G.
*Osgood, Charles F.
O'Shea, Donal B.
Oslon, Steve G.
Osner, H. J.
Osofsky, Barbara L.
Osondu, Kevin E.
Osserman, Robert
Osterburg, James
Ostermeyer, Georg Peter
Osterwalder, Konrad
Ostrom, T. G.
Oswald, Urs
Ota, Clem Z.
•Ota, Schoichi
Otal, Javier
Otal, Jean-Pierre J. P.
Otermat, Scott C.
Otero, Maria Carmen
Otsuki, Nobukazu
Otway, Thomas H.
Oursler, C. C.
Overholt, Marius
Oversteegen, Lex G.
Owa, Shigeyoshi
Owings, James C., Jr.
Oyabu, Takashi
Ozaki, Isao
Ozimkoski, Raymond E.
*Ozols, Vilnis
Ozsvath, Istvan
Pacheco-Castelao, Jose M.
Paciorek, Joseph W.
Packer, Judith A.
Packer, Lindsay Arthur
Pade, Offer
Pagano, Miriam E.
Page, David A.
Pahuja, Sangeeta
Paige, Eugene C., Jr.
Paige, Lowell J.
Paisner, Helen L.
Pak, Jingyal
Palais, Eleanor G.
*Palais, Richard S.
Palka, Bruce P.
Pallara, Diego Massimo
Pallaschke, Diethard
Palled, Shivappa V.
Palmer, Edgar M.
Palmer, John Bergin
Palmer, Theodore W.
Pan, Ting K.
*Panchal, Champak D.
Panchapagesan, T. V.
Pandit, Onkar Nath
*Pankin, Mark D.
Paoletti, Roberto
*Paolucci, Michael J.
Papangelou, Fredos
Papanicolaou, George C.
Papantonopoulou, Aigli Helen
•Papas, Theodore Thomas
Pappas, Peter C.
Pardee, Otway O'M
Parish, James L.
Park, Chull
Park, Efton L.
Park, Gary Iljin
Park, Hong-Suh
Park, Jong Geun
Park, Kwang S.
*Park, Kyewon
Park, Kyoo-Hong
*Park, Sehie
Park, Young Soo
*Parker, Ellen Maycock
Parker, Elwood G.
Parker, Francis D.
Parker, George D.
Parker, S. T.
Parker, Willard A.
Parks, Harold R.
Parks, Teresa A.
Parr, James T.
•Parr, Wallace E.
Parrish, Daniel M.
Parrish, Herbert C.
Parrott, David
Parrott, Tim F.
•Parry, Walter R.
*Parry, William
Parsons, Charles D.
Parsons, John D.
Partridge, Eric Dorsey
Paschke, William L.
Pascual, Felino Garcia
Pascual-Gainza, Pere
Pascuas, Daniel
Pascucci, Richard S.
Pasini, Antonio
Paskewitz, Charles W.
Passell, Nicholas
Passerini, Henry J.
Passman, Donald S.
Passty, Gregory B.
*Pathak, Vijay Damodar
*Patil, Dattatraya J.
Patterson, Reba
Patterson, Samuel E.
Patton, Charles M.
Patton, Robert M.
Patty, C. Wayne
*Patula, William T.
*Paúl, Pedro J.
*Paulling, John M. B.
*Paulowich, David G.
Paulsen, Vern I.
Paulson, Clifford R.
*Paur, Sandra O.
*Paveri-Fontana, Stefano L.
Payne, Lawrence E.
Payne, Stanley E.
Pazy, Amnon J.
Pearce, Kent
Pears, Alan R.
Pearson, Robert W.
Pearson, Ronald K.
Pearson, Stephen C.
*Peart, Paul B.
Peccati, Lorenzo
Peck, Emily Mann
Peck, Paul S.
Pedersen, Edward A.
Pedersen, Franklin D.
Pedersen, Henrik
Pedersen, Jean J.
*Pedersen, John F.
Peek, James M.
Peglar, George W.
Pego, Robert L.
•Peiffer, Barry L.
Peil, Timothy S.
Peitgen, Heinz O.
Peixoto, Mauricio M.
Peleg, Bezalel
*Peletier, Lambertus A.
*Peligrad, Costel
*Pelletier, Donald H.
*Peltier, Charles F.
Pence, Dennis D.
Pendergraft, Kelly J.
*Pengelley, David John
Pennell, Stephen A.
Penney, Carol W.
Penney, David E.
Pennington, Robin Amie
Pennisten, John W.
Pepper, Paul M.
Perdew, Paul M.
Perelli, Alberto
Perez de Vargas, Alberto
*Perez-Olguin, Juan Luis
Perk, Jacques H. H.
Perkel, Manley
Perkins, A. Louise
Perkins, Peter
Perlis, Robert V.
Perlman, Sanford
Perrine, Serge
Perry, Peter Anton
Perry, William L.
Persek, Stephen C.
Person, Laura J.
Pertica, Horacio N.
*Peschke, Georg
Peskin, Barbara R.
Pesotan, Hoshang
Pestana, Dinis Duarte
Petermann, G. E.
*Peters, Chris A. M.
Peters, James Vincent
Peters, John E.
Peters, Klaus
*Peters, Meinhard H.
Petersen, Karl E.
Petersen, Troels
Peterson, Charles L.
Peterson, Gary L.
Peterson, Gregory
Peterson, Peter Robert
Peterson, William C.
*Petri, Monica
*Petricka, Russell J.
Petrie, Emily R.
Petro, John W.
*Petryshyn, W. V.
Pettet, Martin R.
Petticrew, James W.
Petty, Clinton M.
•Petulante, Nelson R.
Peyerimhoff, Alexander
Peyriere, Jacques
*Pfaendtner, James W.
Pfau, Matthias
Pfeifer, Glenn L.
Pfeiffer, Paul E.
Pflug, Peter
Phadke, Bhalchandra Balvant
Phanord, Dieudonne D.
Pheidas, Athanasios C.
Phelps, Robert R.
Phili, Christine Melle
Phillips, G. Edric
Phillips, Keith L.
Phillips, Misty Anne
Phillips, Ralph S.
Phillips, Richard E.
Piacentini, Giulia Maria
Piacenza, Robert John
Piazza, Barry L.
Picard, Rainer H.
Piccinni, Paolo
Pichaud, Joelle
Pichet, Claude
Pickel, Paul Frederick
Pickering, Douglas Arthur
*Piene, Ragni
Pierce, John Festus
Pierce, Richard S.
Pierre, Charles B.
Pietrowski, Alfred
Pietruska-Paluba, Katarzyna
Pignedoli, A.
Pigno, Louis
Pigozzi, Don L.
Piirila, Olli-Pekka
Pila, Jonathan S.
Pillay, Anand
Pimbley, George H., Jr.
Pinch, Richard Gilmour Eric
Pinchover, Yehuda
Pinkham, Henry C.
Pinkus, Allan M.
Pinney, Edmund
Pinney, Karen R.
Pinsky, Mark A.
Pinsky, Ross George
Pippert, Raymond E.
Piranian, George
Pisanski, Tomaž
Pischettola, Cos D.
Piston, Edward J.
Pistone, Giovanni
Pitt, Loren D.
Pittie, Harsh V.
Pittnauer, Franz
*Pitts, Andrew M.
Pitts, David R.
Pixley, Carl P.
Pizer, Arnold K.
Plachky, Detlef
Plank, Donald L.
Plante, Joseph F.
Platt, Bryce Orion
Plaza, Jan A.
Plesken, Wilhelm
Plohr, Bradley J.
Plotnick, Steven P.
Podio-Guidugli, Paolo
Poguntke, Detlev
Pohst, Michael E.
Pokorny, Martin Peter
Polachek, Harry
Polemarchakis, H.
Polimeni, Albert D.
Poliquin, René A.
Polites, George W.
Polking, John C.
•Pollack, Daniel
Pollack, Richard
Pollatsek, Harriet S.
Pollingher, Adolf
Polonsky, Ivan P.
Poluikis, John Anthony
Pomeranz, Shirley B.
Ponthieux, Delores Marie
Poon, Chi Cheung
Poorman, Alan G.
van der Poorten, Alfred J.
Popa, S.
Pop-Stojanovic, Zoran R.
*Poritz, Alan B.
Port, Sidney C.
Porta, Horacio A.
Porte, Jean
*Porter, Gerald J.
Porter, John F.
Porter, Kathryn Frost
*Porter, Lawrence D.
Porter, Willis B.
Portinari, Joao C.
*Pöschel, Jürgen
Posey, Eldon E.
*Posner, Edward C.
Post, Karel A.
Poston, Tim
Pothen, Alex
Potoczny, Henry B.
Potts, Donald H.
Pouliezos, Nikolaos S.
Poulsen, Ebbe T.
*Pourahmadi, Mohsen
*Pourciau, Bruce Hunter
Pour-El, Marian B.
Powell, C. Spencer
*Power, Stephen Charles
Powers, Morris Walton
Powers, Robert C.
Powers, Robert T.
*Powers, Victoria Ann
Powls, Keith W.
Praciano-Pereira, Tarcisio
*Praeger, Cheryl E.
Prakash, Jagdish
Prakash, Nirmala
*Prather, Carl Lindell
Pratt, Vaughan R.
Pratts, Michael John
Preiss, Mitchell Paul
Preissendorfer, Manfred W.
*Pressley, A. N.
*Prest, Michael Y.
Preston, Gordon B.
Prevot, Kenneth J.
Price, G. Baley
*Price, John F.
Price, Roderick A.
Price, Thomas E., Jr.
Priddy, Stewart B.
Priestley, William M.
Prieto, Carlos

Primc, Mirko
Prince, Geoffrey Eamonn
Propp, James Gary
Protas, David S.
Protopopescu, V.
Protter, Philip E.
Proulx, Viera Krnanova
Pruitt, William E.
Pruss, Jan
Prussner, Laird Drew
•Przybylski, Thomas L.
*Przytycki, Jozef H.
Pszczel, Mark B.
*Pu, Hwang-Wen
Pucci, Patrizia
Puerta, Fernando
Pun, Ping-Sham
Putnam, Alfred L.
*Putnam, Jeffrey B.
Putt, Harold L.
Puttaswamy, T. K.
Quarles, D. A., Jr.
Queen, Clifford S.
Quigley, Frank D.
Quillen, Charles C.
Quinn, Declan P. F.
Quinn, Frank S.
Quinn, Grace S.
Quinn, Joseph E.
Quinn, Michael Paul
Quint, Richard A.
Quinto, Eric Todd
Quiring, Donald K.
Rabau, Patrick F.
Rabinovitch, Peter
Rabinowitz, Paul H.
Rabinowitz, Stanley
*Rademacher, Hans-Bert
*Radford, David E.
Radjabalipour, Mehdi
*Radjavi, Heydar
Radkowski, Alfred F.
Radulescu, Nicholas Andrew
Radzikowski, Pawel
Rajan, Dayanand S.
*Rajca, John F.
Rajnak, Stanley L.
Rakesh
*Ralevic, Nebojsa V.
Rall, Louis B.
Ralston, James V.
Ramakrishnan, Dinakar
Ramaley, James F.
•Ramalho, Margarita
Ramanujan, Melapalayam S.
Ramaroson, Francois
Ramsay, Bruce E.
Ran, André C. M.
*Randall, A. Duane
Raney, George N.
*Rangaswamy, K. M.
Range, R. Michael
*Rankin, R. A.
Rankin, Samuel Murray, III
Rankin, Stuart A.
Rao, M. M.
Rao, Ranga R.
*Rao, Vidhyanath Kajana
Rapp, P. E.
Raskind, Wayne Mark
Rassias, George Michael
Ratcliff, Gail D. L.
Ratiu, Tudor Stefan
Ratliff, Louis J., Jr.
Ratz, Jurg J.
*Rauch, Jeffrey B.
Rauch, Lawrence L.
Rausen, John
Raussen, Martin
Rave, Werner J.
Ravindran, Kuppusamy
*Ravishankar, Krishnamurthi
Rawnsley, John H.
Rawsthorne, Daniel A.
Rayburn, Marlon C.
Rayko, John C.
Read, Dwight
*Read, Thomas T.
Reade, Maxwell O.
Reardon, Philip C.
*Rebarber, Richard L.
Reber, Douglas C.
Recamán, Bernardo
Rechard, Ottis W.
Redfield, Robert H.
Redheffer, Raymond M.
Redmond, Don
*Redner, Richard A.
Reed, David L.
Reed, Michael C.
Reed, Robert E.
Reeder, Mark S.
Reedy, Christopher L.
Rees, Charles S.
Rees, Mina S.
Reese, Matthias F., III
Reese, Richard H.
Reese, Sylvester
*Reetz, Dieter A.
Reeves, Roy F.
Reeves-Hicks, Ernestine
Regan, Francis
Reichaw, Meir
Reid, K. Brooks
Reid, William H.
Reimann, David
Reineck, James F.
Reiner, Irma M.
*Reinhardt, William N.
Reinoehl, John H.
Reisel, Robert B.
Reisner, Shlomo
Reissner, Eric
Reitberger, Heinrich
Reiter, Stanley
•Reitwiesner, George W.
Rejto, Peter A.
Rempel, Richard S.
Renardy, Michael
*Renault, Jean N.
Renegar, James M.
*Renfro, Dave L.
Renner, Lex E.
Renshaw, James H.
*Repka, Joe
Resch, Richard I.
Resek, Diane
Restrepo, Guillermo
Retherford, James R.
Retnam, P. Xavier Raja
•Retzloff, David G.
Reyes, Francisco G.
Reynolds, David W.
Reynolds, Donald F.
Reynolds, Robert J.
Reynolds, Robert R.
Reza, Fazlollah
Reznick, Bruce A.
Rhai, Tong-Shieng
Rhee, Choon Jai
•Rhee, Kun Min
Rhodes, Frank
Riaza, Roman
Riazi-Kermani, Mohammad
Ribenboim, Paulo
*Ribes, Luis
Ribet, Kenneth A.
*Ricci, Fulvio
Ricci, Stephen J.
Rice, Henry G.
Rice, John R.
Rice, John William
*Rice, Richard E.
*Rich, Andrew
Richards, Franklin B.
Richards, John F.
Richards, Pamela C.
Richert, Hans-Egon
Richert, Norman J.
Richey, Matthew P.
Richmond, Glayvera
Richmond, Jean B.
Richter, Guenther E.
Richter, Horst P.
Richter, Michael M.
Richter, Stefan
*Richter, Wayne H.
Richtmyer, Robert D.
Rickart, Charles E.
Rickey, V. Frederick
Rickman, B.
Riddle, Malcolm Lee
Ridolfo, Anthony S.
Rieffel, Marc A.
Rieger, Georg J.
Riehemann, Robert M.
*Riehm, Carl R.
*Riemen, William P.
Riemenschneider, Oswald
Riepe, Jerry A.
Riesel, Hans I.
Riffi, Mohamed Ishak
Rigdon, Robert D.
Riihentaus, Juhani
Rike, Thomas A.
Riley, Geoffrey William
Riley, Robert F.
Ringeisen, Richard D.
Rinne, Dan C.
Rio, Jose
Rishel, Thomas W.
Rising, William R.
*Risnes, Martin
Ritt, Robert K.
Ritter, David L.
Ritter, Niles D.
Rivet, Roger
Rizvi, Jawaid H.
Rno, Jung-Sik
Roach, Michael D.
Robbins, David A.
Robbins, David P.
Robbins, Leon C., Jr.
Robert, Alain
Roberts, George A.
Roberts, Howard M.
*Roberts, Jean E.
Roberts, Joel L.
Roberts, Joseph B.
*Roberts, Leslie G.
Roberts, Mark
Roberts, Richard C.
Roberts, Roger A.
Roberts, Stephen G.
Robertson, James B.
Robertson, Malcolm S.
Robertson, Neil
Robertson, Neill
Robinson, Clark
Robinson, Daniel A.
Robinson, Derek J. S.
Robinson, E. Arthur, Jr.
Robinson, G. de B.
Robinson, Geoffrey Raymond
Robinson, Helen Drummond
*Robinson, Karl H.
Robinson, Paul Lee
Robinson, Raphael M.
Robinson, Stanley A.
Robinson, Susan D.
Robkin, Eugene E.
Rocha, Alvany
Rocha, Amy L.
Rocha, Luiz F.
•Rochon, Donna F.
Rockett, Andrew M.
Rockwell, Richard D.
Rod, David L.
Rodman, Leiba
Rodriguez, Gerardo
Rodriguez, Gilmar
Rodriguez, Josephine Sears
Rodriguez, Mauro Efrain C.
Rodriguez, Rubi E.
Rodriguez, Sanjurjo Jose
Rodriguez-Anger, Rita V.
Roe, John
Roe, Robert P.
Roeder, David W.
Roessler, E. B.
*Rofman, Edmundo
Rogers, Jack W., Jr.
*Rogers, James T., Jr.
Roggenkamp, Klaus W.
Rohatgi, Vijay K.
Rohm, Dale M.
Rohrlich, David E.
Roitman, Judith
*Rokni, Kamran A.
Rolf, Howard L.
•Romanelli, S.
Romanyuk, Leonid
Romero-Fuster, Maria Carmen
Ronga, Felice L. L.
Ronveaux, Andre
Rood, John J.
Rooney, Gerald E., Jr.
Rooney, Paul G.
Roos, Bernard W.
Roos, Guy
Roos, Paul
Roosenraad, Cris T.
*Roozemond, Leen
Rope, Crispin M.
Rosa, Alexander
*Rosales, Rodolfo
*Rosati, Mario
Rosay, Jean-Pierre
Rose, N. J.
Roselle, David P.
Roseman, Joseph J.
Rosen, Lon M.
Rosen, Michael I.
Rosen, Ned Ira
Rosen, William G.
Rosenbaum, Robert A.
Rosenberg, David
Rosenberg, Steven
Rosenblatt, Joseph Max
Rosenbloom, J. H.
Rosenfeld, Norman S.
Rosenfeld, Ronald L.
Rosenlicht, Maxwell A.
Rosenstein, George M., Jr.
Rosenthal, Arthur J.
Rosenthal, Eric S.
Rosenthal, Erik J.
Rosenthal, Haskell P.
Rosenthal, Seth R.
Rosenthal, Steven M.
*Rosenthal, William E.
Rosier, Ronald C.
Rosoff, Jeffrey A.
Ross, Bertram
*Ross, David A.
Ross, J. Andrew
Ross, Kenneth A.
Ross, Robert G.
Ross, Shepley L., II
Rosser, J. Barkley
Rossi, Guido A.
Rossi, Hugo
Rossler, Otto E.
Rosson, John
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Rothberger, Fritz
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Rothschild, Linda Preiss
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Rowell, William W.
Rowen, Louis Halle
Roxin, Emilio O.
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Rubinstein, Joachim H.
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Rudnick, Karl
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Ruess, W.
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Ruh, Ernst A.
Ruijsenaars, Simon Norbert
*Rulla, James L.
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Rund, Hanno
Rung, Donald C.
Rupp, Russell D.
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Ryan, Michael D.
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Sacksteder, Richard C.
Sadosky, Cora S.
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Sallee, G. Thomas
Salles, Maurice
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Saltzer, Charles
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Sanchez, Rafael J.
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Saper, Leslie David
Saphar, Pierre David
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Sarason, Donald E.
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Schilling, R. J.
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Smith, James L.
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Smith, Mi-Soo Bae
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Smith, Roger R.
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Taylor, Laurence R.
Taylor, Lee A.
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Zia, Lee L.
Ziegler, John Alan
Ziegler, Zvi
Ziemer, William P.
Zierau, Roger Craig
Zierler, Neal
Ziller, Wolfgang
•Zilmer, Delbert E.
Zimmer, J. W.
Zimmerman, Donald W.
Zimmerman, Grenith J.
*Zimmerman, Jay J.
Zimmermann, Benno
Zimmermann-Huisgen, Birge K.
Zink, Thomas F.
Zinn, J.
Zipse, Philip W.
Zirilli, Francesco
Zitarelli, David E.
Zitron, Norman R.
*Zitzler, Siham Braidi
*Zizler, Vaclav
Zlatev, Zahari
Zo, Felipe J.
Zoch, Richmond T.
Zomorrodian, Reza
Zoreda-Lozano, Juan J.
Zorn, Paul
Zorzitto, Frank A.
*Zotov, Natalia V.
Zsido, Laszlo
Zucker, Steven M.
Zuckerman, Gregg J.
Zweibel, John A.
Zweifel, Paul F.
*Zwick, D.
Anonymous (124)

NEW SERIES

University Lecture Series

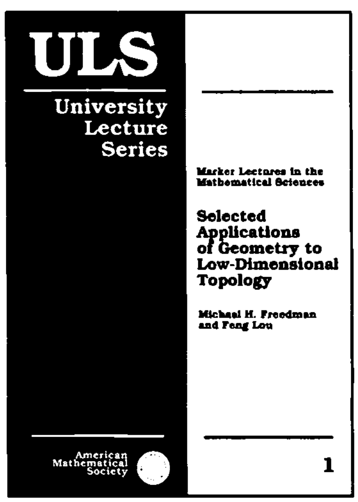
The AMS is pleased to announce the University Lecture Series. This new book series provides a way for excellent, and sometimes inspired, lecture series to reach an audience beyond those able to attend the live lectures. Presented by the outstanding mathematicians of our day, these lectures will be important for their mathematical insight and depth, as well as for their historical and archival value. The inaugural volume in the University Lecture Series is described below.

Selected Applications of Geometry to Low-Dimensional Topology

Michael H. Freedman and Feng Luo

(University Lecture Series, Volume 1)

This book, the inaugural volume in the new University Lecture Series, is based on lectures presented at Pennsylvania State University in February 1987. The Lectures attempt to give a taste of the accomplishments of manifold topology over the last 30 years. By the late 1950s, algebra and topology had produced a successful and beautiful fusion. Geometric methods and insight, now vitally important in topology, encompass analytic objects such as instantons and minimal surfaces, as well as nondifferentiable constructions.



Keeping technical details to a minimum, the authors lead the reader on a fascinating exploration of several developments in geometric topology. They begin with the notions of manifold and smooth structures and the Gauss-Bonnet theorem, and proceed to the topology and geometry of foliated 3-manifolds. They also explain, in terms of general position, why four-dimensional space has special attributes, and they examine the insight Donaldson theory brings. The book ends with a chapter on exotic structures on R^4, with a discussion of the two competing theories of four-dimensional manifolds, one topological and one smooth.

Background material was added to clarify the discussions in the lectures, and references for more detailed study are included. Suitable for graduate students and researchers in mathematics and the physical sciences, the book requires only background in undergraduate mathematics. It should prove valuable for those wishing a not-too-technical introduction to this vital area of current research.

Standing orders are acceptedfor any book series published by the Society. Proforma invoices are sent to standing order customers prior to the publication of each new volume. Shipment is made upon receipt of payment and publication. To begin a standing order for this new series of any other AMS series, please contact Customer Services at 401-455-400.

All prices subject to change. Free shipment by surface; for air delivery, please add $6.50 per title. *Prepayment required.* **Order from** American Mathematical Society, P.O. Box 1571, Annex Station, Providence, RI 02901-1571, or call toll free 800-321-4AMS (321-4267) in the continental U.S. and Canada to charge with VISA or MasterCard.

1980 *Mathematics Subject Classifications*: 57, 53, 54
ISBN 0-8218-7000-9, LC 89-18287
79 pages (softcover), December 1989
Individual member $20, List price $33,
Institutional member $26
To order, please specify ULECT/1NA

1990 AMS Elections

Candidates

OFFICERS

Vice President (one to be elected)
Chandler Davis — Hans F. Weinberger

Secretary*
Robert M. Fossum

Associate Secretaries*
Joseph A. Cima (Southeast) — W. Wistar Comfort (Central)

Treasurer*
Franklin P. Peterson

Associate Treasurer*
Steve Armentrout

Member-at-Large of the Council (five to be elected)

David A. Cox	Edward B. Saff
John M. Franks	Lesley M. Sibner
Frank Gilfeather	Steven H. Weintraub
Kunio Murasugi	Ruth J. Williams
Donald St. P. Richards	Lai-Sang Young

Board of Trustees (one to be elected)
Jane P. Gilman — M. Susan Montgomery

NOMINATING COMMITTEE FOR 1991
(Preferential Ballot, three to be elected)

Michael Aschbacher	Jerry Lawrence Kazdan
Eric D. Bedford	Walter David Neumann
Henri Gillet	Stephen Wainger

EDITORIAL BOARDS COMMITTEE FOR 1991
(Preferential Ballot, two to be elected)

Jon F. Carlson	Stephen S. Shatz
Richard James Milgram	Nolan R. Wallach

*Uncontested offices

Election Information

The ballots for election of members of the Council and Board of Trustees of the Society for 1991 will be mailed on or shortly after September 10, in order for members to receive their ballots well in advance of the November 10 deadline. Prior to casting their ballots members are urged to consult the following articles and sections of the Bylaws of the Society: article I, section 1; article II, sections 1, 2; article III, sections 1, 2, 3; article IV, sections 1, 2, 4; article VII, sections 1, 2, 5. The complete text of the Bylaws appears on pages 1261–1266 of the November 1989 issue of *Notices.* A list of the members of the Council and Board of Trustees serving terms during 1990 appears in the **AMS Reports and Communications** section of this issue.

REPLACEMENT BALLOTS

This year ballots for the AMS election will be mailed September 10, 1990, or within a day or two thereafter. The deadline for receipt of ballots in Providence is November 10, 1990.

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

To help alleviate this problem, the following replacement procedure has been devised: A member who has not received a ballot by October 10, 1990, or who has received a ballot but has accidentally spoiled it, may write after that date to the Secretary of the AMS, Post Office Box 6248, Providence, RI 02940, asking for a second ballot. The request should include the individual's member code and the address to which the replacement ballot should be sent. Immediately upon receipt of the request in the Providence office, a second ballot, which will be indistinguishable from the original, will be sent by first class or air mail. It must be returned in an inner envelope, which will be supplied, on the outside of which is the following statement to be signed by the member:

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

____
signature

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

SUGGESTIONS FOR 1991 NOMINATIONS

Each year the members of the Society are given the opportunity to propose for nomination the names of those individuals they deem both qualified and responsive to their views and needs as part of the mathematical community. Candidates will be nominated by the Council to fill positions on the Council and Board of Trustees to replace those whose terms expire December 31, 1991. See the **AMS Reports and Communications** section of this issue for the list of current members of the Council and Board of Trustees. Members are requested to write their suggestions for such candidates in the appropriate spaces below.

SUGGESTIONS FOR 1991 NOMINATIONS

Council and Board of Trustees

President-Elect (1)

____

Associate Secretaries (2) (Western and Central Sections)

____

____

Members-at-large of the Council (5)

____

____

____

____

____

Member of the Board of Trustees (1)

____

The completed form should be addressed to AMS Nominating Committee, Post Office Box 6248, Providence, RI 02940, to arrive no later than **November 10, 1990.**

Proposed Amendments to the Bylaws of the American Mathematical Society

The Council offers three amendments to the bylaws for possible approval by the members by mail ballot in the 1990 AMS elections. The bylaws of the Society state the following concerning amendments to the bylaws:

> These bylaws may be amended or suspended on recommendation of the Council and with the approval of the membership of the Society, the approval consisting of an affirmative vote by two-thirds of the members present at a business meeting or of two-thirds of the members voting in a mail ballot in which at least ten percent of the members vote, whichever alternative shall have been designated by the Council, and provided notice of the proposed action and of its general nature shall have been given in the call for the meeting or accompanies the ballot in full.

In the statements of the amendments, deleted words are ~~lined out~~ and insertions are in **bold face**.

The ballot on the amendments is on the same sheet as that for officers and Council members.

Terms of Office

This amendment would change the length of the term of the vice-presidents of the Society. It would remove from the bylaws and assign to the Council the determination of the lengths of terms of members of editorial committees and appointed members of communications committees. This amendment also changes the beginning of the terms of office from January 1 to February 1.

If the terms of office begin on February 1, then the timetable for electing members of the Council to its Executive Committee must also be changed. This is accomplished by the second part of this amendment.

Article VII

Election of Officers and Terms of Office

Section 1. The term of office shall be one year in the case of the president-elect and the ex-president; ~~five years in the case of the trustees;~~ two years in the case of the president, ~~the vice-presidents,~~ the secretary, the associate secretaries, the treasurer, and the associate treasurer~~.~~ **;** ~~The term of office in the case of members of the editorial committees and appointed members of the communications committees shall be four years for the *Proceedings* and the *Transactions* and *Memoirs* committees and three years for the remaining committees, except that when the size of an editorial or communications committee is changed, the Council may authorize the appointment of a member for a shorter term. The term of office for~~ **three years in the case of vice-presidents and** members-at-large of the Council ~~shall be three years~~ **, one vice-president and** five ~~of the~~ members-at-large retiring annually **; and five years in the case of the trustees. In the case of members of the editorial committees and appointed members of the communications committees, the term of office shall be determined by the Council.** The term of office for elected members of the Executive Committee shall be four years, one of the elected members retiring annually. All terms of office shall begin on ~~January~~ **February** 1 and terminate on ~~December~~ **January** 31 with the exception that the officials specified in Articles I, II, III, IV, and V (excepting the president-elect and ex-president) shall continue to serve until their successors have been duly elected or appointed and qualified.

Section 4. On or before ~~January~~ **February** 15, the secretary shall send to all members of the Council for a mail vote a ballot containing two names for each place to be filled on the Executive Committee. The nominees shall be chosen by a committee appointed by the president. Members of the Council may vote for persons not nominated. Any member of the Council who is not an *ex officio* member of the Executive Committee (see Article V, Section 1) shall be eligible for election to the Executive Committee. In case a member is elected to the Executive Committee for a term extending beyond the regular term on the Council, that person shall automatically continue as a member of the Council during the remainder of that term on the Executive Committee.

Method of Election

The effect of this amendment would be to remove from the ballot elections for those offices which are not contested. These include elections for the positions of secretary, associate secretary, treasurer, and associate treasurer. These officers would be appointed by the Council.

Article VII

Election of Officers and Terms of Office

Section 2. The president-elect, the vice-presidents, ~~the secretary, the associate secretaries, the treasurer, the associate treasurer~~, the trustees, and the members-at-large of the Council shall be elected by written ballot. An official ballot shall be sent to each member of the Society by the secretary on or before October 10, and such ballots, if returned to the secretary in envelopes bearing the name of the voter and received within thirty days, shall be counted. Each ballot shall contain one or more names proposed by the Council for each office to be filled, with blank spaces in which the voter may substitute other names. A plurality of all votes cast shall be necessary for election. In case of failure to secure a plurality for any office, the Council shall choose by written ballot among the members having the highest number of votes. **The secretary, the associate secretaries, the treasurer, and the associate treasurer shall be appointed by the Council in a manner designated by the Council.** Each committee named in Article III, Section 1 or 3, shall be appointed by the Council in a manner designated by the Council. Each such committee shall elect one of its members as chairman in a manner designated by the Council.

Retired Members

Long-standing members of the Society who have retired may remain members of the Society without paying dues. The privilege of receiving the *Bulletin of the American Mathematical Society* is currently not accorded to these members. The effect of this amendment would be to allow these members to continue to receive the *Bulletin*.

Article IX

Dues and Privileges of Members

Section 8. After retirement from active service on account of age or on account of long term disability, any ordinary or contributing member who is not in arrears of dues and with membership extending over at least twenty years may, by giving proper notification to the secretary, have dues remitted~~,~~ **.** ~~on the understanding that the member will thereafter~~ **Such a member shall** receive the *Notices* ~~but not~~ **and may request to receive** the *Bulletin* **as privileges of membership during each year until membership ends.**

Amherst, Massachusetts University of Massachusetts, Amherst October 20 – 21

Second Announcement

The eight-hundred-and-sixtieth meeting of the American Mathematical Society will be held at the University of Massachusetts, Amherst, Massachusetts, on Saturday, October 20, and Sunday, October 21, 1990. All scientific sessions will be held in the Lederle Graduate Research Tower and several nearby buildings.

Invited Addresses

By invitation of the Eastern Sectional Program Committee, there will be four invited one-hour addresses. The speakers, their affiliations, the titles of their talks, and the scheduled times of presentation are:

CHRISTOPHER B. CROKE, University of Pennsylvania, *On the rigidity induced by the length of geodesics; problems and recent progress*, 11:00 a.m. Saturday.

WILLIAM M. GOLDMAN, University of Maryland, College Park, *Complex hyberbolic Kleinian groups*, 11:00 a.m. Sunday.

JOHN J. MALLET-PARET, Brown University, *Global dynamics of delay differential equations*, 1:30 p.m. Saturday.

HENRY P. MCKEAN JR., New York University, Courant Institute, *Two symplectic structures*, 1:30 p.m. Sunday.

Special Sessions

By invitation of the same committee, there will be nine special sessions of selected twenty-minute papers. The topics of these sessions and the names and affiliations of the organizers are as follows:

Hyperbolic manifolds, COLIN C. ADAMS, Williams College.

Lattices, geometry, and combinatorics, M. K. BENNETT and GARRETT BIRKHOFF, Harvard University.

Nonlinear dynamics in mathematics and science, MELVYN BERGER and ROBERT GARDNER, University of Massachusetts, Amherst.

Semigroups, HASKELL COHEN, University of Massachusetts, Amherst.

Discrete groups and geometric structures in 2, 3, and 4 dimensions, WILLIAM M. GOLDMAN, and BERNARD MASKIT, SUNY at Stony Brook.

Lie groups and algebraic groups, JAMES E. HUMPHREYS, and IVAN MIRKOVIĆ, University of Massachusetts, Amherst.

Algebraic graph theory, CHJAN LIM, Rensselaer Polytechnic Institute.

Ergodic theory, V. S. PRASAD, University of Lowell.

Aperiodicity and order, CHARLES RADIN, University of Texas, Austin, and MARJORIE SENECHAL, Smith College.

Abstracts for consideration for these sessions should have been submitted by the **July 16, 1990** deadline. This deadline was previously published in the Calendar of AMS Meetings and Conferences and in the Invited Speakers and Special Sessions section of *Notices*.

Contributed Papers

There will also be sessions for contributed ten-minute papers. Late papers will not be accommodated.

Registration

The registration desk will be located in the 16th floor lobby of the Lederle Graduate Research Tower and will be open from 8:00 a.m. to 5:00 p.m. on Saturday, October 20, and from 8:00 a.m. to noon on Sunday, October 21. The registration fees are $30 for members of the AMS, $45 for nonmembers, and $10 for students or unemployed mathematicians.

Other Events of Interest

On Friday, October 19, there will be an international symposium on *Nonlinear Dynamics in Mathematics and Science*, hosted by the Center for Applied Mathematics of the University of Massachusetts, Amherst, and the five college applied mathematics committees and sponsored by the Office of Naval Research. This conference will take place from 10:00 a.m. until the late evening in the Mathematics Colloquium Room (1634 Graduate Research Tower). Many distinguished mathematicians and scientists from this country and abroad (Soviet Union, England, and Japan) have been invited to participate in this major event. Here is a chance to learn of many of the major research developments in this field and to meet many of the major contributors–all in one day. The invited participants include R. Coifman, R. Devaney, R. Dobrushin, C. Foias, L. E. Fraenkel, C. Jones, V. Judovich, G. Knightly, N. Kopell, H. Matano, H. McKean, A. Polyakov, J. Spruck, J. T. Stuart, and J. Toland. In relation to the conference, there will be a two-day Special Session of invited talks on nonlinear dynamics on Saturday and Sunday organized by M. S. Berger and R. Gardner.

Social Event

There will be a social event hosted by the Department of Mathematics and Statistics, late Saturday afternoon.

Petition Table

A petition table will be set up in the registration area. Additional information about petition tables can be found in a box in the announcement of the Columbus meetings in the April 1990 issue of *Notices*.

Accommodations

Rooms have been blocked for participants at the following hotels or motels in the area. Because of the popularity of the New England fall foliage, hotel/motel reservations should be made as soon as possible. Participants should make their own reservations directly and mention the AMS meeting. The deadline for reservations at the Lincoln Campus Center is September 29th; Lord Jeffery Inn, October 5th; Motel 6, September 30th; Country Belle Motel, September 9th; Howard Johnson Motel, September 19th; and University Motor Lodge, was August 19th.

Country Belle Motel (two miles from campus)
392 Russell Street, Hadley, MA 01035 (Rte.9)
Telephone: 413-586-0715

Single $54 Double $54

Howard Johnson Motel (two miles from campus)
401 Russell Street, Hadley, MA 01035 (Rte.9)
Telephone: 413-586-0114

Single $85 Double $85

Lincoln Campus Center Hotel (on campus)
University of Massachusetts, Amherst, MA 01003
Telephone: 413-549-6000

Single $54 Double $64

Lord Jeffery Inn (one mile from campus)
30 Boltwood Avenue, Amherst, MA 01002
Telephone: 413-253-2576

Single $80 Double $80

Motel 6 (ten miles from campus)
State Road, (I-91 Exit 24, North rte. 5 and 10), South Deerfield, MA 01373
Telephone: 413-665-7161

Single $29.56 Double $36.15

University Motor Lodge (1/4 mile from campus)
345 North Pleasant Street, Amherst, MA 01002
Telephone: 413-527-8468

Single $67 Double $67

Food Service

Meals will be available at the following campus locations. Saturday only: Top of the Campus Restaurant (located in Lincoln Campus Center on the 11th floor). Hours are from 5:00 p.m. to 9:00 p.m.

Saturday and Sunday: Hatch Cafeteria 8:00 a.m. – 10:30 p.m.

Saturday: Newman Center 8:30 a.m. – 4:00 p.m.

Sunday: Newman Center 8:30 a.m. – 10:00 p.m.

Parking

Parking will be permitted in any of the parking lots on campus from 6:00 p.m. Friday until 7:00 a.m. Monday at no charge. The only restrictions apply to spaces indicated as reserved for handicapped or towing zone areas. Parking at other hours is available for a fee at the parking garage adjacent to the Lincoln Campus Center.

Travel and Local Information

The University of Massachusetts, Amherst, is accessible by air, bus, or car. In the town of Amherst there is no taxi service but it is expected that the Pioneer Valley Transit Authority (PVTA) bus service will be available to and from the campus. Amherst is approximately a one-hour drive from Bradley International Airport in Windsor Locks, Connecticut, which is served by such major airlines as American, Delta, Eastern, TWA, United, and USAir.

Participants are advised to fly in and out of Bradley since it is closer and more convenient than Logan International Airport in Boston. Peter Pan Bus Line is available at Bradley and runs directly to the campus. Peter Pan presently operates daily between the hours of 7:00 a.m. and 8:15 p.m. (10:15 p.m. on Friday). Return buses to Bradley from the campus presently operate daily from 5:05 a.m. until 6:20 p.m. (8:20 p.m on Sunday).

Most major car rental companies have agencies at Bradley International Airport. Directions for participants driving to the meeting are as follow:

FROM THE NORTH: Route 91 South to Exit 25 (South Deerfield) onto Route 116 South to UMass Exit onto Massachusetts Avenue.

FROM THE SOUTH: Route 91 North to Exit 19 (Amherst) onto Route 9 to Route 116 North (left turn at lights) to UMass Exit onto Massachusetts Avenue (turn right).

FROM THE EAST: Massachusetts Turnpike (Route 90) West to Exit 4 (West Springfield), onto Route 91 North (Holyoke Exit) to Exit 19 (Amherst), onto Route 9 to Route 116 North (left turn at lights), to UMass Exit onto Massachusetts Avenue (turn right).

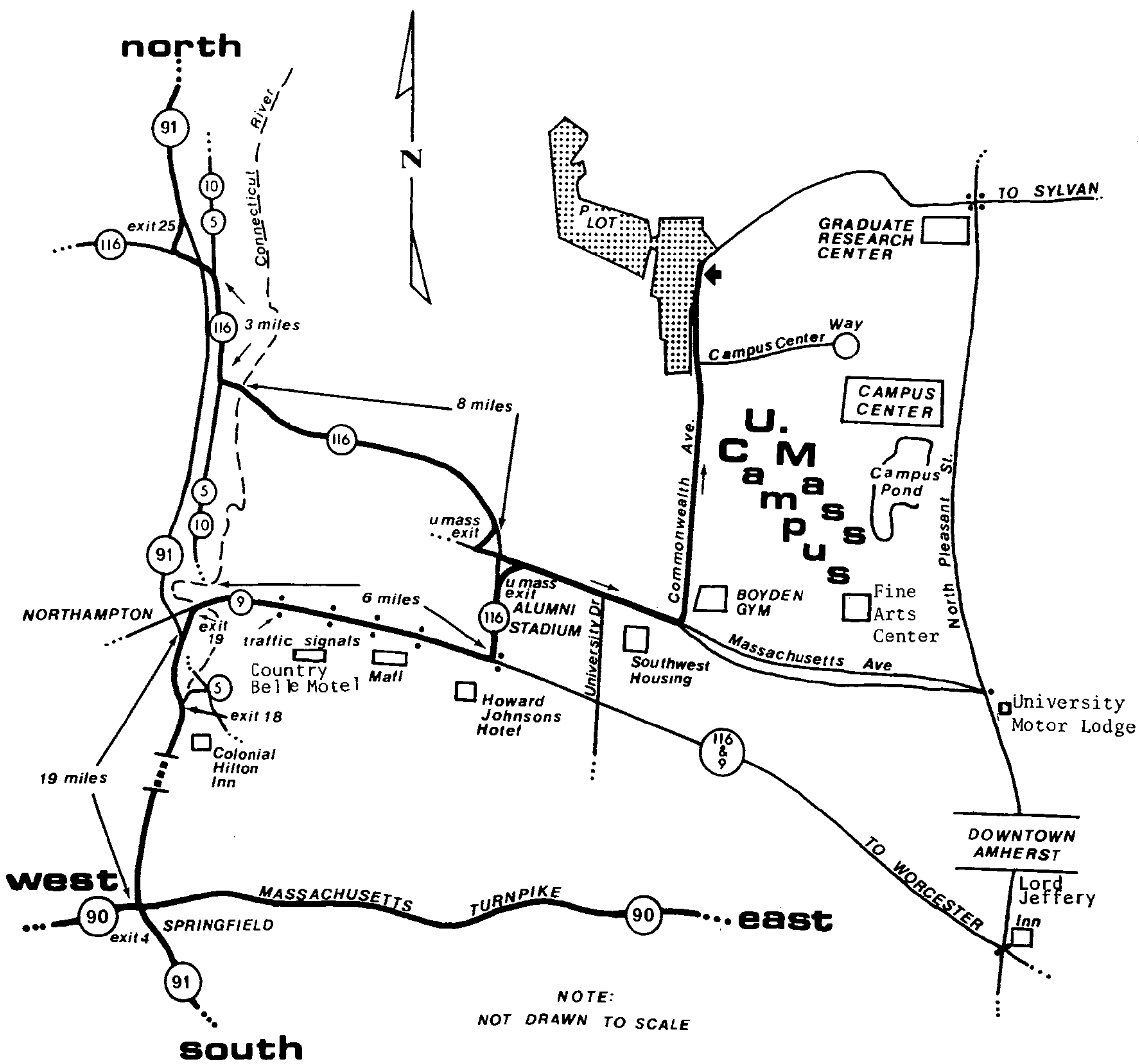
FROM THE WEST: Massachusetts Turnpike (Route 90) to Exit 4 (West Springfield), onto Route 91 North (Holyoke Exit) to Exit 19 (Amherst), onto Route 9 to Route 116 North (left turn at lights) to UMass Exit onto Massachusetts Avenue (turn right).

Weather and Local Attractions

Weather conditions in October can vary greatly. Balmy Indian Summer weather is expected, but rapid changes in conditions have brought on snow storms in the past. Participants should be prepared for both warm and cold conditions.

W. Wistar Comfort
Associate Secretary
Middletown, Connecticut

University of Massachusetts



Denton, Texas
University of North Texas
November 2 – 3

Second Announcement

The eight-hundred-and-sixty-first meeting of the American Mathematical Society will be held at the University of North Texas, Denton, Texas on Friday, November 2, and Saturday, November 3, 1990. All scientific sessions will be held in the Union Building on the campus.

Invited Addresses

By invitation of the Central Section Program Committee, there will be four invited one-hour addresses. The speakers, their affiliations, and the titles of their talks where available are:

AVNER D. ASH, Ohio State University, *Galois representations attached to GL(n,Z).*

PETER S. CONSTANTIN, University of Chicago, *Navier-Stokes equations: Some new results and directions.*

JOHN E. LUECKE, University of Texas, Austin, *Title to be announced.*

CLARENCE WILKERSON, Purdue University, *Classifying spaces and finite loop spaces.*

Special Sessions

By invitation of the same committee, there will be eleven Special Sessions of selected twenty-minute papers. The topics, and the names and affiliations of the organizers, are as follows:

Arithmetic groups, AVNER D. ASH and MARK S. REEDER, University of Oklahoma.

Geometric inequalities and convex bodies, ILYA BAKELMAN, Texas A&M University.

Banach spaces-functional analysis, ELIZABETH M. BATOR, RUSSELL G. BILYEU, and PAUL W. LEWIS, University of North Texas, Denton.

Commutative algebra, SCOTT T. CHAPMAN, Trinity University, and NICK H. VAUGHN, University of North Texas, Denton.

Texas topology and geometry, DANIEL S. FREED, ROBERT F. WILLIAMS, and MICHAEL WOLF, University of Texas, Austin.

The probability theory of patterns and runs, ANANT P. GODBOLE, Michigan Technological University.

Low dimensional topology, JOHN LUECKE and ROBERT MYERS, Oklahoma State University.

Representation theory of Lie groups, LISA MANTINI and ROGER C. ZIERAU, Oklahoma State University

Differential equations, JOHN W. NEUBERGER and HENRY A. WARCHALL, University of North Texas, Denton.

Algebraic geometry, PETER F. STILLER, Texas A&M University.

Several complex variables, EMIL J. STRAUBE, Texas A&M University.

Abstracts for consideration for these sessions should have been submitted by the **July 16, 1990** deadline. This deadline was previously published in the Calendar of AMS Meetings and Conferences and in the Invited Speakers and Special Sessions section of *Notices.*

Contributed Papers

There will also be sessions for contributed ten-minute papers. Late papers will not be accommodated.

Registration

The meeting registration desk will be located in the Gallery Reception Area in the Union Building and will be open from 7:00 p.m. to 9:00 p.m. on Thursday, from 8:00 a.m. to 2:00 p.m. on Friday, and from 8:00 a.m. to noon on Saturday. The registration fees are $30 for members of the AMS, $45 for nonmembers, and $10 for students or unemployed mathematicians.

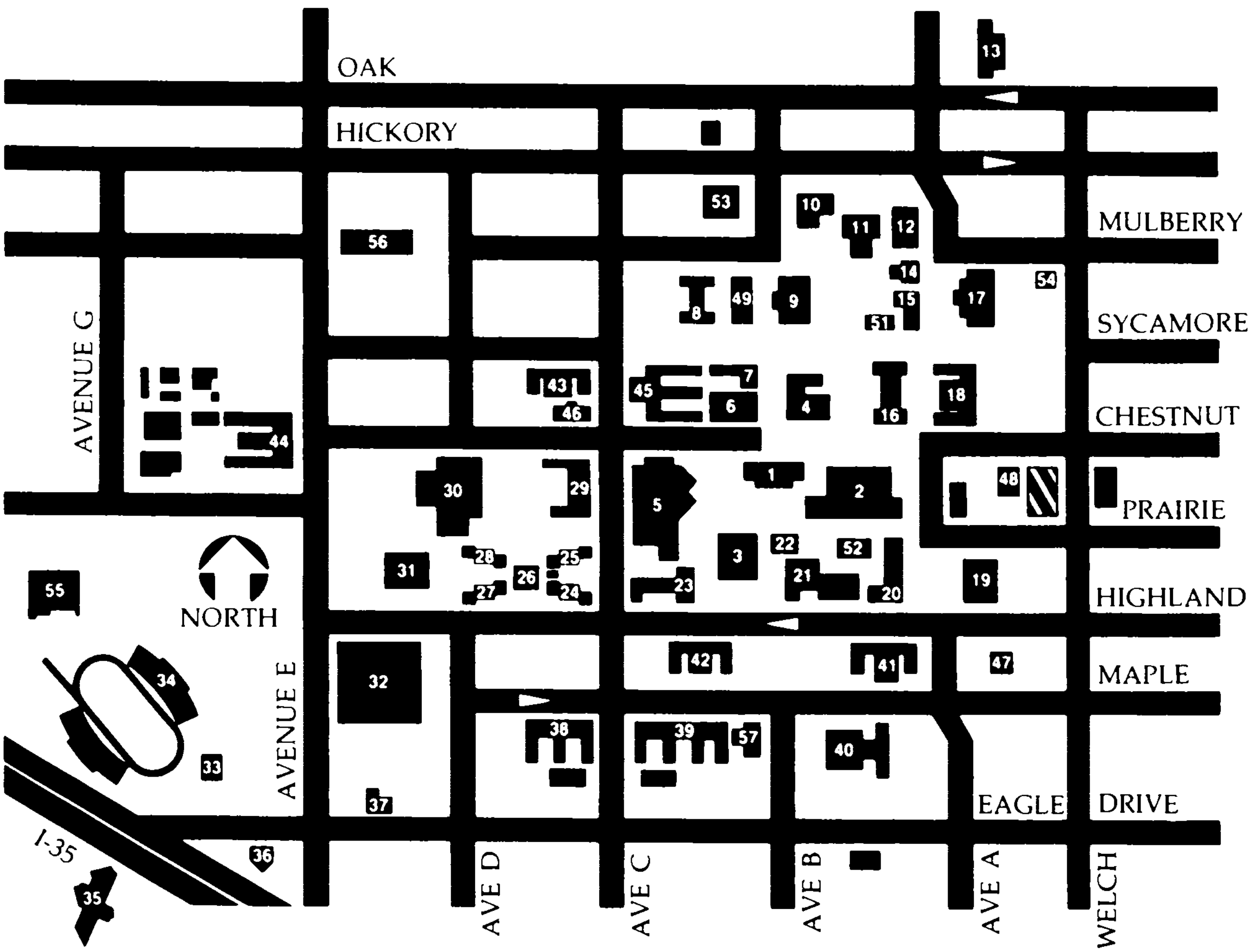
Petition Table

A petition table will be set up in the registration area. Additional information about petition tables can be found in a box in the announcement for the Columbus meetings in the April 1990 issue of *Notices.*

Accommodations

Special rates have been negotiated at selected local hotels,

University of North Texas



Parking Garage

2 University Union

9 Math Department Offices

4 Science Library

35 Sheraton Hotel

all of which are located on the I-35 corridor. Both the Royal Hotel Suites and the Sheraton are within easy walking distance of the campus. Participants should make their own arrangements directly with the hotel of their choice and ask for the special AMS meeting rate. The rates listed are subject to change and do not include applicable taxes. The deadline for reservation at all locations is **October 1, 1990 to obtain the published rates**. The AMS is not responsible for rate changes or accommodations offered by hotels/motels.

Holiday Inn (2.5 miles from campus)
1500 Dallas Drive, Denton, TX 76205
Telephone: 817-387-3511

Single $40 Double $40

LaQuinta Motor Inn (1.5 miles from campus)
700 Fort Worth Drive, Denton, TX 76205
Telephone: 817-387-5840

Single $31 Double $36

Motel 6 (3 miles from campus)
I-35 North of University Drive, Denton, TX 76205
Telephone: 817-566-4798

Single $21.95 Double $27.95

Auburn Inn (2 miles from campus)
820 S I-35E at Teasley Lane, Denton, TX 76205
Telephone: 817-387-0591

Single $35 Double $35

Royal Hotel Suites (.5 miles from campus)
1210 I-35E, Denton, TX 76205
Telephone: 817-383-2007

Single $24 Double $34

Sheraton Hotel (.5 miles from campus)
2211 I-35E, Denton, TX 76205
Telephone: 817-565-8499

Single $53 Double $58

Food Service

Many fast food restaurants are located within two blocks of the campus, and more formal dining is available at the Sheraton Hotel and several local restaurants. Food service in the Union will only be available according to the following schedule: Breakfast, lunch, and sandwiches until 5:00 p.m. on Thursday; breakfast and lunch on Friday; and lunch only on Saturday.

Travel

Denton is located approximately 35 miles north of Dallas and Fort Worth and 25 miles north of DFW International Airport, which is served by most major airlines. Airport shuttle service is available from the DFW International Airport to Denton (Telephone 817-565-9936 two to five days in advance for reservations). However, since one-way fare is $16 and only the Royal Hotel Suites and the Sheraton Hotel are within easy walking distance from campus, those flying to DFW should consider renting a car and driving to Denton.

Weather

Autumn in North Texas is a pleasant season with mild, sunny weather punctuated by short periods of rainfall. The average temperature for November is 61.5 degrees Fahrenheit with relative humidity around 55 percent. The average date of the first freeze is November 8.

Andy Roy Magid
Associate Secretary
Norman, Oklahoma

Irvine, California University of California, Irvine November 10 – 11

Second Announcement

The eight-hundred-and-sixty-second meeting of the American Mathematical Society will be held at the University of California, Irvine (UCI) campus at Campus Blvd in Irvine, California on Saturday, November 10th, and Sunday, November 11th, 1990. All Special Sessions and sessions for contributed papers will be held in the Physical Sciences complex: Physical Sciences I or II, the Physical Sciences Lecture Hall or the Physical Sciences Lecture Facility. This meeting will be held in conjunction with a meeting of the Southern California Section of the Mathematical Association of America (MAA).

Invited Addresses

By invitation of the Western Section Program Committee, there will be three invited one-hour addresses. The speakers, their affiliations, and the titles of their talks are:

JENNIFER T. CHAYES, University of California, Los Angeles, *Nature of the critical phenomenon in self-organized criticality.*

MICHAEL D. FRIED, University of California, Irvine, *Parameter spaces in the inverse Galois Problem.*

NICHOLAS J. KOREVAAR, University of Utah, *Constant mean curvature surfaces.*

Special Sessions

By invitation of the same committee, there will be eight Special Sessions of selected twenty-minute papers. The topics and the names and affiliations of the organizers are as follows:

Probability theory in mathematical physics, JENNIFER T. CHAYES, and GLEN H. SWINDLE, University of California, Los Angeles.

Interactions between group theory and logic, PAUL C. EKLOF, University of California, Irvine.

Interactions between group theory and geometry/number theory, MICHAEL D. FRIED and ROBERT M. GURALNICK, University of California, Irvine.

Moduli space applications, MICHAEL D. FRIED and DAVID HARBATER, University of California, Irvine.

Quantum and statistical mechanics, ABEL KLEIN, University of California, Irvine.

Geometric p.d.e.'s: mean and scalar curvature problems, NICHOLAS J. KOREVAAR and ANDREJS E. TREIBERGS, University of Utah.

Operator theory/operator algebras, BERNARD RUSSO, University of California, Irvine.

Abstracts for consideration for these sessions should have been submitted by the **July 16, 1990** deadline. This deadline was previously published in the Calendar of AMS Meetings and Conferences and in the Invited Speakers and Special Sessions section of *Notices*.

Contributed Papers

There will also be sessions for contributed ten-minute papers. Late papers will not be accommodated.

Registration

The meeting registration desk will be located in the lobby of the Physical Sciences II building, near Parking Lot 12, and will be open from 8:00 a.m. to 4:00 p.m. on Saturday, and 8:00 a.m. to noon on Sunday. The registration fees are $30 for members of the AMS, $45 for nonmembers, and $10 for students or unemployed mathematicians. There is a special one-day fee of $15 for MAA members on Saturday only.

Social Event

The MAA portion of the conference will have a luncheon speaker, Harvey B. Keynes. On Saturday night, various of the Special Session organizers have been encouraged to arrange a dinner of Special Session attendees and speakers. Participants are encouraged to ask any Special Session organizer about this event.

Petition Table

A petition table will be set up in the registration area. Additional information about petition tables can be found in a box in the announcement of the Columbus meetings in the April 1990 issue of *Notices*.

Accommodations

Unfortunately, there is no housing available on the campus during the year; however, four of the hotels do offer shuttle service to UCI. Some hotels offer shuttle service to and from Orange County Airport (on MacArthur Boulevard) and taxi service is available from each hotel to the UCI campus. Participants should be sure to mention the UCI when making reservations to obtain the special rate. The AMS is not responsible for rate changes or accommodations offered by hotels/motels.

The following hotels offer shuttle service to UCI.

Sheraton Newport Beach
4545 MacArthur Boulevard
Newport Beach, CA 92660
Telephone: 714-833-0570

Single or Double $65

The Irvine Hilton and Towers
17900 Jamboree Boulevard
Irvine, CA 92714
Telephone: 714-863-3111

Single or Double $68

Marriott Suites Newport Beach
500 Bayview Circle
Newport Beach, CA 92660
Telephone: 714-854-4500

Single or Double $79

The following hotels are within walking distance or require taxi service to UCI.

The Airporter Inn Hotel
18700 MacArthur Boulevard
Irvine, CA 92715
Telephone: 714-833-2770 or 800-432-7018 (in California) or 800-854-3012 (outside California)

Single or double $49
Participants are urged to make reservations at this hotel as soon as possible to insure the above rate. Taxi service to campus is approximately $6.50.

Comfort Suites
2620 Hotel Terrace Drive
Santa Ana, CA 92705
Telephone: 714-966-5200

Single, per suite $49
Double, per suite $54
Taxi service to campus is approximately $10.

Country-Side Inn
325 Bristol Street
P.O. Box 10117
Newport Beach, CA 92658-0117
Telephone: 714-549-0300

Single $55 Double $60
Taxi service to campus is approximately $10.

Radisson Plaza Hotel Orange County Airport
18800 MacArthur Boulevard
Irvine, CA 92715
Telephone: 714-833-9999

Single or Double $70
Taxi service to campus is approximately $6.50.

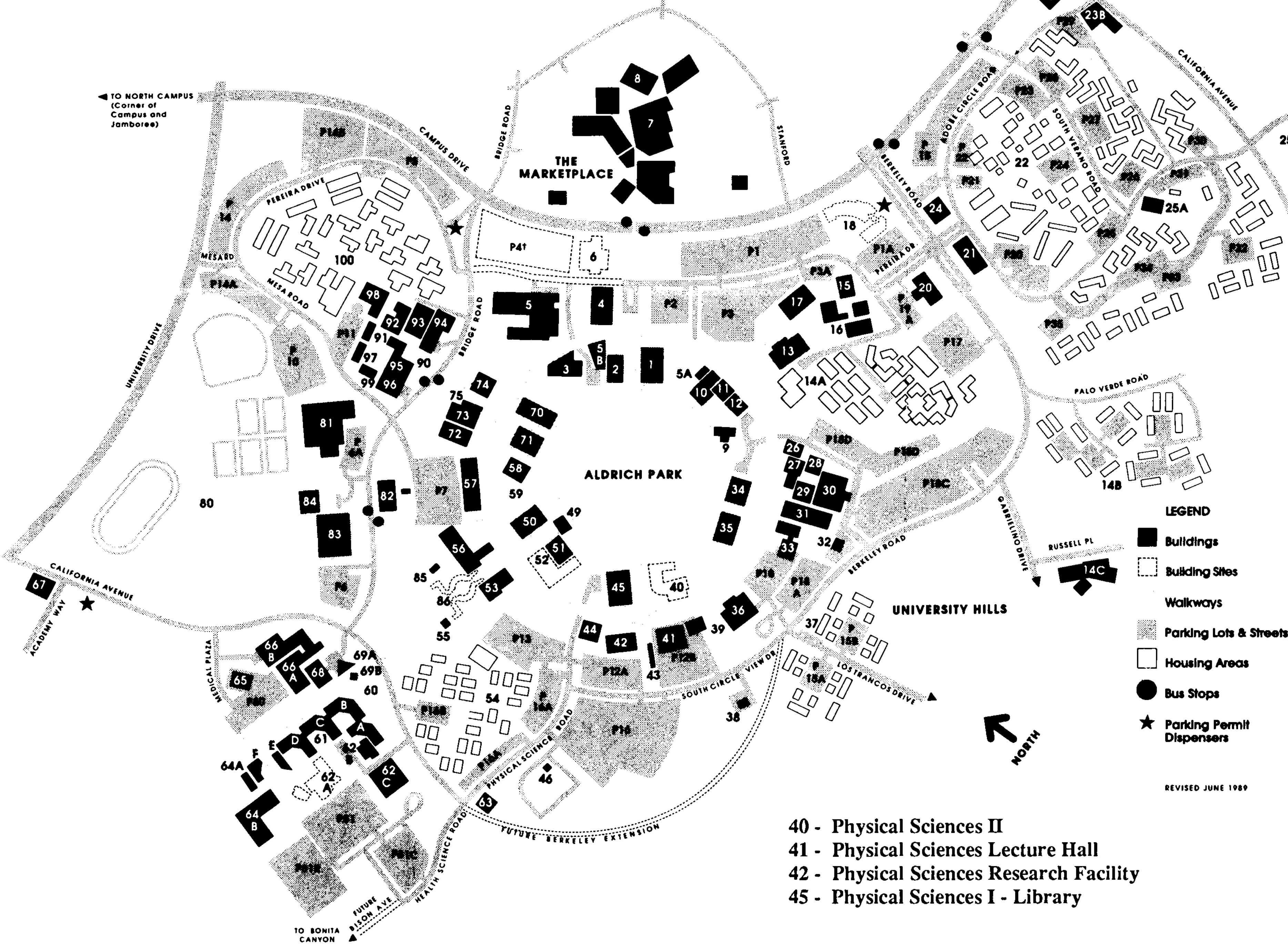
Food Service

On the UCI campus, lunch will be available at "Joe's on the Green," which serves hefty sandwiches, many flavors of pizza, pasta, beer, wine, etc. It will be open especially for the conference and service is expected to be excellent. For more formal dining, the "Market Place" across from Campus Boulevard has wonderful shops and at least four restaurants, one of them serving Chinese food.

Travel

There are two convenient airports to the conference: Los Angeles International Airport (LAX) and Orange County Airport (OCA)) also known as the **John Wayne Airport**. Shuttle service is available to UCI or to any of the hotels from OCA. There is also a convenient shuttle or bus service from LAX to OCA. For participants traveling by car to the campus, please see the following directions:
LAX to MacArthur Boulevard: When leaving LAX, take the Sepulveda exit. Stay in the right lane on Sepulveda until you see a sign that says **405 South**. Turn right at that corner and then immediately get in the left lane for the marker indicating the entrance to the freeway. After merging into the freeway traffic, drive (for approximately 45 minutes) until you see the exit across from OCA. The streets for Irvine include MacArthur Blvd, Jamboree, and Culver. Turn left on **MacArthur Blvd**, heading for the beach. Drive approximately five minutes past Jamboree and under a viaduct, to **University Ave** exit. At that point, you will see a sign for UCI; turn right and drive down the long exit ramp to the bottom of the hill. Turn right and enter the campus on the first street, **California Street**. Follow the signs to the parking Kiosk, the Sciences Complex and Parking Lot 12.

University of California, Irvine



40 - Physical Sciences II
41 - Physical Sciences Lecture Hall
42 - Physical Sciences Research Facility
45 - Physical Sciences I - Library

Parking

The UCI Physical Sciences Complex is located near a collection of large parking lots on Circle Drive. Principal among these is Parking Lot 12. There is no parking fee on Sunday. Kiosks for the parking stickers for Saturday are located at all three large entrance streets (California, Bridge, and Berkeley) to the University. Parking stickers are $4 for all day and $3 for half a day.

Weather and Local Attractions

The famous Southern California weather is characterized by warm breezes during the day—dare we say balmy—followed by cool exotic nights. Even in November, one can expect comfortable temperatures (75°F in the afternoon, 65°F in the evening). It is as advertised. The local attractions are of the nature of amusement park type: the renowned beaches (especially Main beach in Laguna Beach), the marsh lands tour on UCI campus, Disneyland, and Knotts Berry Farm (only 15 minutes from the campus). A special tour of the marsh lands has been arranged for Saturday, November 10, at 10:00 a.m. For the serious shopper, *Fashion Island* is the place to go. It is the closest thing in the UCI area to Rodeo Drive and it is much prettier. Finally, the search for quintessential Southern California ends at Balboa Island. This combines fantastic dining and viewing on an inlet.

Lance W. Small
Associate Secretary
La Jolla, California

Invited Speakers and Special Sessions

Invited Speakers at AMS Meetings

The individuals listed below have accepted invitations to address the Society at the times and places indicated. For some meetings, the list of speakers is incomplete.

Amherst, MA, October 1990

Christopher B. Croke
William M. Goldman
John J. Mallet-Paret
Henry P. McKean, Jr.

Denton, TX, November 1990

Avner D. Ash
Peter S. Constantin
John Luecke
Clarence W. Wilkerson

Irvine, CA, November 1990

Jennifer T. Chayes
Michael D. Fried
Nicholas J. Korevaar

San Francisco, CA, January 1991

Michael F. Atiyah (Gibbs Lecture)
Shiing S. Chern (AMS/MAA Lecture)
Rebecca A. Herb (AMS/MAA Lecture)
Maria M. Klawe
Robert D. MacPherson (Colloquium Lectures)
Grigorii Aleksandrovič Margulis
Frank Morgan (AMS/MAA Lecture)
George Daniel Mostow (Retiring Presidential Address)
Kenneth A. Ribet
Christel Rotthaus (AMS/AWM/MAA Lecture)
Héctor J. Sussmann

South Bend, IN, March 1991

Leonid G. Makar-Limanov
Donald G. Saari
Stephen D. Smith
Deane Yang

Tampa, FL, March 1991

Josefina Alvarez
Ronald A. DeVore
Michel L. Lapidus
Donald St. P. Richards

Orono, ME, August 1991

Richard M. Schoen (Progress in Mathematics Lecture)

Fargo, ND, October 1991

Ian D. Macdonald
Harald Upmeier
Henry C. Wente
Sylvia M. Wiegand

Baltimore, MD, January 1992

Michael E. Fisher (Gibbs Lecture)

Invited addresses at Sectional Meetings are selected by the Section Program Committee, usually twelve to eighteen months in advance of a meeting. Members wishing to nominate candidates for invited addresses should send the relevant information to the Associate Secretary for the Section who will forward it to the Section Program Committee.

Organizers and Topics of Special Sessions

The list below contains all the information about Special Sessions at meetings of the Society available at the time this issue of *Notices* went to the printer. The section below entitled **Information for Organizers** describes the timetable for announcing the existence of Special Sessions.

October 1990 Meeting in Amherst, Massachusetts
Eastern Section
Associate Secretary: W. Wistar Comfort
Deadline for organizers: Expired
Deadline for consideration: Expired

Colin C. Adams, *Hyperbolic manifolds*
M. K. Bennett and Garrett Birkhoff, *Lattices, geometry, and combinatorics*
Melvyn S. Berger and Robert A. Gardner, *Nonlinear dynamics in mathematics and science*
Haskell Cohen, *Semigroups*

William M. Goldman and Bernard Maskit, *Discrete groups and geometric structures in 2, 3 and 4 dimensions*
James E. Humphreys and Ivan Mirković, *Lie groups and algebraic groups*
Chjan C. Lim, *Algebraic graph theory*
V. S. Prasad, *Ergodic theory*
Charles Radin and Marjorie Senechal, *Aperiodicity and order*

November 1990 Meeting in Denton, Texas
Central Section
Associate Secretary: Andy R. Magid
Deadline for organizers: Expired
Deadline for consideration: Expired

Avner D. Ash and Mark S. Reeder, *Arithmetic groups*
Elizabeth M. Bator, Russell G. Bilyeu and Paul W. Lewis, *Banach spaces—functional analysis*
Ilya Bakelman, *Geometric inequalities and convex bodies*
Scott T. Chapman and Nick H. Vaughan, *Commutative algebra*
Daniel S. Freed, Robert F. Williams and Michael Wolf, *Texas topology and geometry*
Anant P. Godbole, *The probability theory of patterns and runs*
John Luecke and Robert Myers, *Low dimensional topology*
Lisa Mantini and Roger C. Zierau, *Representation theory of Lie groups*
John W. Neuberger and Henry A. Warchall, *Differential equations*
Peter F. Stiller, *Algebraic geometry*
Emil J. Straube, *Several complex variables*

November 1990 Meeting in Irvine, California
Western Section
Associate Secretary: Lance W. Small
Deadline for organizers: Expired
Deadline for consideration: Expired

Jennifer T. Chayes and Glen H. Swindle, *Probability theory in mathematical physics*
Paul C. Eklof, *Interactions between group theory and logic*
Michael D. Fried and Robert M. Guralnick, *Interactions between group theory and geometry/number theory*
Michael D. Fried and David Harbater, *Moduli space applications*
Abel Klein, *Quantum and statistical mechanics*
Nicholas J. Korevaar and Andrejs E. Treibergs, *Geometric p.d.e.'s: mean and scalar curvature problems*
Bernard Russo, *Operator theory/operator algebras*

January 1991 Meeting in San Francisco, California
Associate Secretary: Andy R. Magid
Deadline for organizers: Expired
Deadline for consideration: September 19, 1990

Alok Aggarwal and Maria M. Klawe, *Matrix searching, Monge arrays and Ackemann's inverse: algorithms and lower bounds*
Frederick J. Almgren, Albert Marden and Jean E. Taylor, *Computing optimal geometries*
William Beckner and J. Michael Pearson, *Geometric Fourier analysis*
Melvyn S. Berger, *Turbulence*
Bruce E. Blackadar, *C* - algebras and noncommutative topology*
Ed Dubinsky and James J. Kaput, *Research in undergraduate education* (AMS/MAA Session)
Naomi Fisher, Harvey B. Keynes and Philip D. Wagreich, *Mathematics and education reform* (AMS/MAA session)
John R. Graef and Jack K. Hale, *Oscillation and dynamics in delay equations*
Kevin A. Grasse and Héctor J. Sussmann, *Nonlinear control theory and related topics*
Helmut Groemer and Jane Yeager, *Analytical methods in convexity*
William B. Jacob, *Real algebraic geometry*
Victor J. Katz and David E. Rowe, *History of mathematics*
Esther R. Lamken, *Combinatorial design theory*
Kirk E. Lancaster, *Boundary behavior in partial differential equations*
M. Susan Montgomery and Earl J. Taft, *Hopf algebras*
David Mumford, *Automatic theorem proving*
Kenneth A. Ribet, *Arithmetical algebraic geometry*
Lester J. Senechal, *Research papers by undergraduates*
Antoinette Trembinska, *Entire function theory*

March 1991 Meeting in South Bend, Indiana
Central Section
Associate Secretary: Andy R. Magid
Deadline for organizers: Expired
Deadline for consideration: December 13, 1990

Jonathan L. Alperin and Stephen D. Smith, *Simplicial complexes associated to finite groups and their representations*
Steven A. Buechler, *Model theory*
Frank X. Connolly, *Geometric topology*
William G. Dwyer and Anthony D. Elmendorf, *Algebraic topology*
Gail R. Letzter, Peter Malcolmson and Frank Okoh, *Noncommutative ring theory*
John E. McCarthy, *Hilbert spaces of analytic functions*
Mohsen Pourahmadi, *Probability and prediction theory*

March 1991 Meeting in Tampa, Florida
Southeastern Section
Associate Secretary: Joseph A. Cima
Deadline for organizers: Expired
Deadline for consideration: December 13, 1990

Josefina Alvarez, *Harmonic analysis and applications*
Ronald A. DeVore, Edward B. Saff and B. Shektman, *Approximation theory*
David A. Drake, Chat Yin Ho and Geoffrey R. Robinson, *Finite groups and related topics*
Paul E. Ehrlich and Stephen J. Summers, *Differential geometry and mathematical physics*
Paul M. Gauthier, *Several complex variables*
Ladnor D. Geissinger, William H. Graves and L. Senechal, *Microcomputers and workstations in mathematics: teaching and research*
Joseph Glover and Arunava Mukherjea, *Nonlinear boundary value problems*
Michel L. Lapidus and Robert S. Strichartz, *Fractal and spectral geometry*
Sung J. Lee and Y. You, *Operator methods for control problems*
R. Kent Nagle and Mary E. Parrott, *Nonlinear boundary value problems*
John F. Pedersen, W. Edwin Clark, W. Richard Stark, Jospeh J. Liang and Gregory L. McColm, *Mathematical issues in biologically motivated computing*
Donald St. P. Richards, *Hypergeometric functions on domains of positivity, jack polynomials, and applications*

June 1991 Meeting in Portland, Oregon
Western Section
Associate Secretary: Lance W. Small
Deadline for organizers: September 13, 1990
Deadline for consideration: March 5, 1991

August 1991 Meeting in Orono, Maine
Associate Secretary: Joseph A. Cima
Deadline for organizers: November 15, 1990
Deadline for consideration: May 8, 1991

October 1991 Meeting in Philadelphia, Pennsylvania
Eastern Section
Associate Secretary: W. Wistar Comfort
Deadline for organizers: January 10, 1991
Deadline for consideration: July 11, 1991

October 1991 Meeting in Fargo, North Dakota
Central Section
Associate Secretary: Andy R. Magid
Deadline for organizers: January 25, 1991
Deadline for consideration: July 11, 1991

Joseph P. Brennan and Sylvia M. Wiegand, *Commutative algebra*
Dogan Comez, *Ergodic theory*
Kendall E. Nygard, *Operations research*
James H. Olsen and Mark Pavicic, *Mathematical foundations of computer graphics*
Warren E. Shreve, *Graph theory*
Vasant A. Ubhaya, *Approximation theory*
Harald Upmeier, *Multivariate operator theory in symmetric domains*

November 1991 Meeting in Santa Barbara, California
Western Section
Associate Secretary: Lance W. Small
Deadline for organizers: February 7, 1991
Deadline for consideration: August 20, 1991

January 1992 Meeting in Baltimore, Maryland
Associate Secretary: Lance W. Small
Deadline for organizers: April 8, 1991
Deadline for consideration: September 11, 1991

March 1992 Meeting in Tuscaloosa, Alabama
Southeast Section
Associate Secretary: Joseph A. Cima
Deadline for organizers: June 13, 1991
Deadline for consideration: To be announced

March 1992 Meeting in Springfield, Missouri
Central Section
Associate Secretary: Andy R. Magid
Deadline for organizers: June 26, 1991
Deadline for consideration: To be announced

June 1992 Meeting in Cambridge, England
Associate Secretary: Robert M. Fossum
Deadline for organizers: September 28, 1991
Deadline for consideration: To be announced

January 1993 Meeting in San Antonio, Texas
Associate Secretary: W. Wistar Comfort
Deadline for organizers: April 13, 1992
Deadline for consideration: To be announced

August 1993 Meeting in Vancouver, British Columbia, Canada
Associate Secretary: Lance W. Small
Deadline for organizers: November 11, 1992
Deadline for consideration: To be announced

January 1994 Meeting in Cincinnati, Ohio
Associate Secretary: Joseph A. Cima
Deadline for organizers: April 5, 1993
Deadline for consideration: To be announced

January 1996 Meeting in Orlando, Florida
Associate Secretary: Lance W. Small
Deadline for organizers: April 12, 1995
Deadline for consideration: To be announced

Information for Organizers

Special Sessions at Annual and Summer Meetings are held under the supervision of the Program Committee for National Meetings (PCNM). They are administered by the Associate Secretary in charge of that meeting with staff assistance from the Meetings and Editorial Departments in the Society office in Providence.

According to the "Rules for Special Sessions" of the Society, Special Sessions are selected by the PCNM from a list of proposed Special Sessions in essentially the same manner as Invited Speakers are selected. The number of Special Sessions at a Summer or Annual Meeting is limited. The algorithm that determines the number of Special Sessions allowed at a given meeting, while simple, is not repeated here, but can be found in "Rules for Special Sessions" on page 614 in the April 1988 issue of *Notices*.

Each Invited Speaker is invited to generate a Special Session, either by personally organizing one or by having a Special Session organized by others. Proposals to organize a Special Session are sometimes requested either by the PCNM or by the Associate Secretary. Other proposals to organize a Special Session may be submitted to the Associate Secretary in charge of that meeting (who is an *ex-officio* member of the committee and whose address may be found below). These proposals must be in the hands of the PCNM at least nine months prior to the meeting at which the Special Session is to be held in order that the committee may consider all the proposals for Special Sessions simultaneously. Proposals that are sent to the Providence office of the Society, to *Notices*, or directed to anyone other than the Associate Secretary will have to be forwarded and may not be received in time to be considered for acceptance.

It should be noted that Special Sessions must be announced in *Notices* in such a timely fashion that any member of the Society who so wishes may submit an abstract for consideration for presentation in the Special Session before the deadline for such consideration. This deadline is usually three weeks before the deadline for abstracts for the meeting in question.

Special Sessions are very effective at Sectional Meetings and can usually be accommodated. The processing of proposals for Special Sessions for Sectional Meetings is handled in essentially the same manner as for Annual and Summer Meetings by the Section Program Committee. Again, no Special Session at a Sectional Meeting may be approved so late that its announcement appears past the deadline after which members can no longer send abstracts for consideration for presentation in that Special Session.

The Society reserves the right of first refusal for the publication of proceedings of any Special Session. These proceedings appear in the book series *Contemporary Mathematics*.

More precise details concerning proposals for and organizing of Special Sessions may be found in the "Rules for Special Sessions" or may be obtained from any Associate Secretary.

Proposals for Special Sessions to the Associate Secretaries

The programs of Sectional Meetings are arranged by the Associate Secretary for the section in question:

Western Section
Lance W. Small, Associate Secretary
Department of Mathematics
University of California, San Diego
La Jolla, CA 92093
Electronic mail: g_small@math.ams.com
(Telephone 619-534-3590)

Central Section
Andy R. Magid, Associate Secretary
Department of Mathematics
University of Oklahoma
601 Elm PHSC 423
Norman, OK 73019
Electronic mail: g_magid@math.ams.com
(Telephone 405-325-6711)

Eastern Section
W. Wistar Comfort, Associate Secretary
Department of Mathematics
Wesleyan University
Middletown, CT 06457
Electronic mail: g_comfort@math.ams.com
(Telephone 203-347-9411)

Southeastern Section
Joseph A. Cima, Associate Secretary
Department of Mathematics
University of North Carolina, Chapel Hill
Chapel Hill, NC 27599-3902
Electronic mail: g_cima@math.ams.com
(Telephone 919-962-1050)

As a general rule, members who anticipate organizing Special Sessions at AMS meetings are advised to seek approval at least nine months prior to the scheduled date of the meeting. No Special Sessions can be approved too late to provide adequate advance notice to members who wish to participate.

Information for Speakers

A great many of the papers presented in Special Sessions at meetings of the Society are invited papers, but any member of the Society who wishes to do so may submit an abstract for consideration for presentation in a Special Session, provided it is received in Providence prior to the special early deadline announced above and in the announcements of the meeting at which the Special Session has been scheduled. Contributors should know that there is a limitation in size of a single Special Session, so that it is sometimes true that all places are filled by invitation. Papers not accepted for a Special Session are considered as ten-minute contributed papers.

Abstracts of papers submitted for consideration for presentation at a Special Session must be received by the Providence office (Editorial Department, American Mathematical Society, P. O. Box 6248, Providence, RI 02940) by the special deadline for Special Sessions, which is usually three weeks earlier than the deadline for contributed papers for the same meeting. The Council has decreed that no paper, whether invited or contributed, may be listed in the program of a meeting of the Society unless an abstract of the paper has been received in Providence prior to the deadline.

Electronic submission of abstracts is available to those who use the TEX typesetting system. Requests to obtain the package of files may be sent electronically via the Internet to **abs-request@math.ams.com.** Requesting the files electronically will likely be the fastest and most convenient way, but users may also obtain the package on IBM or Macintosh diskettes, available free of charge by writing to: Electronic Abstracts, American Mathematical Society, Publications Division, P.O. Box 6248, Providence, RI 02940, USA. When requesting the abstracts package, users should be sure to specify whether they want the plain TEX, AMS-TEX, or the LATEX package.

Number of Papers Presented
Joint Authorship

Although an individual may present only one ten-minute contributed paper at a meeting, any combination of joint authorship may be accepted, provided no individual speaks more than once. An author can speak by invitation in more than one Special Session at the same meeting.

An individual may contribute only one abstract by title in any one issue of *Abstracts*, but joint authors are treated as a separate category. Thus, in addition to abstracts from two individual authors, one joint abstract by them may also be accepted for an issue.

Site Selection for Sectional Meetings

Sectional Meeting sites are recommended by the Associate Secretary for the Section and approved by the Committee of Associate Secretaries and Secretary. Recommendations are usually made eighteen to twenty-four months in advance. Host departments supply local information, ten to twelve rooms with overhead projectors for contributed paper sessions and special sessions, an auditorium with twin overhead projectors for invited addresses, and registration clerks. The Society partially reimburses for the rental of facilities and equipment, and for staffing the registration desk. Most host departments volunteer; to do so, or for more information, contact the Associate Secretary for the Section.

Call for Topics For 1992 Conferences

Suggestions are invited from mathematicians, either singly or in groups, for topics of the various conferences that will be organized by the Society in 1992. Topics are still being accepted for the 1992 AMS-IMS-SIAM Joint Summer Research Conferences in the Mathematical Sciences and for the August 1992 Short Course Series. Individuals interested in proposing a topic should refer to the July/August issue of *Notices* for further information.

Joint Mathematics Meetings in San Francisco
AMS Special Sessions and Contributed Papers
MAA Contributed Papers

The Joint Mathematics Meetings in San Francisco will be held January 16–19 (Wednesday–Saturday), 1991. The first full announcement of the meeting will appear in the October 1990 issues of *Notices* and *Focus*. This preliminary announcement is made to encourage members' participation and to provide lead time for submission of abstracts for consideration in AMS Special Sessions and for submission of abstracts for AMS and MAA Contributed Paper Sessions.

AMS Special Sessions

A list of Special Sessions for this meeting can be found in the **Invited Speakers and Special Sessions Information** section of this issue.

Most of the papers to be presented at these Special Sessions will be by invitation; however, anyone contributing an abstract for the meeting who feels that his or her paper would be particularly appropriate for one of these sessions should indicate this clearly on the abstract, **and should submit it by September 19, 1990, three weeks earlier than the normal deadline for contributed papers,** in order that it be considered for inclusion.

Abstracts should be prepared on the standard AMS form available from the AMS office in Providence or in departments of mathematics and should be sent to Abstracts, Editorial Department, American Mathematical Society, Post Office Box 6248, Providence, Rhode Island 02940. A charge of $16 is imposed for retyping abstracts that are not in camera-ready form.

AMS Contributed Paper Sessions

Abstracts should be prepared on the standard AMS form available from the AMS office in Providence or in departments of mathematics and should be sent to Abstracts, Editorial Department, American Mathematical Society, Post Office Box 6248, Providence, Rhode Island 02940, **so as to arrive by the abstract deadline of October 10, 1990.** A charge of $16 is imposed for retyping abstracts that are not in camera-ready form. **Late papers will not be accepted.**

Participants planning to submit abstracts for AMS ten-minute contributed papers by the October 10 deadline should be sure to indicate on the abstract any special scheduling requests. Failing that, these requests should be communicated to the AMS Associate Secretary, Andy R. Magid, Department of Mathematics, University of Oklahoma, 601 Elm PHSC 423, Norman, OK 73019, Electronic mail: g_magid@math.ams.com, (Telephone 405–325–6711). These individuals should also be aware that, because of time and space limitations and an anticipated higher number of abstracts being submitted (based on the numbers submitting for meeting in San Francisco in the past), it may be necessary to schedule some sessions of AMS Contributed Papers on Thursday and Friday evenings, January 17 and 18.

Electronic Submission of AMS Abstracts

This service is available to those who use the TEX typesetting system and can be used for abstracts of papers to be presented at this meeting. Requests to obtain the package of files may be sent by electronic mail on the Internet to **abs-request@math.ams.com**. Requesting the files electronically will likely be the fastest and most convenient way, but users may also obtain the package on IBM or Macintosh diskettes, available free of charge by writing to: Secretary to Director of Publication, American Mathematical Society, Publications Division, P.O. Box 6248, Providence, RI 02940. When requesting the abstracts package, users should be sure to specify whether they want the plain TEX, AMS-TEX, or the LATEX package. Again, late papers will not be accepted.

MAA Contributed Papers

Contributed papers are being accepted on several topics in collegiate mathematics for presentation in contributed paper sessions at the meeting. The topics, organizers, their affiliations, and the days they will meet are:

- *Professional development for teachers of mathematics*, JOHN DOSSEY, Illinois State University, and ELIZABETH J. TELES, Montgomery College, Maryland. Wednesday and/or Thursday.

  This session is sponsored by the Committee on Faculty Development (John Dossey, chair). Papers are invited that describe departmental, system, state, regional, or sectional programs aimed at promoting continued faculty growth in mathematics or its teaching. Special consideration will be given to programs which are easily transported from one setting to another. Topics to be discussed can include, but are not limited to, the following: special faculty study programs, focused colloquia series, reading/study groups, teaching improvement programs, and the development and use of technological aids.

- *Statistics and probability*, SHELDON P. GORDON, Suffolk Community College, and FLORENCE S. GORDON, New York Institute of Technology. Friday and/or Saturday.

Contributed papers on any issue relating to statistics and probability courses in the mathematics curriculum are welcome. For instance, 1.) What are some innovative approaches to teaching these courses (such as the use of computers and other technology, simulations, exploratory data analysis or student "research" projects)? 2.) What does statistical literacy mean for liberal arts, science, mathematics, business or social science students? 3.) What statistical ideas are being introduced into the secondary curriculum and what are the implications for the undergraduate curriculum?

- *Alternatives to the lecture method*, JAMES R.C. LEITZEL, The Ohio State University. Friday and/or Saturday.

This session, sponsored by the Committee on the Mathematical Education of Teachers (COMET), will be devoted to classroom practices which provide alternatives to a strictly lecture approach. Papers are solicited which address strategies and techniques for classroom practice across a variety of topics in the undergraduate curriculum. Presentations which represent large and small class size and upper division as well as lower division courses are desired.

- *Humanistic mathematics*, ALVIN WHITE, Harvey Mudd College and Humanistic Math Network, MARILYN FRANKENSTEIN, University of Massachusetts, Boston, and JOAN COUNTRYMAN, Germantown Friends High School. Wednesday and/or Thursday

Contributions are invited that describe teaching, using, or creating mathematics as a humanistic discipline. The paper should describe the experience and its effect, if any, on the point of view. Philosophical and/or historical papers that contribute to mathematics as a humanistic discipline are also welcome.

- *Lesser known geometrical gems*, DON CHAKERIAN, University of California, Davis, RICHARD PFEIFER, San Jose State University, and JANE SANGWINE-YAGER, Saint Mary's College. Wednesday and/or Thursday

Contributed papers are invited which illustrate interesting but not widely known results which may be used by the teacher to enliven an upper division geometry course. These may include new insights and forgotten classics in geometry that deserve wider appreciation.

- *Using history in the teaching of mathematics*, DAVID E. ZITARELLI, Temple University. Friday and/or Saturday.

The history of mathematics is used in various ways to enrich and to teach mathematics. Papers in this session should address such uses in courses ranging from liberal arts courses for non-science majors to required courses for mathematics majors. Of particular interest are descriptions of history of mathematics courses, including graduate level courses and those designed for education majors.

Presentations are normally limited to ten minutes, although selected contributors may be given up to twenty minutes. Individuals wishing to submit papers for any of these sessions should send the following information to the MAA Washington office at 1529 Eighteenth Street, NW, Washington, DC 20036 **by September 25**:

1. A page giving the author's name, author's address, the intended session, and a one-paragraph abstract (for distribution at the meeting);
2. A one-page outline of the presentation.

Rooms where sessions of contributed papers will be held are equipped with overhead projector and screen. Blackboards are not available. Persons having other equipment needs should contact the MAA Associate Secretary (Kenneth A. Ross, Department of Mathematics, University of Oregon, Eugene, OR 97403) as soon as possible, but in any case **prior to November 16**. Upon request, the following will be made available: one additional overhead projector/screen, 35mm carousel slide projector, 16mm film projector, or VHS video cassette recorder with a color monitor.

Mathematical Sciences Meetings and Conferences

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 or symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. (Information on meetings of the Society, and on meetings sponsored by the Society, will be found inside the front cover.)
AN ANNOUNCEMENT will be published in *Notices* if it contains a call for papers, and specifies the place, date, subject (when applicable), and the speakers; a second full 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 each 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 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 *Notices*, care of the American Mathematical Society in Providence.
DEADLINES for entries in this section are listed on the inside front cover of each issue. 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 *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.
EFFECTIVE with the 1990 volume of *Notices*, the complete list of Mathematical Sciences Meetings and Conferences will be published only in the September issue. In all other issues, only meetings and conferences for the twelve-month period following the month of that issue will appear. As new information is received for meetings and conferences that will occur later than the twelve-month period, it will be announced at the end of the listing in the next possible issue. That information will not be repeated until the date of the meeting or conference falls within the twelve-month period.

1990. **IMACS International Workshop on Massively Parallel Methods in Computational Physics**, Boulder, Colorado. (Sep. 1989, p. 914)

1990. **IMACS Conference on Computer Aided Design**, Yugoslavia. (Sep. 1989, p. 914)

1990. **CWI-IMACS Symposia on Parallel Scientific Computing**, Amsterdam, The Netherlands. (Feb. 1990, p. 216)

1990. **Concentration Year on Stochastic Models, Statistical Methods, and Algorithms in Image Analysis**, Rome, Italy. (Apr. 1990, p. 491)

1990–1991. **Academic Year Devoted to Operator Theory and Complex Analysis**, Mittag-Leffler Institute, Djursholm, Sweden. (Dec. 1989, p. 1432)

September 1990

13–18. **The Marshall Hall 80th Birthday Conference on Coding Theory, Design Theory and Group Theory**, University of Vermont, Burlington, VT. (May/Jun. 1990, p. 608)

16–22. **Ankündigung der Jahrestagung 1990**, Universität Bremen, Bremen, W. Germany. (May/Jun. 1990, p. 609)

16–22. **Risikotheorie**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

16–22. **Algebraic Methods in Computing Science**, University College of Swansea, Swansea, Wales. (Jul./Aug. 1990, p. 738)

17–21. **Atelier International de Theorie des Ensembles**, Marseille, France. (Jan. 1990, p. 60)

17–22. **DMV-Jahrestagung 1990**, Bremen, Federal Republic of Germany. (Jul./Aug. 1989, p. 769)

19–21. **Third IMACS International Conference on Modelling and Simulation of Electrical Machines and Static Converters**, ENSEM - Nancy, France. (May/Jun. 1990, p. 609)

23–29. **Random Graphs and Combinatorical Structures**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

24–28. **Structure Galoisienne Arithmetique**, Marseille, France. (Jan. 1990, p. 60)

24–28. **IMACS-GAMM International Symposium on Computer Arithmetic, Scientific Computation and Mathematical Modelling - SCAN 1990**, Albena (near Varna), Bulgaria. (Feb. 1990, p. 225)

24–28. **International Symposium on Structures in Mathematical Theories**, San Sebastian, Espagna. (May/Jun. 1990, p. 609)

24–29. **Mathematical Modelling of Industrial Processes**, Tecnopolis, Bari. (Feb. 1990, p. 225)

24–30. **Ibero-American Conference**, Seville, Spain. (Apr. 1990, p. 497)

25–29. **International Symposium on Structures in Mathematical Theories**, San Sebastián, Spain. (Apr. 1990, p. 497)

27–29. **Topology and Geometry of Manifolds**, Bologna, Italy. (May/Jun. 1990, p. 609)

28–29. **Linear Algebra and its Applications**, Miami University, Oxford, OH. (Apr. 1990, p. 497)

30–October 6. **Diophantische Approximationen**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

October 1990

1–4. **Third European Conference on**

Multigrid Methods, Bonn, Federal Republic of Germany. (Jul./Aug. 1990, p. 739)

1–5. **Organisations et Theorie des Jeux**, Marseille, France. (Jan. 1990, p. 60)

1–5. **Third Joint Europe/U.S. Short Course in Hypersonics**, RWTH Aachen Univ. of Technology, Federal Republic of Germany. (Mar. 1990, p. 332)

1–5. **Methodes D'Elements Finis Mixtes**, Roquencourt, France. (Jul./Aug. 1990, p. 739)

5–6. **Math-History Conference**, LaCrosse, WI. (Jan. 1990, p. 60)

5–7. **Workshop on Partial Differential Equations**, Cornell Univ., Ithaca, NY. (Mar. 1990, p. 332)

5–8. **Second Annual SUNYA Conference on Topology and Group Theory**, State University of New York at Albany. (Jul./Aug. 1990, p. 739)

7–13. **Arbeitsgemeinschaft Mit Aktuellem Thema**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

8–12. **Congres Franco-Sovietique de Programmation Mathematique**, Marseille, France. (Jan. 1990, p. 60)

* 12–13. **IMA Workshop: Connecting to Industry**, University of Minnesota, Minneapolis, MN.

PROGRAM: The workshop will include presentation of problems by A. Friedman, P. Castro (Eastman Kodak), G. McDonald (General Motors) and others, and round table discussions on how mathematicians can form interactions with industry.
INFORMATION: Institute for Mathematics and Its Applications, University of Minnesota, 514 Vincent Hall, 206 Church St. S.E., Minneapolis, MN 55455; (612)624-6066.

14–20. **Geometrie**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

15–19. **Modeles pour L'Analyse des Donnees Multidimensionnelles**, Marseille, France. (Jan. 1990, p. 60)

15–19. **Tercer Congreso Nacional de Matemáticas**, San José, Costa Rica. (Feb. 1990, p. 225)

* 15–19. **IMA Workshop: Shocked Induced Transitions and Phase Structures in General Media**, University of Minnesota, Minneapolis, MN.

PROGRAM: This workshop will focus on the thermodynamics and mechanics of dynamic phase transitions that are mainly inertially driven.
ORGANIZERS: R. Fosdick, E. Dunn, and M. Slemrod.
INFORMATION: Institute for Mathematics and Its Applications, University of Minnesota, 514 Vincent Hall, 206 Church St., S.E., Minneapolis, MN 55455-0436; 612-624-6066.

18–21. **Sixteenth Annual Convention of the American Mathematical Association of Two-Year Colleges**, Dallas, TX. (May/Jun. 1990, p. 609)

19. **International Meeting on Nonlinear Dynamics in Mathematics & Science**, University of Massachusetts at Amherst. (Please note addition to invited speaker list from Jul./Aug. 1990, p. 739)

INVITED SPEAKERS: England: J.T. Stuart, J. Toland, L.E. Fraenkel; U.S.S.R.: V.I. Judovitch, O.A. Ladyhenskaya, A. Dubroischin; Japan: H. Matano; U.S.A.: H. McKean, A. Polyakov, R. Coifman, C. Jones, G. Knightly, C. Foias, R. Devaney, N. Kopell.

19–20. **Nineteenth Midwest Conference on Differential and Integral Equations**, Univ. of Missouri-Rolla, Rolla, MO. (Apr. 1990, p. 498)

19–20. **Twelfth Midwest Probability Colloquium**, Northwestern University, Evanston, IL. (May/Jun. 1990, p. 610)

19–20. **1990 Mathematical Sciences Department Chairs Colloquium**, Arlington, VA. (Jul./Aug. 1990, p. 739)

20–21. **Eastern Section**, University of Massachusetts at Amherst, Amherst, MA.

INFORMATION: W. Drady, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

21–27. **Mathematische Methoden In Der Robotik**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

21–27. **Arithmetik der Körper**, Oberwolfach, Federal Republic of Germany. (Oct. 1989, p. 1098)

21–27. **International Functional Analysis Meeting on the Occasion of the Sixtieth Birthday of Professor M. Valdivia**, Peñiscola, Spain. (May/Jun. 1990, p. 610)

21–27. **Algebraic and Combinatorial Problems in Multivariate Approximation Theory**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 740)

22–24. **Thirty-first Annual Foundations of Computer Science**, St. Louis, MO. (Jul./Aug. 1990, p. 740)

22–25. **Fifth Jerusalem Conference on Information Technology (JCIT-5)**, Jerusalem, Israel. (Jan. 1990, p. 60)

22–26. **Journées de Probabilités**, Marseille, France. (Jul./Aug. 1990, p. 740)

* 23–26. **Visualization '90**, San Francisco, CA.

PROGRAM: The conference will explore how visualization is being used to extract knowledge from data. It is concerned with all aspects of visualization, with a focus on interdisciplinary techniques. It will allow a dialogue to occur between the developers of visualization methods and visualization users across the full spectrum of science, engineering, and business.
KEYNOTE SPEAKER: Gordon Bell, Stardent Corporation.
INFORMATION: Visualization '90, The IEEE Computer Society, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1903.

24–26. **Fifth Annual Conference of the Midwest College Learning Center Association - Breaking Barriers to Learning**, Milwaukee, WI. (Jul./Aug. 1990, p. 740)

* 26–27. **Seventh Auburn Miniconference on Real Analysis**, Auburn University, AL.

PROGRAM: Principle speakers will deliver hour addresses and there will be two days of sessions for contributed 20-minute talks.
INVITED SPEAKERS: M.E. Rudin and W. Rudin of the Univ. of Wisconsin, Madison.
INFORMATION: J. Brown (205-844-6595) or G. DeSouza (205-844-6565 or gdesouza@auducvax.bitnet), Division of Mathematics, Auburn Univ., AL 36849-5310.

26–27. **Statistical Mechanics at the 45th Parallel: Fourth Annual Meeting**, Université de Montréal, Canada. (Feb. 1990, p. 226)

26–28. **Twenty-first U.S.L. Mathematics Conference (Algebra)**, University of Southwestern Louisianna, Lafayette, LA. (May/Jun. 1990, p. 610)

28–November 1. **North American Conference on Logic Programming 1990 (NACLP '90)**, Austin, TX. (Jul./Aug. 1990, p. 740)

28–November 3. **Mathematical Economics**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

29–November 2. **Trieste Conference on Integrable Systems**, Trieste, Italy. (Jan. 1990, p. 61)

29–November 2. **Algorithme Parallele et Architectures Nouvelles**, Marseille, France. (Jan. 1990, p. 61)

29–November 2. **The International Conference "D-Modules and Microlocal Geometry"**, Lisbon, Portugal. (Mar. 1990, p. 333)

29–November 16. **Workshop on Mathematical Ecology**, Trieste, Italy. (Jan. 1990, p. 61)

31–November 3. **Latinamerican Seminar on Applications of Mathematics and Computer Science to Biology**, La Habana, Cuba. (Feb. 1990, p. 226)

November 1990

2–3. **Central Section Meeting of the AMS**, University of North Texas, Denton, TX.

INFORMATION: W. Drady, AMS, P.O. Box 6248, Providence, RI 02940.

*2–3. **Fifth Annual Pi Mu Epsilon Regional Undergraduate Mathematics Conference**, St. Norbert College, DePere, WI.

INVITED SPEAKER: J. LaDuke, DePaul University.

INFORMATION: R. Poss, St. Norbert College, DePere, WI 54115; 414-337-3198.

4–10. **Wahrscheinlichkeitsmaße auf Gruppen**, Oberwolfach, Federal Republic of Germany. (Oct. 1989, p. 1098)

5–7. **Mathematiques Informatique**, Marseille, France. (Jul./Aug. 1990, p. 740)

5–8. **Second SIAM Conference on Linear Algebra in Signals, Systems & Controls**, San Francisco, CA. (Jul./Aug. 1990, p. 740)

6–7. **1990 ACM Conference on Critical Issues**, Arlington, VA. (Apr. 1990, p. 498)

*7–8. **Third Annual Conference on Mathematical Models for Psychotherapy Research**, Nathan Kline Institute for Psychiatric Research, New York.

PURPOSE: This conference will discuss exciting new problems in the topological and dynamic analysis of trajectories and surfaces in n-dimensional spaces (n > 4) which have arisen in quantifying psychotherapy research data. This research has successfully used mathematical physics, stochastic processes, and information theory to identify natural laws of human communication.

PROGRAM: 1). Overview of the research, its origin and purpose. 2). Results to date. 3). Invited papers. 4). The frontier.

CALL FOR PAPERS: Papers on the use of methods from functional analysis, topology, dynamical systems theory, chaos theory–or other fruitful domains–for studying vector time series (lengths 300-3500) of behavioral data will be considered.

INFORMATION: A.F. Badalamenti or R.J. Langs, The Nathan Kline Institute, Old Orangeburg Rd., Orangeburg, NY 10962; 914-365-2000, exts. 1646 & 1652.

9–11. **Third Annual Conference on Technology in Collegiate Mathematics**, The Ohio State Univ., Columbus, OH. (Mar. 1990, p. 333)

10. **Differential Geometry Day**, Eastern Illinois University, Charleston, IL. (Apr. 1990, p. 498)

10–11. **Far Western Section**, University of California, Irvine, CA.

INFORMATION: W. Drady, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

12–16. **Supercomputing '90**, New York, NY. (Sep. 1989, p. 920)

12–16. **Workshop on Representations of Reductive Groups over Finite Fields**, Mathematical Sciences Research Institute, Berkeley, CA. (Jan. 1990, p. 61)

12–16. **Supercomputing '90**, New York, NY. (Jul./Aug. 1990, p. 740)

*12–16. **IMA Workshop on Microstructure and Phase Transition**, University if Minnesota, Minneapolis, MN.

PROGRAM: The emphasis will be the discussion of phase transitions, defect structures and metastability, especially in solids, from the viewpoint of experiment, constitutive theory, and the development and use of numerical results to reconcile experiment with theory.

ORGANIZERS: D. Kinderlehrer, R. James, J.L. Ericksen, and M. Luskin.

INFORMATION: Institute for Mathematics and Its Applications, University of Minnesota, 514 Vincent Hall, 206 Church St., S.E., Minneapolis, MN 55455-0436; 612-624-6066.

16–17. **Tenth Annual Southeastern-Atlantic Regional Conference on Differential Equations**, Virginia Polytechnic Institute and State University, Blacksburg, VA. (May/Jun. 1990, p. 610)

18–24. **Komplexitätstheorie**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

19–22. **Huygens' Principle 1690-1990, Theory and Applications**, Scheveningen, The Hague, The Netherlands. (May/Jun. 1990, p. 610)

21–23. **Colloque Franco-Belge de Statistique**, Marseille, France. (Jul./Aug. 1990, p. 740)

25–28. **Mathematics and its Applications**, University of Bahrain, State of Bahrain. (May/Jun. 1990, p. 610)

25–December 1. **Stochastische Approximation Und Optimierungsprobleme In Der Statistik**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

25–December 1. **Lineare Modelle und Multivariate Statistische Verfahren**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1989, p. 769)

26–30. **Seminaire Sud-Rhodanien de Geometrie Differentielle**, Marseille, France. (Jul./Aug. 1990, p. 741)

December 1990

2–8. **Multigrid Methods**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

3–5. **First International Symposium on Uncertainty and Analysis: Fuzzy Reasoning, Probabilistic Methods and Risk Management**, College Park, Maryland. (Oct. 1989, p. 1098)

3–7. **Sixteenth Australasian Conference on Combinatorial Mathematics and Combinatorial Computing**, Palmerston North, New Zealand. (Feb. 1990, p. 226)

3–7. **SINO-JAPANESE Joint Seminar on Nonlinear PDEs with Emphasis on Reaction-Diffusion Aspects.**, Taipei, Taiwan. (Jan. 1990, p. 61)

3–7. **Workshop on General Group Representation Theory**, Mathematical Sciences

Research Institute, Berkeley, CA. (Jan. 1990, p. 61)

*9–11. **Canadian Mathematical Society Winter Meeting**, University of Waterloo, Ontario.

INVITED SPEAKERS: P. Hanlon, Michigan; N. Kopell, Boston; S. Lichtenbaum, Cornell; S. Semmes, Rice; D. Voiculescu, Berkeley; A. Gleason, Harvard.
SPECIAL SESSIONS: Algebraic combinatorics (I. Goulden, Waterloo); nonlinear oscillations (J. Belair, Montreal; W. Langford, Guelph); algebraic k-theory (R. Jardine, Western); harmonic analysis (E. Sawyer, McMaster); operator algebras (K. Davidson, Waterloo; I. Putnam, Dalhousie); mathematical education (T. Davison, McMaster).
INFORMATION: C. Riehm, Chairman of Scientific Committee, McMaster University, 416-525-9140, ext. 3415; email: riehm@mcmaster.ca; F. Zorzitto, Local Organizer, Univ. of Waterloo, 519-888-4073, email: puremath@water.waterloo.edu.

*9–14. **International Conference on Mathematical Theory of Control**, I.I.T. Bombay.

ORGANIZING COMMITTEE: S.D. Agashe, V.V. Athani, U.B. Desai, M.C. Joshi (Chair), M.M. Kulkarni, K.P. Madhavan, M.C. Srisailam, M. Vidyasagar.
CONFERENCE TOPICS: System theory: linear and nonlinear; optimal control theory: ordinary differential equations as well as partial differential equations; stochastic filtering and control theory: including stochastic partial differential equations; frequency domain theory: including H^∞ theory; computational techniques in control and optimization.
INFORMATION: M.C. Joshi, Chairman, Organizing Committee, Dept. of Math., I.I.T. Bombay - 400076; Tel: 5141421; Fax: (91)22-5141880 or A.V. Balakrishnan, Chairman, International Programme Committee, Dept. of Elect. Eng. & Math., U.C.L.A., California 90024; 213-825-2180; Fax: 213-206-8495.

9–15. **Allgemeine Ungleichungen**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

11–12. **Integral Valued Polynomials Encounter**, CIRM, Marseille, France. (Jul./Aug. 1990, p. 741)

11–13. **Third Joint IFSA-EC and EURO-WG Workshop on Fuzzy Sets**, Visegrád, Hungary. (May/Jun. 1990, p. 611)

15–19. **Curves and Surfaces: An Algorithmic Viewpoint**, Kent State Univ., Kent, OH. (Apr. 1990, p. 499)

16–22. **Mathematische Logik**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

17–21. **Non-linear Dispersive Wave Systems**, Univ. of Central Florida, Orlando, FL. (Apr. 1990, p. 499)

*17–21. **International Conference on Theory of Differential Equations and Applications to Oceanography**, Goa University, Bamboli, St. Cruz, India.

PROGRAM: The increasing aximonatization and algebraization of modern mathematics makes the theory of differential equations almost totally unintelligible to a scientist concerned with solving equations occuring in his investigations. This has led to a parting of ways. The conference is an attempt at ameliorating this situation by bringing together experts in the theory of differential equations and theoretical physical oceanographers.
INVITED SPEAKERS: V. Lakshmikantham (Florida, U.S.A.); K. Deimling (Pederborn, F.R.G.); A. Robinson (Harvard, U.S.A.); G.M. Reznik (Moscow, U.S.S.R.); M.K.V. Murthy (Pisa, Italy); M.P. Singh (New Deli, India); E. Roxin (Rhode Island, U.S.A.); E. Zalesni (Moscow, U.S.S.R.); P. Prasad (Bangalore, India); D.K. Sinha (Calcutta, India).
INFORMATION: Goa Univ., Dept. of Math. Sci., Bambolim, St. Cruz P.O., Goa 403 005, India.

25–January 1. **Lineare Modelle Und Multivariate Statistische Verfahren**, Oberwolfach, Federal Republic of Germany. (Apr. 1989, p. 498)

27–31. **Holiday Symposium on Recent Developments in Homotopy Theory**, New Mexico State Univ., Las Cruces, NM. (Jul./Aug. 1990, p. 741)

1991. **IMACS Symposium on Parallel and Distributed Computing in Engineering Systems**, Athens, Greece. (Jul./Aug. 1990, p. 741)

Spring 1991. **IMACS International Symposium on Iterative Methods in Linear Algebra**, Brussels Free Univ., Brussels, Belgium. (Mar. 1990, p. 334)

January 1991

6–12. **Automorphe Formen und Anwendungen**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 499)

7–9. **SIAM Workshop on Automatic Differentiation of Algorithms: Theory, Implementation, and Application**, Breckenridge, CO. (Jul./Aug. 1990, p. 741)

7–10. **Sixth Caribbean Conference in Combinatorics and Computing**, University of the West Indies, St. Augustine, Trinidad. (Jan. 1990, p. 61)

13–19. **Combinatorical Optimization**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 499)

14–15. **AMS Short Course on "Probabilistic Combinatorics and its Applications"**, San Francisco, CA.

INFORMATION: D. Plante, AMS, P.O. Box 6248, Providence, RI 02940.

16–19. **Joint Mathematics Meetings**, San Francisco, CA. (including the annual meetings of the AMS, AWM, MAA, and NAM)

INFORMATION: H. Daly, AMS, P.O. Box 6248, Providence, RI 02940.

*20. **Informal Workshop on the Teaching of Calculus**, San Francisco, CA

INFORMATION: G. Strange, Room 2-240, Massachusetts Institute of Technology, Cambridge, MA 02139.

20–26. **Spektraltheorie Singulärer Gewöhnlicher Differentialoperatoren**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 499)

*21–25. **IMA Workshop on Statistical Thermodynamics and Differential Geometry of Microstructured Material**, University of Minnesota, Minneapolis, MN.

PROGRAM: The purpose is to bring together researchers interested in the generation of statistical mechanical free energy theories which predict the appearance of the various microstructures, in the development of the topological and geometrical methods needed for a mathematical description of the subparts and dividing, surfaces of heterogeneous materials, and in the development of modern computer-aided mathematical models and graphics for effective exposition of the salient features of microstructures materials.

ORGANIZERS: H.T. Davis, J.C.C. Nitsche.

INFORMATION: Institute for Mathematics and Its Applications, University of Minnesota, Minneapolis, MN 55455-4036; 612-624-6066.

27–February 2. **Harmonische Analyse und Darstellungstheorie Topologischer Gruppen**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 499)

28–30. **Second ACM-SIAM Symposium on Discrete Algorithms**, San Francisco, CA. (Jul./Aug. 1990, p. 741)

February 1991

3–9. **Konstruktive Methoden in der Komplexen Analysis**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 499)

*4–8. **Winter School on Infinite Dimensional Differential Geometry**, Wien, Austria.

PROGRAM: The mornings will be devoted to lectures by A.A. Kirillov, G.I. Ol'šanskii, and V. Schechtmann. The afternoons will be devoted to lectures by other participants. Participants are expected to pay a fee of öS 500.- which will be used to support the stay of mathematicians from eastern countries. Students and mathematicians from eastern countries may participate freely.

INFORMATION: P.W. Michor, Institute für Mathematik, Univ. Wien, Strudlhofgasse 4, A-1090 Wien, Austria; email: michor@awirap.bitnet.

10–16. **Endlichdimensionale Lie-Algebren**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 499)

10–16. **Affine Differentialgeometrie**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 499)

17–23. **Experimentelle, Insbesondere Computergraphische Methoden in der Mathematik**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 742)

17–23. **Krein Spaces and Applications to Differential Operators**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 742)

24–March 2. **Medical Statistics: Statistical Models for Longitudinal Data**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 500)

25–March 1. **IEEE Computer Society COMPCON Spring '91**, San Francisco, CA. (Jan. 1990, p. 62)

March 1991

3–9. **Partielle Differentialgleichungen**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 500)

*4–15. **Workshop on Mathematical Physics and Geometry**, Trieste, Italy.

ORGANIZERS: X. Gomez Mont (C.I.M.A.T., Guanajuato/U.N.A.M., Mexico City), M.S. Narasimhan (T.I.F.R., Bombay).

INFORMATION: International Centre for Theoretical Physics, I.C.T.P., P.O. Box 586, 34100 Trieste, Italy.

5–7. **Association for Computing Machinery 1991 Computer Science Conference**, San Antonio Convention Center, San Antonio, TX. (May/Jun. 1990, p. 611)

7–8. **Twenty-second ACM SIGCSE Technical Symposium on Education in the Computing Sciences**, San Antonio, TX. (May/Jun. 1990, p.612)

7–10. **International Conference on Differential Equations**, Cadi Ayyad University, Marrakech, Morocco. (May/Jun. 1990, p.612)

10–16. **Mathematische Stochastik**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 500)

11–15. **NSF-CBMS Regional Research Conference on Nonlinear Dispersive Wave Systems**, University of Central Florida, Orlando, FL. (Jul/Aug. 1990, p. 742)

*11–15. **IMA Workshop on Free Boundaries in Viscous Flows**, University of Minnesota, Minneapolis, MN.

PROGRAM: Viscous flows interact with liquid/fluid interfaces and solidification fronts in a wide variety of technologies including the processing of coatings, polymers, semiconductors single crystals and other advanced materials. This workshop addresses the mathematical treatment of the dynamical and instability phenomena in such flows.

ORGANIZERS: R. Brown, S. Davis, S. Kistler.

INFORMATION: Institute for Mathematics and Its Applications, University of Minnesota, 514 Vincent Hall, 206 Church St., S.E., Minneapolis, MN 55455-0436; 612-624-6066.

13–15. **IMACS Workshop on Decision Support Systems and Qualitative Reasoning**, LAAS-Toulouse, France. (May/Jun. 1990, p. 612)

*13–16. **Twenty-Second Annual Iranian Mathematics Conference**, Ferdowsi University of Mashhad, Iran.

INFORMATION: M.R.R. Moghaddam, Dept. of Math., Faculty of Science 2, P.O. Box 1159, Mashhad Univ., Mashhad 91775-Iran; telex: 512271 FUOM IR.

*14–16. **Sixth S.E.A. Meeting, Southeastern Approximation Theorists Annual Meeting**, Memphis State Univ., Memphis, TN. (Please note date change from Mar. 1990, p. 334)

16–17. **Central Section**, Indiana University, South Bend, IN.

INFORMATION: W. Drady, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

17–23. **Elementare und Analytische Zahlentheorie**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 500)

17–24. **Sixth International Conference on Geometry**, University of Haifa, Israel. (May/Jun. 1990, p. 612)

22–23. **Southeastern Section**, University of South Florida, Tampa, FL.

INFORMATION: W. Drady, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

22–24. **Fifth SIAM Conference on Parallel Processing for Scientific Computing**, Houston, TX. (Mar. 1990, p. 334)

24–30. **Gewöhnliche Differentialgleichungen**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 500)

25–27. **Fifth SIAM Conference on Parallel Processing for Scientific Computing**, Houston, TX. (Jul./Aug. 1990, p. 742)

25–28. **International Conference on Mathematical Linguistics - ICML '91**, Barcelona, Spain. (Jul./Aug. 1990, p. 742)

31–April 6. **Arbeitsgemeinschaft mit Aktuellum Thema**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 500)

April 1991

2-4. **IMACS International Symposium on Iterative Methods in Linear Algebra**, Brussels Free Universities, Belgium. (May/Jun. 1990, p. 612)

7-13. **Algebraische Gruppen**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 500)

8-12. **Seventh International Conference on Data Engineering**, Kobe, Japan. (Apr. 1990, p. 500)

8-12. **NASECODE VII, The Seventh International Conference on the Numerical Analysis of Semiconductor Devices and Integrated Circuits**, Copper Mountain, Colorado. (May/Jun. 1990, p. 612)

10-12. **Fourth International Conference on Rewriting Techniques and Applications (RTA-91)**, Como, Italy. (Jul./Aug. 1990, p. 743)

* 11-16. **Assessment in Mathematics Education and Its Effects**, Calonge (Costa Brava), Spain.

PROGRAM: One of the objectives is to provide background for a volume on assessment in the series of ICMI Studies.
INFORMATION: M. Niss, IMFUFA, Roskilde Univ., P.O. Box 260, DK 4000 Denmark, Tel: +45 46757711 ext. 2266; Fax: +45 46755065; or C. Alsina, Secció Matemàtiques, ETSAB, Univ. Politècnica de Catalunya, Diagonal 649, E 08028 Barcelona, Spain.

14-20. **Brauer Groups and Representation Theory of Finite Groups**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 500)

* 15-19. **IMA Workshop on Variational Problems**, University of Minnesota, Minneapolis, MN.

PROGRAM: Variational methods have been very successful in the study of a great variety of practical and theoretical problems. One aim of the workshop is to highlight new methods directions and problems in variational and free boundary theory. Some examples of topics include noncoercive variational and quasi-variational contact problems, free boundary problems with surface tension in nonvariational form, new variational formulations and approximations to problems in plasma physics.
ORGANIZERS: A. Friedman, J. Spruck.
INFORMATION: Institute for Mathematics and Its Applications, University of Minnesota, 514 Vincent Hall, 206 Church St., S.E., Minneapolis, MN 55455-0436; 612-624-6066.

* 18-20. **Determinantal Ideals and Representation Theory**, University of Arkansas, Fayetteville, Arkansas.

PRINCIPLE SPEAKER: D.A. Buchsbaum, Brandeis University.
CALL FOR PAPERS: Contributed papers should be submitted before February 15, 1991.
INFORMATION: J. Duncan or I. Monroe, Dept. of Mathematical Sciences, SCEN 301, Univ. of Arkansas, Fayetteville, AR 72701.

21-27. **Numerical Linear Algebra**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 743)

23-26. **Mathematical and Numerical Aspects of Wave Propagation Phenomena**, Strasbourg, France. (Jul./Aug. 1990, p. 743)

28-May 4. **Deductive Systems**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 501)

May 1991

May/June 1991. **IMACS Workshop on Decision Support Systems and Qualitative Reasoning**, Toulouse, France. (Mar. 1990, p. 334)

* 2-3. **Twenty-Second Annual Pittsburgh Conference on Modeling and Simulation**, University of Pittsburgh, PA.

CONFERENCE TOPICS: Microprocessors, personal computer applications and software, artificial intelligence, expert systems, robotics and all aspects of control theory and applications, as well as social, economic, geography, regional science, and global modeling and simulation.
CALL FOR PAPERS: Special sessions are planned on microprocessors in education. Only papers not published previously will be considered. These papers should describe significant contributions which add to the knowledge in a particular area or which describe progress of research currently being conducted. Two copies of titles, authors, all author's addresses, abstracts and summaries should be submitted by January 31, 1991. The abstract should be approximately 50 words in length and the summary should be of sufficient length and detail to permit careful evaluation.
INFORMATION: W.G. Vogt or M.H. Mickle, Modeling and Simulation Conference, 348 Benedum Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15261.

5-11. **Darstellungstheorie Endlich-Dimensionaler Algebren**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 743)

6-8. **Fifth SIAM International Symposium on Domain Decomposition Methods for Partial Differential Equations**, Norfolk, VA. (Jul./Aug. 1990, p. 743)

7-10. **IMACS Symposium on Modelling and Simulation of Control Systems**, Casablanca, Morocco. (Mar. 1990, p. 334)

7-14. **Singapore Number Theory Workshop**, National Univ. of Singapore, Kent Ridge, Singapore. (Jul./Aug. 1990, p. 743)

12-18. **Nichtlineare Evolutionsgleichungen**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 501)

13-17. **Conference in Harmonic Analysis in Honor of E.M. Stein**, Princeton University, Princeton, NJ. (Mar. 1990, p. 334)

* 13-18. **IMA Workshop on Degenerate Diffusions**, University of Minnesota, Minneapolis, MN.

PROGRAM: The emphasis in this workshop will be on current and new problems in nonlinear diffusion equations involving free boundaries or sharp interfaces. The motivation for studying these problems is both mathematical and practical. The objective of this workshop is to provide some focus in this endeavor, and by inviting scientists and engineers as well as mathematicians, to keep it firmly linked to concrete problems. The last two days of the workshop will be a celebration of Jim Serrin's sixty-fifth birthday.
ORGANIZERS: W.-M. Ni, L.A. Peletier, J.-L. Vazquez.
INFORMATION: Institute for Mathematics and Its Applications, University of Minnesota, 514 Vincent Hall,

206 Church St., S.E., Minneapolis, MN 55455-0436; 612-624-6066.

* 15–17. **Third IEEE Conference on Computer Workstations: Accomplishments and Challenges**, Falmouth (Cape Cod), MA.

CONFERENCE TOPICS: Design of workstation computing environments, workstation and system architecture, application and system management, user interface technologies, exploiting parallelism and massive memory, network support for high performance distributed computing, computer-aided software engineering, information management systems, real-time sensing and control, issues of scale, and innovative ideas and technologies.

CALL FOR PAPERS: Papers should be no longer than about 5000 words (20 double-spaced pages), and must be received by September 15, 1990. Both technical and case-study papers are solicited; case studies should describe existing systems and include performance or operational data where practical. The conference will also include a poster session for discussing work in progress. Individuals with a specific interest in participating in the poster session are invited to submit a one-page abstract describing their project. Send five copies of each submission to the address below.

INFORMATION: K. Marzullo, Program co-chair, CCW '91, Dept. of Comp. Sci., Upson Hall, Cornell Univ., Ithaca, NY 14853.

* 17–20. **Conference/Workshop on Continuum Theory and Dynamical Systems**, University of Southwestern Louisianna, Lafayette, LA.

PROGRAM: The purpose is to introduce mathematicians in each of these fields with the relevant concepts in the other field. It will serve as an introduction to anyone who is interested in applications of Continuum Theory to Dynamical Systems. The two day workshop will be followed by talks on this topic by invited speakers.

WORKSHOP SPEAKERS: M. Barge, S. Nadler.

INVITED SPEAKERS: K. Alligood, M. Brown, R. Devaney, J. Franks, J. Harrison, J. Kennedy, L. Oversteegen, J. Rogers.

CALL FOR PAPERS: Authors will have approximately 10 minutes to present contributed papers. To contribute you must submit an abstract by March 15, 1991.

INFORMATION: Conference Director, T. West, Dept. of Math., Univ. of Southwestern Louisianna, Lafayette, LA 70504; 318-231-5289; Fax: 318-231-6195; email: trw7348@usl.edu.

19–25. **Differentialgeometrie im Grossen**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 501)

* 20–24. **Eleventh International Conference on Distributed Computing Systems**, Arlington, TX.

PROGRAM: This conference encompasses the technical aspects of specifying, designing, implementing, and evaluating distributed computing systems.

CALL FOR PAPERS: Authors are requested to submit five copies (in English) of their double-space typed manuscript (maximum of 20 pages) with an abstract to the Program Chairman by October 23, 1990. Submit papers to B.W. Wah (address below). In addition to papers, proposals for one day tutorials are solicited in any of the conference areas. Submit them to the Tutorial Chairman by October 1, 1990: B. Buckles, Dept. of Comp. Sci., Tulane Univ., New Orleans, LA 70118; 504-865-5840; Fax: 504-865-6740.

INFORMATION: B.W. Wah, 11th ICDCS Program Chairman, Coordinated Science Lab., MC228, Univ. of Illinois, 1101 W. Springfield Ave., Urbana, IL 61801-3082; 217-333-3516; Fax: 217-244-1764; email: wah%aquinas@uxc.cso.uiuc.edu.

22–24. **Second International Conference on Algebraic Methodology and Software Technology, (AMAST)**, Iowa City, IA. (Apr. 1990, p. 501)

* 26–31. **Signal Theory and Image Processing**, Cetraro, Italy.

ORGANIZING COMMITTEE: C.A. Berenstein, A. Sood, and D.C. Struppa (G. Mason Univ.); G. Pieroni (Univ. of Houston); J. Guenot (Univ. of Calabria); W. Schempp (Univ. of Siegen).

INVITED SPEAKERS: C.A. Berenstein, G. Mason Univ.; J.P. Fitch, Lawrence Livermore Nat'l Lab.; N.E. Hurt, Zeta Assoc., VA; G. Pieroni, Univ. of Houston; W. Schempp, Univ. of Siegen; L.P. Yaroslavsky, Institute of Information Transmission Problems, Moscow; Y.Y. Zeevi, Harvard-Rutgers-Technion.

INFORMATION: D.C. Struppa, Dept. of Math. Sciences, George Mason Univ., Fairfax, VA 22030; Fax: 703-323-3849; tel: 703-323-2477; or D.C. Struppa, Dept. of Math., Univ. of Calabria, 87036 Rende (CS), Italy; Fax: 011-39-984-401186; tel: 011-39-984-493256; email: dstruppa@gmuvax.gmu.edu.

26–June 1. **Optimalsteuerung und Variationsrechnung-Optimal Control**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 501)

29–June 1. **Eighth Biennial Conference of the Association of Christians in the Mathematical Sciences**, Wheaton College, Wheaton, IL. (Jul./Aug. 1990, p. 743)

* 29–June 1. **Methods in Module Theory**, University of Colorado, Colorado Springs, CO.

PROGRAM: This conference will consist of presentations and discussions regarding various techniques which have recently been used to solve classical problems in the theory of modules.

ORGANIZING COMMITTEE: G. Abrams (gdabrams@colospgs.bitnet), J. Haefner (haefner@colospgs.bitnet), K.M. Rangaswamy (kmranga@colospgs.bitnet).

INVITED SPEAKERS: K. Fuller, R. Guralnick, L. Levy, R. Wiegand, B. Zimmermann-Huisgen.

INFORMATION: Methods in Module Theory, Dept. of Math., Univ. of Colorado, Colorado Springs, CO 80933.

June 1991

June 1991. **Third IMACS International Symposium on Computational Acoustics**, Harvard Univ., Cambridge, MA. (Mar. 1990, p. 334)

2–8. **Diskrete Geometrie**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 501)

3–7. **1991 Annual Meeting of the Statistical Society of Canada**, Toronto, Ontario, Canada. (Mar. 1990, p. 334)

* 9–10. **Special Session on Polymer Configurations: Nonlinear and Nonlocal Diffusion Problems**, University of Minnesota, Minneapolis, MN.

PROGRAM: This special session will constitute the first two days (and the more mathematical part) of the Symposium on Tethered Chains in Polymer Microstructures, June 9 - 13, 1991.The symposium will cover theoretical experimental and computer simulation work on the configurations and manifestations of the signature behavior of tethered chains.
ORGANIZERS: F.S. Bates, A. Halperin, T.P. Lodge, M. Tirrell.
INFORMATION: Institute for Mathematics and Its Applications, University of Minnesota, 514 Vincent Hall, 206 Church St., S.E., Minneapolis, MN 55455-0436; 612-624-6066.

9–15. **Singuläre Störungsrechnung**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 501)

10–14. **Bernoulli Society Twentieth Conference on Stochastic Processes and their Applications**, Nahariya, Israel. (Nov. 1989, p. 1254)

13–15. **Western Sectional Meeting**, Portland State University, Portland, Oregon.

INFORMATION: W. Drady, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

17–21. **1991 International Symposium on the Mathematical Theory of Networks and Systems (MTNS-91)**, International Conference Center Kobe, Kobe, Japan. (Nov. 1989, p. 1254)

17–21. **European Conference on Elliptic and Parabolic Problems**, Pont á Mousson, France. (May/Jun. 1990, p. 613)

23–29. **Mathematische Methoden des VLSI-Entwurfs und des Distributed Computing**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 744)

26–28. **Third IMACS International Symposium on Computational Acoustics**, Harvard University, Cambridge, MA. (Jul./Aug. 1990, p. 744)

30–July 6. **Elliptische Operatoren auf Singulären und Nichtkompakten Manigfaltigkeiten**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 501)

July 1991

1–5. **The Mathematics of Nonlinear Systems**, University of Bath, United Kingdom. (Jan. 1990, p. 62)

2–5. **European Control Conference**, Grenoble, France. (Jul./Aug. 1990, p. 744)

7–13. **Computational Number Theory**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 744)

8–12. **Second International Conference on Industrial and Applied Mathematics**, Washington, DC. (Apr. 1990, p. 501)

8–14. **ICOR '91 International Conference on Radicals**, Szekszárd, Hungary. (Apr. 1990, p. 502)

14–20. **Dynamische Systeme**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 502)

15–17. **Fifth IFAC/IMACS Symposium on Computer Aided Design in Control and Engineering Systems**, Swansea, UK. (Mar. 1990, p. 334)

* 15–18. **Sixth Annual IEEE Symposium on Logic in Computer Science**, Amsterdam, The Netherlands.

PROGRAM: The LICS Symposium aims for wide coverage of theoretical and practical issues in Computer Science that relate to logic in a broad sense, including algebraic, categorical and topological approaches.
CONFERENCE TOPICS: Abstract data types, automated deduction, concurrency, constructive mathematics, data base theory, finite model theory, knowledge representation, lambda and combinatory calculi, logical aspects of computational complexity, logics in artificial intelligence, logic programming, modal and temporal logics, program logic and semantics, rewrite rules, software specification, type systems, verification.
CALL FOR PAPERS: Twenty copies of a cover page and eight copies of a detailed abstract–not a full paper–should be received by January 2, 1991. The cover page of the submission should include the title and authors, a brief synopsis, and the corresponding author's name, address, phone #, FAX #, and email address if available. Abstracts of fewer than 1500 words are rarely adequate, but the total abstract, including references, should not exceed 4000 words.
INFORMATION: D. Leivant, School of Computer Science, Carnegie Mellon University, Pittsburgh, PA 15213; email: lics@cs.cmu.edu.

21–27. **Halbgruppentheorie**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 744)

22–26. **Thirteenth IMACS World Congress on Computation and Applied Mathematics**, Trinity College, Dublin University, Dublin, Ireland. (Apr. 1990, p. 502)

28–August 3. **Gruppen und Geometrien**, Oberwolfach, Federal Republic of Germany. (Apr. 1990, p. 502)

August 1991

3–7. **Interamerican Conference on Mathematics Education**, Univ. of Miami, Coral Gables, FL. (Apr. 1990, p. 502)

4–10. **Effiziente Algorithmen**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 744)

5–8. **ICMI-China Regional Conference on Mathematics Education**, Beijing, China. (Jul./Aug. 1990, p. 744)

5–9. **Fourteenth International Symposium on Mathematical Programming**, Amsterdam, The Netherlands. (Jul./Aug. 1990, p. 745)

8–11. **Joint Mathematics Meetings**, University of Maine, Orono, ME. (including the summer meetings of the AMS, AWM, MAA, and PME)

INFORMATION: H. Daly, AMS, P.O. Box 6248, Providence, RI 02940.

11–17. **European Young Statisticians Meeting**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 745)

* 14–16. **Short Conference on Uniform Mathematics and Applications (International Conference on Quasi-Uniformities and Related Structures)**, Bern, Switzerland.

PURPOSE: The topic of the meeting will be topology and its applications in different fields of mathematics and computer science. There will be invited lectures and 25-minute contributed talks. Several workshops will be organized in accordance with the announced short talks.
INFORMATION: Organizing Committee (Conference on Uniform Mathematics), Department of Mathematics, University of Bern, Sidlerstrasse 5,

3012 Bern, Switzerland.

18–24. **The Navier-Stokes Equations: Theory and Numerical Methods**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 745)

* 18–24. **The Third Conference of the Canadian Number Theory Association**, Queen's University, Kingston, Ontario.

CONFERENCE TOPICS: Number Theory with special emphasis on analytic number theory, arithmetical algebraic geometry, and diophantine approximation.
INFORMATION: N. Yui, Dept. of Math. and Stat., Queen's Univ., Kingston, Ontario Canada K7L 3N6; 613-545-2421; email: yuin@qucdn.bitnet.

18–September 4. **Twenty-first Summer Ecole de Calcul des Probabilités**, Saint Flour, France. (Jul./Aug. 1990, p. 745)

19–22. **1991 Joint Statistical Meetings**, Atlanta, GA. (Mar. 1988, p. 466)

* 19–September 6. **College on Singularity Theory**, Trieste, Italy.

ORGANIZERS: V.I. Arnold (Steklov Math. Inst., Moscow), L. Dung Trang (Univ. de Paris VII), K. Saito (R.I.M.S., Kyoto Univ), B. Teissier (Ecole Normale Supérieure, Paris).
INFORMATION: International Centre for Theoretical Physics, I.C.T.P., P.O. Box 586, 34100 Trieste, Italy.

21–25. **The International Conference on the Theory of Rings, Algebras, and Modules in Honor of A.I. Shirshov**, Barnaul, U.S.S.R. (Jul./Aug. 1990, p. 745)

25–31. **Klassifikation Komplex-Algebraischer Varietäten**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 745)

September 1991

1–7. **Topologie**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 745)

8–14. **Niedrigidimensionale Topologie**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 745)

8–14. **Knoten und Verschlingungen**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 745)

* 9–27. **School on Dynamical Systems**, Trieste, Italy.

ORGANIZERS: J. Palis Jr. (I.M.P.A., Rio de Janeiro), Ya. Sinai (Landau Inst. for Theoretical Physics, Moscow).
INFORMATION: International Centre for Theoretical Physics, I.C.T.P., P.O. Box 586, 34100 Trieste, Italy.

10–13. **IFAC/IMACS Symposium on Fault Detection, Supervision and Safety for Technical Processes-SAFEPROCESS '91**, Baden-Baden, Federal Republic of Germany. (Apr. 1990, p. 502)

15–20. **DMV-Jahrestagung 1991**, Bielefeld, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

15–21. **Geometrie der Banachräume**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

16–19. **Fourth SIAM Conference on Applied Linear Algebra**, Univ. of Minnesota, Minneapolis, MN. (Apr. 1990, p. 502)

22–28. **Nonlinear and Random Vibrations**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

23–29. **Sixth Symposium on Classical Analysis**, Kazimierz Dolny, Poland. (Apr. 1990, p. 502)

* 24–27. **International Conference on Theoretical Aspects of Computer Software**, Tohoku Univ., Sendai, Japan.

PROGRAM: The TACS conference will focus on theoretical foundations of programming, and theoretical aspects of the design, analysis and implementation of programming languages and systems, including, but not limited to the following topics: logic, proof, specification and semantics of programs and languages; theories and models of concurrent, parallel, and distributed computation; constructive logic, category theory, and type theory in computer science; theory-based for specifying, synthesizing, transforming, testing, and verifying software. The scientific program will consist of invited lectures, contributed talks, poster and demo sessions, and a panel discussion.
INVITED SPEAKERS: R. Constable, Cornell Univ.; S. Hayashi, Ryukoku Univ.; G.D. Plotkin, Edinburgh Univ.; M. Sato, Tohoku Univ.; M. Hagiya, Kyoto Univ.; A.R. Meyer, MIT; A. Pnueli, Weizmann Inst.; D.S. Scott, Carnegie-Mellon Univ.
INFORMATION: T. Ito, Dept. of Information Engineering, Tohoku Univ., Sendai, Japan 980; email: ito@ito.ecei.tohoku.ac.jp; Fax: 81 22 267 4404; or A.R. Meyer, MIT Lab. for Comp. Sci., 545 Technology Square, NE43-315, Cambridge, MA 02139; email:meyer@theory.lcs.mit.edu; Fax: (617)253-3480.

25–27. **Ninth GAMM Conference on Numerical Methods in Fluid Mechanics**, Lausanne, Switzerland. (May/Jun. 1990, p. 613)

29–October 5. **Kombinatorik Geordneter Mengen**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

October 1991

6–12. **Arbeitsgemeinschaft mit Aktuellem Thema (wird in den Mitteilungen der DMV Heft 3/1991 bekanntgegeben)**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

* 7–11. **Workshop on Stochastic and Deterministic Models**, Trieste, Italy.

ORGANIZERS: F. Chersi, S. Invernizzi, A. Wedlin (Univ. degli di Trieste).
INFORMATION: International Centre for Theoretical Physics, I.C.T.P., P.O. Box 586, 34100 Trieste, Italy.

12–13. **Eastern Section**, Temple University, Philadelphia, PA.

INFORMATION: W. Drady, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

13–19. **Geometrie**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

20–26. **C^*-Algebren**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

25–26. **Central Section**, North Dakota State University, Fargo, ND.

INFORMATION: W. Drady, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

November 1991

3–9. **Mengenlehre**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

9–10. **Western Sectional Meeting**, University of California, Santa Barbara. (Jul./Aug. 1990, p. 746)

17–23. **Singularitäten der Kontinuumsmechanik: Numerische und Konstruktive Methoden zu Ihrer Behandlung**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

18–22. **Supercomputing '91**, Albuquerque, NM. (Jan. 1990, p. 62)

24–30. **Numerische Methoden der Approximationstheorie**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

December 1991

1–7. **Statistik Stochastischer Prozesse**, Oberwolfach, F.R.G. (Jul./Aug. 1990, p. 746)

8–14. **Stochastic Geometry, Geometric Statistics, Stereology**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

15–21. **Quantenstochastik**, Oberwolfach, Federal Republic of Germany. (Jul./Aug. 1990, p. 746)

27–31. **Holiday Symposium on the Impact of Software Systems in Mathematical Research**, New Mexico State Univ., Las Cruces, NM. (Jul./Aug. 1990, p. 746)

1992. **IMACS Symposium on Symbolic Computation in Engineering Design**, IDN, Lille, France. (Jul./Aug. 1990, p. 746)

January 1992

8–11. **Joint Mathematics Meetings**, Baltimore, MD. (including the annual meetings of the AMS, AWM, MAA and NAM)

INFORMATION: H. Daly, AMS, P.O. Box 6248, Providence, RI 02940.

February 1992

24–28. **IEEE Computer Society COMPCON Spring '92**, San Francisco, CA. (Jan. 1990, p. 62)

March 1992

27–28. **Central Section**, Southwest Missouri State University, Springfield, MO.

INFORMATION: W. Drady, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

April 1992

*April 1992. **Eighth International Conference on Mathematical and Computer Modelling**, United States.

INFORMATION: X.J.R. Avula, President, IAMCM, Univ. of Missouri, Rolla, Dept. of Engineering Mechanics, P.O. Box 1488, Rolla, MO 65401-0249.

May 1992

29–31. **Twenty-first International Symposium on Multi-Valued Logic**, Sendai 980, Japan. (Jan. 1990, p. 62)

June 1992

* 14–20. **Fifth International Symposium on Statistical Decision Theory and Related Topics**, Purdue University, West Lafayette, IN.

INFORMATION: S.S. Gupta, Dept. of Stat., Purdue Univ., West Lafayette, IN 47907; email: tej@1.cc.purdue.edu; Fax: 317-494-0558.

15–19. **Twenty-first International Conference on Stochastic Processes and their Applications**, Toronto, Canada. (May/Jun. 1990, p. 613)

29–July 1. **Joint Meeting with the London Mathematical Society**, Cambridge, England.

INFORMATION: H. Daly, American Mathematical Society, Post Office Box 6248, Providence, Rhode Island 02940.

August 1992

* 16–23. **Seventh International Congress on Mathematical Education (ICME-7)**, Québec, Canada.

PROGRAM: This will be the seventh in a series of congresses following those of Lyons (1969), Exeter (1972), Karlsruhe (1976), Berkeley (1980), Adelaide (1984), and Budapest (1988). In an effort to meet the diverse needs and interests of the 3000-3500 expected participants, the program will cover all of the major areas of mathematics education at the elementary, secondary, and post-secondary levels. Activities will include lectures, working groups, topic groups, workshops, short communications, posters, project presentations, and films, as well as exhibitions of textbooks, software, and other types of materials.

CONFERENCE THEMES: Improving students' attitudes and motivation, mathematics for early school leavers, innovative assessment of students in mathematics, students' misconceptions and inconsistencies of thought, the impact of calculators on the elementary school curriculum, the role of geometry in general education, probability and statistics for the future citizen, modelling activities in the classroom, students' difficulties in calculus, undergraduate mathematics for different groups of students, pre-service and in-service teacher education, methodologies for research in mathematics education.

INFORMATION: Congrès ICME-7 Congress, Univ. Laval, Québec, QC Canada G1K 7P4; 418-656-7592; fax: 418-656-2000; email: icme-7@lavalvm1.bitnet.

January 1993

13–16. **Joint Mathematics Meetings**, San Antonio, TX. (including the annual meetings of the AMS, AWM, MAA, and NAM)

INFORMATION: H. Daly, AMS, P.O. Box 6248, Providence, RI 02940.

January 1994

5–8. **Joint Mathematics Meetings**, Cincinnati, OH. (including the annual meetings of the AMS, AWM, MAA, and NAM)

INFORMATION: H. Daly, AMS, P.O. Box 6248, Providence, RI 02940.

New AMS Publications

PROCEEDINGS OF THE GIBBS SYMPOSIUM YALE UNIVERSITY, MAY 15–17, 1989 D. G. Caldi and G. D. Mostow, Editors

This volume, a joint publication with the American Institute of Physics, contains the proceedings of a symposium held May 15–17, 1989, at Yale University. The symposium was organized to honor the memory of Josiah Willard Gibbs, one of the giants of theoretical physics, on the 150th anniversary of his birth. The range of the topics covered in the symposium reflects the extraordinary versatility of Gibbs's ideas. Despite their widely separated expertises, the symposium speakers made an effort to present their lectures in a way that would be understandable to all the participants. The result was a genuine exchange of ideas across disciplines that is captured in this volume.

Three of the articles in the book provide perspectives on Gibbs, the man, and on the place his work occupies in the history of science. There are also contributions from leading scientists who assess the state of the art in those areas of physics and mathematics in which Gibbs worked, primarily those having to do with statistical mechanics and thermodynamics. To underscore the great generality of Gibbs's methods and the broad applicability of his work, contributions were also solicited from distinguished investigators in a number of different fields, such as geophysics, number theory, general relativity, and economics. Some of these fields are far removed from those to which Gibbs contributed directly, but Gibbs's hand is still discernible in them.

In addition to the historical and research oriented articles, the book contains other material that provides some colorful background on Gibbs and his world. Focusing on Gibbs and the teaching of science, the final article is a commentary, embellished with personal reminiscences, on what to do and what to avoid in the education of prospective scientists. In the appendix, the editors have included a transcription of the Yale Physical Club (which continues to this day as the Physics Club) for the meeting following the death of Gibbs in 1903. The minutes provide a flavor of the esteem in which Gibbs was held by his colleagues and a vivid glimpse of the Yale Physics Department at the time. The appendix also has a section presenting a number of examples of various Gibbsian surfaces generated by computer graphics, for the graphical presentation of Gibbs's concepts dates back to Gibbs himself.

Readers will appreciate the variety in this well-rounded volume, and it would make an excellent addition to any library. It is a fitting tribute to Josiah Willard Gibbs, a towering figure in American science and mathematics.

Contents

1980 *Mathematics Subject Classifications*: 01A55, 11D09, 11E45, 11F66, 11F67, 11F70, 11G05, 11G40, 11R39, 22E50, 22E55, 60G15, 76N15, 80-02, 80-03(01A55), 80A10, 80A50, 82A15, 82A25, 82A30, 82A97, 86A15, 90-02, 90-03 (01A99)
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THE JOY OF TeX A Gourmet Guide to Typesetting with the AMS-TeX Macro Package, Second Edition M. D. Spivak

This is the second edition of *The Joy of TeX*, the user-friendly guide to AMS-TeX, which is a software package based on the revolutionary computer typesetting language TeX. AMS-TeX was designed to simplify the typesetting of mathematical quantities, equations, and displays, and to format the output according to any of various preset style specifications. This second edition of *Joy* has been updated to reflect the changes introduced in Version 2.0 of the AMS-TeX macro package.

The first two parts of the manual, "Starters" and "Main Courses," teach the reader how to typeset the kind of text and mathematics one ordinarily encounters. "Sauces and Pickles," the third section, treats more exotic problems and includes a 60-page dictionary on special techniques. The manual also includes descriptions of conventions of mathematical typography to help the novice technical typist. Appendices list handy summaries of frequently used and more esoteric symbols.

This manual will prove useful for technical typists as well as scientists who prepare their own manuscripts. For the novice, exercises sprinkled generously throughout each chapter encourage the reader to sit down at a terminal and learn through experimentation.

Contents

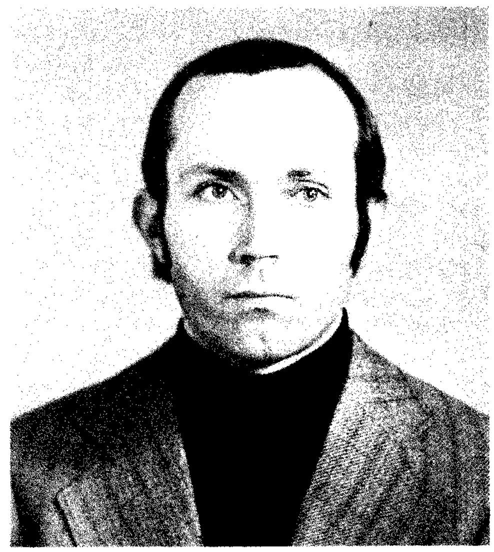
1980 *Mathematics Subject Classifications*: 00, 68
ISBN 0-8218-2997-1, LC 90-1082
320 pages (softcover), September 1990
Individual member $31, List price $38,
Institutional member $35
To order, please specify JOYT/N

INVERSE SOURCE PROBLEMS
Victor Isakov

(Mathematical Surveys and Monographs, Volume 34)

Inverse problems arise in many areas of mathematical physics, and applications are rapidly expanding to such areas as geophysics, chemistry, medicine, and engineering. The main theme of this book is uniqueness, stability, and existence of solutions of inverse problems for partial differential equations. Focusing primarily on the inverse problem of potential theory and closely related questions such as coefficient identification problems, this book will give readers an understanding of the results of a substantial part of the theory of inverse problems and of some of the new ideas and methods used.

The author provides complete proofs of most general uniqueness theorems for the inverse problem of gravimetry, a detailed study of regularity properties (including examples of non-regular domains with regular potentials), counterexamples to uniqueness and uniqueness theorems, and a treatment of the theory of non-stationary problems. In addition, the book deals with the orthogonality method, formulates several important unsolved problems, and suggests certain technical means appropriate for further study; some numerical methods are also outlined. Requiring a background in the basics of differential equations and function theory, this book is directed at mathematicians specializing in partial differential equations and potential theory, as well as physicists, geophysicists, and engineers.



BIOGRAPHY

Victor Isakov was born on November 4, 1947 in Novokuznetzk, Siberia. He graduated from Novosibirsk University in 1971 and received his Ph.D. from the Institute of Mathematics, Novosibirsk, in 1973. Since then, he held research and teaching positions at those institutions. He came to the United States in 1987, where he held positions at the Courant Institute and at Cornell University. Currently, he is professor of mathematics at Wichita State University. Isakov has published about forty papers, mainly on inverse problems for partial differential equations, including the inverse problem of potential theory, the Dirichlet-to-Neumann map, and the inverse scattering problem. In addition, he has studied uniqueness in the Cauchy problem.

Contents

1980 *Mathematics Subject Classifications*: 35R30; 31-XX, 35-XX, 86-XX
ISBN 0-8218-1532-6, LC 90-37843, ISSN 0076-5376
193 pages (hardcover), July 1990
Individual member $43, List price $72,
Institutional member $58
To order, please specify SURV/34N

FESTSCHRIFT IN HONOR OF I. I. PIATETSKI-SHAPIRO, PARTS I–II
S. Gelbart, R. Howe, and P. Sarnak, Editors

(Israel Mathematical Conference Proceedings, Volume 2–3)

These two books are the second and third volumes in a new AMS book series, *Israel Mathematical Conference Proceedings*, published by the Weizmann Science Press of Israel. They contain the proceedings of a workshop on L-functions, Number Theory, and Harmonic Analysis, held at Tel Aviv University in May, 1989. The workshop was organized to honor and review the impact of the work of Ilya I. Piatetski-Shapiro on the occasion of his sixtieth birthday.

Piatetski-Shapiro has been making major contributions to applied and theoretical mathematics for the past forty years. His work has touched such scientific areas as cell biology, geophysics, automata, homogeneous networks, and digital computers. These two volumes reflect the impact of his work on pure mathematics, in areas ranging from trigonometrical series and analytic number theory to group representations, algebraic geometry, and automorphic L-functions.

Some of the papers in this volume were originally presented during the workshop, while others were solicited shortly afterward. All were prepared especially for this collection and are dedicated to Piatetski-Shapiro. The first volume contains papers on representation theory, while the second focuses on analysis, number theory, and automorphic L-functions. The two volumes comprise contributions by some of the top international experts in these areas.

Contents

1980 *Mathematics Subject Classification*: 11, 22
Volume 2
327 pages (softcover), September 1990
Individual member $36, List price $40
Institutional member $36
To order, please specify ISMC/2N

Volume 3
339 pages (softcover), September 1990
Individual member $36, List price $40
Institutional member $36
To order, please specify ISMC/3N

Set of Volumes 2 and 3
Individual member $68, List price $76
Institutional member $68
To order, please specify ISMSET/2/3N

NEWTON POLYHEDRA WITHOUT COORDINATES/NEWTON POLYHEDRA OF IDEALS
Boris Youssin

(Memoirs of the AMS, Number 433)

This book creates a commutative algebra background for explicit and canonical resolution of singularities of algebraic varieties. The author's construction provides a coordinate-free definition of some Newton polyhedra related to a germ of functions or an ideal. In addition, the construction is significant as a step toward an explicit and canonical resolution of singularities in characteristic zero. The book is intended for researchers in algebraic geometry and commutative algebra.

Contents

1980 *Mathematics Subject Classifications*: 13J05; 14E15, 13B20
ISBN 0-8218-2495-3, LC 90-595, ISSN 0065-9266
99 pages (softcover), September 1990
Individual member $11, List price $19,
Institutional member $15
To order, please specify MEMO/433N

HOMOTOPY FORMULAS IN THE TANGENTIAL CAUCHY-RIEMANN COMPLEX
François Treves

(Memoirs of the AMS, Number 434)

This book presents a unified approach to homotopy formulas in the tangential Cauchy-Riemann complex, mainly on real hypersurfaces in complex space, but also on certain generic submanifolds of higher codimension. The construction combines the Bochner-Martinelli integral formulas with the FBI (Fourier-Bros-Iagolnitzer) minitransform. The hypersurface admits supporting manifolds of the appropriate holomorphic type from above and below. The supporting manifolds allow the selection of good "phase functions" and correspond to a kind of weak convexity in some directions, and concavity in others.

This book will provide readers with a deeper understanding of the local theory of CR structures. Though it is essentially self-contained, the book does require some knowledge of complex and real analysis and of differential forms.

Contents

1980 *Mathematics Subject Classifications*: 32; 35
ISBN 0-8218-2496-1, LC 90-612, ISSN 0065-9266
121 pages (softcover), September 1990
Individual member $12, List price $20,
Institutional member $16
To order, please specify MEMO/434N

HECKE ALGEBRAS
Aloys Krieg

(Memoirs of the AMS, Number 435)

Directed at mathematicians interested in representation theory or number theory (and automorphic forms in particular), this book provides an introduction to the algebraic theory of Hecke algebras. The first part deals with the basic isomorphism theorems for abstract Hecke algebras. The author generalizes Maschke's classical theorem to determine the structure of finite-dimensional Hecke algebras, then goes on to discuss in more detail several examples of Hecke algebras for finite groups. The second part, which is of a more number-theoretic nature, starts with an explicit description of the Hecke algebra associated with $SL(2,Z)$, and then generalizes the results to the unimodular group of arbitrary degree. In addition, the author describes the structure of the Hecke algebra associated with the Siegel modular group and explicitly derives, for generators of the Hecke algebra, the commutation relation with the Siegel Φ-operator. Readers will gain an understanding of the role of Hecke algebras in number theory and in representation theory.

Contents

1980 *Mathematics Subject Classifications*: 10D12, 10D20, 20C05, 20H30
ISBN 0-8218-2497-X, LC 90-40201, ISSN 0065-9266
158 pages (softcover), September 1990
Individual member $14, List price $23,
Institutional member $18
To order, please specify MEMO/435N

SOCIÉTÉ MATHÉMATIQUE DE FRANCE, ASTÉRISQUE

The AMS distributes Astérisque only in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF, B.P. 126-05, 75226 Paris Cedex 05, France, or to OFFILIB, 48 rue Gay-Lussac, 75240 Paris Cedex 05, France. Individual members of either AMS or SMF are entitled to the member price. (ISSN 0303-1179)

SÉMINAIRE SUR LES PINCEAUX DE COURBES ELLIPTIQUES (À LA RECHERCHE DE "MORDELL EFFECTIF")
L. Szpiro, Editor

(Astérisque, Number 183)

This seminar is organized around the "discriminant conjecture": on a given number field, the minimal discriminant of an elliptic curve must have a polynomial bound in terms of the conductor of the elliptic curve. Consequences and limitations of this conjecture are given by D. W. Masser (lower bound for the degree), M. Flexor and J. Oesterlé (torsion point of elliptic curves), and L. Szpiro (Frey curves, Fermat conjecture, etc.). A conjectural "effective Mordell" for modular curves implies the conjecture (A. N. Parshin). This result is explained, together with its limitations, in the papers of L. Moret-Bailly, J. B. Bost, J. F. Mestre, and R. Elkik. Isogenies of elliptic curves are studied also in D. Bertrand's paper, and C. Soulé exhibits links between "classical" analysis and Arakelov's theory. The latter is basic for the problems presented here.

Contents

1980 *Mathematics Subject Classification*: 14
ISSN 0303-1179
136 pages (softcover), 1990
Individual AMS or SMF member $12, List price $17
To order, please specify AST/183N

The following publication originally appeared in the July/August 1990 issue of *Notices*. It is being reprinted here with the corrected prices.

THE MAXIMAL FACTORIZATIONS OF THE FINITE SIMPLE GROUPS AND THEIR AUTOMORPHISM GROUPS
Martin W. Liebeck, Cheryl E. Praeger, and Jan Saxl

(Memoirs of the AMS, Number 432)

Factorizations of finite groups as a product of two proper subgroups arise naturally in several areas of group theory, geometry, and applications. In this book, the authors determine all factorizations of the finite simple groups and their automorphism groups as a product of two maximal subgroups. The proof involves detailed study of the geometry of simple groups, and there is a substantial introductory section presenting this material. One of the major unsolved problems in the theory of finite groups is the classification of the maximal subgroups of the finite simple groups and their automorphism groups. As an application of their main results, the authors present an effective classification of the maximal subgroups of one such class, the finite alternating and symmetric groups. Requiring a basic knowledge of group theory, the book is directed at research mathematicians and graduate students.

Contents

Classical groups of large dimension: factorizations as a product of two geometric subgroups; *Classical groups of large dimension: factorizations in which one of the factors is non-geometric*; *Classical groups of small dimension*; *Factorizations of sporadic groups*; *Factorizations of alternating groups*; *Factorizations of exceptional groups of Lie type*; *On maximal subgroups of symmetric and alternating groups*; *Lower bounds for dimensions of representations of sporadic groups*; *Uniqueness of certain representations of Suz and* Co_1; *Orbit decomposition of* $B_4(q)$ *on a spin module*.

1980 *Mathematics Subject Classification*: 20
ISBN 0-8218-2494-5, LC 90-31827, ISSN 0065-9266
151 pages (softcover), July 1990
Individual member $13, List price $21,
Institutional member $17
To order, please specify MEMO/432N

The following publications originally appeared in the July/August 1990 issue of *Notices*. They are being reprinted here with the corrected book descriptions.

HARMONIC ANALYSIS AND PARTIAL DIFFERENTIAL EQUATIONS
Mario Milman and Tomas Schonbek, Editors

(Contemporary Mathematics, Volume 107)

This book brings together ten papers presented at the Conference on Harmonic Analysis and Partial Differential Equations, held in April 1987 at Florida Atlantic University. The papers illuminate the relationship between harmonic analysis and partial differential equations and present results of some of the foremost experts in these areas. Among the topics covered are: application of fully nonlinear, uniformly elliptic equations to the Monge Ampère equation; estimates for Green functions for the purpose of studying Dirichlet problems for operators in non-divergence form; an extension of classical potential theory to the case of nonsmooth domains; the relation between Riesz potentials and maximal fractional operators due to Muckenhoupt and Wheeden; and the Lax-Phillips scattering theory applied to the double Hilbert transform. Directed at research mathematicians and graduate students, the papers require knowledge of the classical tools of analysis, such as measure theory, Sobolev spaces, and potential theory.

Contents

B. Barcelo, L. Escauriaza, and E. Fabes, *Gradient estimates at the boundary for solutions to nondivergence elliptic equations*; **L. A. Caffarelli**, *Interior regularity of solutions to Monge Ampère equations*; **M. Cotlar and C. Sadosky**, *The Helson-Szegö theorem in* L^p *of the bidimensional torus*; **B. E. J. Dahlberg and G. Verchota**, *Galerkin methods for the boundary integral equations of elliptic equations in nonsmooth domains*; **R. Fefferman**, *Some applications of Hardy spaces and BMO in harmonic analysis and partial differential equations*; **B. Jawerth, C. Perez, and G. Welland**, *The positive cone in Triebel-Lizorkin spaces and the relation among potential and maximal operators*; **R. Johnson**, *Changes of variable and* A_p *weights*; **C. E. Kenig**, *Progress on two problems posed by Rivière*; **A. C. Lazer and P. J. McKenna**, *Fredholm theory for periodic solutions of some semilinear P.D.E.s with homogeneous nonlinearities*; **W. A. Strauss**, *Stability of solitary waves*.

1980 *Mathematics Subject Classifications*: 35-06, 42-06
ISBN 0-8218-5113-6, LC 90-34635, ISSN 0271-4132
129 pages (softcover), July 1990
Individual member $23, List price $38,
Institutional member $30
To order, please specify CONM/107N

MATHEMATICS OF NONLINEAR SCIENCE
Melvyn S. Berger, Editor

(Contemporary Mathematics, Volume 108)

This volume contains the proceedings of an AMS Special Session on the Mathematics of Nonlinear Science, held in Phoenix in January 1989. This area of research encompasses a large and rapidly growing set of ideas concerning the relationship of mathematics to science, in which the fundamental laws of nature are extended beyond common sense into new areas where the dual aspects of order and chaos abound.

These papers, generally analytic in nature, deal primarily with mathematical aspects of physical science and non-chaotic phenomenon. Important new areas are discussed, such as instability, global extensions of KAM theory, new ideas concerning integrable systems, bifurcation and its applications in fluids, and various aspects of gauge theory. Altogether, the topics explored here represent an excellent survey of some of the new research in the mathematics of nonlinear science.

Contents

Roger K. Alexander, *Multiple steady states in tubular chemical reactors*; **M. S. Berger**, *Two new approaches to large amplitude* *quasi-periodic motions of certain nonlinear Hamiltonian systems*; **Y. Y. Chen**, *Vortices for the Ginzburg-Landau equations–the nonsymmetric case in bounded domain*; **Andrew Szeri and Philip Holmes**, *Nonlinear stability and bifurcation in Hamiltonian systems with symmetry*; **Eli Isaacson and Blake Temple**, *Nonlinear resonance in inhomogeneous systems of conservation laws*; **George H. Knightly and D. Sather**, *Bifurcation and stability in rotating, plane Couette-Poiseuille flow*; **Kenneth R. Meyer and Dieter S. Schmidt**, *Bifurcations of central configurations in the N-body problem*; **M. S. Berger and J. Nee**, *Leapfrogging of vortex filaments in an ideal fluid*; **J. W. Neuberger**, *Calculation of sharp shocks using Sobolev gradients*; **John Palmer and Craig A. Tracy**, *Monodromy preserving deformation of the Dirac operator acting on the hyperbolic plane*; **M. S. Berger and M. Schechter**, *Bifurcation from equilibria for certain infinite-dimensional dynamical systems*; **Victor Shubov**, *On dynamics of discrete and continuous σ-models (chiral fields) with values in Riemannian manifolds*; **Srdjan Stojanovic**, *Direct study for some nonlinear elliptic control problems*.

1980 *Mathematics Subject Classifications*: 70, 34, 35, 49, 58
ISBN 0-8218-5114-4, LC 90-574, ISSN 0271-4132
154 pages (softcover), July 1990
Individual member $19, List price $32,
Institutional member $26
To order, please specify CONM/108N

THÉORIE DE HODGE

(Astérisque, Number 179–180)

This volume contains several contributions of a conference on Hodge Theory held in Luminy in June 1987. There is an exposition of the recent quite spectacular results on intersection cohomology with values in a polarized variation of Hodge structure, and with constant values on locally symmetric spaces, on mixed Hodge modules and perverse sheaves. Several subjects at the border line of Hodge Theory are presented as well: extensions of variations of Hodge structure, applications to Hodge Theory, to vanishing theorems, and to singularities.

1980 Mathematics Subject Classification: 14
ISSN 0303-1179
278 pages (softcover), 1989
Individual AMS or SMF member $23,
List price $33
To order, please specify AST/179-80NA

All prices subject to change. Free shipment by surface; for air delivery, please add $6.50 per title. *Prepayment required.*
Order from American Mathematical Society, P.O. Box 1571, Annex Station, Providence, RI 02901-1571, or call toll free 800-321-4AMS (321-4267) in the continental U.S. and Canada to charge with VISA or MasterCard.

NONLINEAR WAVE EQUATIONS

Walter A. Strauss

(CBMS Regional Conference Series, Number 73 • Supported by the National Science Foundation)

The theory of nonlinear wave equations in the absence of shocks began in the 1960s. Despite a great deal of recent activity in this area, some major issues remain unsolved, such as sharp conditions for the global existence of solutions with arbitrary initial data, and the global phase portrait in the presence of periodic solutions and traveling waves.

This book, based on lectures presented by the author at George Mason University in January 1989, seeks to present the sharpest results to date in this area. The author surveys the fundamental qualitative properties of the solutions of nonlinear wave equations in the absence of boundaries and shocks. These properties include the existence and regularity of global solutions, strong and weak singularities, asymptotic properties, scattering theory and stability of solitary waves. Wave equations of hyperbolic, Schrödinger, and KdV type are discussed, as well as the Yang-Mills and the Vlasov-Maxwell equations.

The book offers readers a broad overview of the field and an understanding of the most recent developments, as well as the status of some important unsolved problems. Intended for mathematicians and physicists interested in nonlinear waves, this book would be suitable as the basis for an advanced graduate-level course.

1980 *Mathematics Subject Classifications*: 35L70, 35Q20, 35B35, 35P25, 81E10, 82A45
ISBN 0-8218-0725-0, LC 89-18167, ISSN 0160-7642 • 91 pages (softcover), December 1989
All individuals $13, List price $21 • To order, please specify CBMS/73NA

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AMS Reports and Communications

Recent Appointments

Committee members' terms of office on standing committees expire on December 31 of the year given in parentheses following their names, unless otherwise specified.

President William Browder has appointed Richard A. Askey (1992), Joan S. Birman (1992), R. Keith Dennis (1992), Steve Gersten (1992), and Dennis P. Sullivan (1992) to the *Collected Works Editorial Committee.* Professor Dennis will serve as chair.

Richard W. Beals (1991) has been appointed chair of the *Contemporary Mathematics Editorial Committee* by President William Browder. Continuing members of the committee are Sylvain E. Cappell (1991), Jonathan Goodman (1990), Craig Huneke (1992), Jan Mycielski (1990), Linda Preiss Rothschild (1992), and Michael E. Taylor (1991).

Chandler Davis, Robert MacPherson, Hugo Rossi, and Lance W. Small have been appointed to an ad hoc *Committee to Study Relations with Soviet Mathematicians* by President William Browder. Professor MacPherson will serve as chair.

Robert L. Bryant (1992), Joseph Lipman (1992), Raghavan Narasimhan (1992), and John B. Wagoner (1992) have been appointed by President William Browder to the *Centennial Fellowship Committee.* Dusa McDuff (1991) has been appointed chair. Continuing members of the committee are Alexander J. Nagel (1991), and Karl Rubin (1991). Terms expire on June 30.

President William Browder has appointed Joan S. Birman, Linda Keen, and Karen Uhlenbeck to the *Committee to Select the Winner of the Satter Prize for 1991.* Professor Keen will serve as chair.

Mark Mahowald (1992) has been appointed by President William Browder to the *Committee to Select the Winner of the Steele Prize.* Continuing members of the committee are Alexandre J. Chorin (1992), Charles L. Fefferman (1991), William J. Haboush (1992), Jun-ichi Igusa (1991), Arthur M. Jaffe (1992), and George Lusztig (1992). Terms expire on June 30.

Edgar H. Brown, Jr., Michael H. Freedman, and Mikhael Gromov have been appointed to the *Committee to Select the Winner of the Veblen Prize for 1991.* Professor Freedman will serve as chair.

Gilbert Strang (1991) has been appointed chair of the AMS-SIAM *Committee on Applied Mathematics* by Presidents William Browder (AMS) and Ivar Stakgold (SIAM). Continuing members of the committee are James M. Hyman (1990), Andrew J. Majda (1992), Lawrence A. Shepp (1991), Joel Spencer (1992), and Robert F. Warming 1990.

President William Browder appointed Richard A. Askey (ex officio), Hyman Bass (1991), Jerry L. Bona (ex officio), Cathleen S. Morawetz (ex officio), Warren Page (1991), Gian-Carlo Rota (1991), Clifford Taubes (ex officio), and Alan D. Weinstein (1991) to the *Liaison Committee with AAAS.* Professor Bona will serve as chair.

Statistics on Women Mathematicians Compiled by the AMS

At its August 1985 meeting, the Council of the AMS approved a motion to regularly assemble and report in *Notices* information on the relative numbers of men versus women in at least the following categories: membership in the AMS; invited hour addresses at AMS meetings; speakers at special sessions at AMS meetings; and members of editorial boards of AMS journals.

It was subsequently decided that this information would be gathered by determining the sex of the individuals in the above categories based on name identification and that additional information on the number of Ph.D.'s granted to women would also be collected using the AMS-MAA Annual Survey. Since name identification was used, the information for some categories necessitated the use of four classifications:

Male: names that were obviously male;
Female: names that were obviously female;
Unknown: names that could not be identified as clearly male or female (e.g., only initials given); and
Foreign: foreign names that could not be identified as clearly male or female.

The following is the fifth reporting of this information. Updated reports will appear annually in *Notices.*

Members of the AMS Residing in the U.S.

Male:	13,913	72%
Female:	3,061	16%
Unknown:	1,667	9%
Foreign:	639	3%
Total checked:	19,280	

Invited Hour Address Speakers at AMS Meetings (1980–1989)

Male:	351	92%
Female:	30	8%
Unknown:	1	0%
Foreign:	0	0%
Total checked:	383	

Speakers at Special Sessions at AMS Meetings (1985–1989)

Male:	3,132	80%
Female:	312	8%
Unknown:	277	7%
Foreign:	202	5%
Total checked:	3,873	

Trustees and Council Members

	1989		1988		1987		1986	
Total:	53		56		65		65	
Male:	46	87%	46	82%	52	80%	56	86%
Female:	7	13%	10	18%	13	20%	9	14%

Members of Editorial Boards of AMS Journals

	1989		1988		1987		1986		1985		1984		1983		1982		1981		1980	
Total:	194		161		133		109		102		93		90		83		85		82	
Male:	182	94%	148	92%	125	94%	104	95%	94	92%	85	91%	84	93%	77	93%	79	93%	77	94%
Female:	11	6%	13	8%	8	6%	5	5%	8	8%	8	9%	6	7%	6	7%	6	7%	5	6%

Ph.D.'s Granted to U.S. Citizens

	1989		1988		1987		1986		1985		1984		1983		1982		1981		1980	
Total:	411		363		362		386		396		433		455		519		567		578	
Male:	313	76%	287	79%	289	80%	304	79%	315	80%	346	80%	366	80%	431	83%	465	82%	491	85%
Female:	98	24%	76	21%	73	20%	82	21%	81	20%	87	20%	89	20%	88	17%	102	18%	87	15%

Officers and Committee Members

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

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

1. Officers

President	William Browder	1990
President-Elect	Michael Artin	1990
Vice-Presidents	Lenore Blum	1991
	Sun-Yung Alice Chang	1990
	Dennis P. Sullivan	1991
Secretary	Robert M. Fossum	1990
Former Secretary	Everett Pitcher	1990
Associate Secretaries	Joseph A. Cima	1990
	W. Wistar Comfort	1990
	Andy Roy Magid	1991
	Lance W. Small	1991
Treasurer	Franklin P. Peterson	1990
Associate Treasurer	Steve Armentrout	1990

1.1. Liaison Committee

All members of this committee serve *ex officio.*

Chair	William Browder
	Robert M. Fossum
	Franklin P. Peterson

2. Council

2.0.1. Officers of the AMS

President	William Browder	1990
President-Elect	Michael Artin	1990
Vice-Presidents	Lenore Blum	1991
	Sun-Yung Alice Chang	1990
	Dennis P. Sullivan	1991
Secretary	Robert M. Fossum	1990
Former Secretary	Everett Pitcher	1990
Associate Secretaries*	Joseph A. Cima	1990
	W. Wistar Comfort	1990
	Andy Roy Magid	1991
	Lance W. Small	1991
Treasurer	Franklin P. Peterson	1990
Associate Treasurer	Steve Armentrout	1990

2.0.2. Representatives of Committees

American Journal of Mathematics	M. Salah Baouendi	1992
Bulletin	Murray H. Protter	1991
Colloquium	Raoul H. Bott	1990
Journal of the AMS	Michael Artin	1991
Committee to Monitor Problems in Communication	Richard S. Palais	1990
Mathematical Reviews	B. A. Taylor	1992
Mathematical Surveys and Monographs	M. Susan Montgomery	1990
Mathematics of Computation	Walter Gautschi	1992
Proceedings	William J. Davis	1991
Science Policy Committee	Michael C. Reed	1992
Transactions and Memoirs	David J. Saltman	1990

2.0.3. Members-at-Large

Jonathan L. Alperin	1991	Irwin Kra	1990
Sheldon Axler	1992	Albert Marden	1990
Joan S. Birman	1992	Carl Pomerance	1992
Fan R. K. Chung	1991	Michael C. Reed	1991
Charles Herbert Clemens	1992	Hugo Rossi	1991
Lawrence J. Corwin	1991	Harold M. Stark	1990
Richard K. Guy	1990	William P. Thurston	1991
Rhonda J. Hughes	1990	Shing-Tung Yau	1992
Robion C. Kirby	1990		

2.1. Executive Committee of the Council

Michael Artin	*ex officio*
M. Salah Baouendi	1993

* Only one Associate Secretary at a time is a voting member of the Council, namely the cognizant Associate Secretary for the scientific sessions.

Chair	William Browder	*ex officio*
	Robert M. Fossum	*ex officio*
	Irwin Kra	1990
	Hugo Rossi	1992
	William P. Thurston	1991

3. Board of Trustees

	Steve Armentrout	*ex officio*
	William Browder	*ex officio*
	Frederick W. Gehring	1992
Chair	Ronald L. Graham	1991
	M. Susan Montgomery	1990
	Franklin P. Peterson	*ex officio*
	John C. Polking	1994
Secretary	Paul J. Sally, Jr.	1993

4. Committees

4.1. Committees of the Council

Standing Committees

4.1.1. Editorial Boards

	Linda Keen	1992
	Carlos Kenig	1991
Chair	Haynes R. Miller	1990
	Richard M. Schoen	1990
	Barry Simon	1992
	Daniel Zelinsky	1991

4.1.2. Nominating Committee

	Joan S. Birman	1991
	James E. Humphreys	1991
	Barbara Lee Keyfitz	1992
	Victor L. Klee, Jr.	1991
	Ray Kunze	1992
Chair	Alan D. Weinstein	1991
	Robert Williams	1992

Ad Hoc Committee

4.1.3. Nominating Committee Scheduling Committee

	Joan S. Birman
Chair	Robert M. Fossum
	Jane P. Gilman
	James W. Maxwell

4.2. Editorial and Communications Committees

4.2.1. Abstracts Editorial Committee

All members of this committee serve *ex officio*.

	Joseph A. Cima
	W. Wistar Comfort
Chair	Robert M. Fossum
	Andy Roy Magid
	Lance W. Small

4.2.2. American Journal of Mathematics, Society's Representatives

Chair	M. Salah Baouendi	1992
	David Gieseker	1991

4.2.3. Bulletin (New Series)

	Roger E. Howe	1990
	Richard S. Palais	1992
Chair	Murray H. Protter	1991

Associate Editors for Research Announcements

William B. Arveson	1990	Ronald L. Graham	1990
Spencer Bloch	1990	Victor W. Guillemin	1990
Gergory L. Cherlin	1992	Frank S. Quinn III	1990
Percy Alec Deift	1990	Peter B. Shalen	1990
Michael D. Fried	1990	Nolan R. Wallach	1990

Associate Editors for Research - Expository Articles

Persi Diaconis	1992	David A. Vogan, Jr.	1992
Jerry Kazdan	1992	Alan D. Weinstein	1992
Barry Mazur	1992	Guido L. Weiss	1990

4.2.4. Colloquium

Chair	Raoul H. Bott	1990
	Charles L. Fefferman	1991
	H. Jerome Keisler	1992

4.2.5. Committee to Monitor Problems in Communication

	Jon Barwise	1992
	Judy Green	1992
	William H. Jaco	*ex officio*
	Arthur M. Jaffe	1991
	Richard G. Larson	1990
	Paul G. Nevai	1991
Chair	Richard S. Palais	1990

4.2.6. Contemporary Mathematics

Chair	Richard W. Beals	1991
	Sylvain E. Cappell	1991
	Jonathan Goodman	1990
	Craig Huneke	1992
	Jan Mycielski	1990
	Linda Preiss Rothschild	1992
	Michael E. Taylor	1991

4.2.7. Collected Works

	Richard A. Askey	1992
	Joan S. Birman	1992
Chair	R. Keith Dennis	1992
	Steve Gersten	1992
	Dennis P. Sullivan	1992

4.2.8. Graduate Studies in Mathematics

	William Fulton	1992
	Lance W. Small	1992

4.2.9. Journal of the AMS

Chair	Michael Artin	1992
	H. Blaine Lawson, Jr.	1991
	Richard B. Melrose	1990
	Wilfried Schmid	1990
	Robert E. Tarjan	1992

Associate Editors

James G. Arthur	1992	Joe Harris	1990
Peter Bickel	1990	Hendrik W. Lenstra, Jr.	1991
Gerd Faltings	1991	Andrew Majda	1992
Charles L. Fefferman	1992	Hugh L. Montgomery	1990
Michael H. Freedman	1990	Paul H. Rabinowitz	1991
Daniel Friedan	1991	Karen Uhlenbeck	1992
Ronald L. Graham	1992	W. Hugh Woodin	1990

4.2.10. Mathematical Reviews

	Leonard D. Berkovitz	1991
	John L. Selfridge	1991
Chair	B. A. Taylor	1992
	Hans F. Weinberger	1990

4.2.11. Mathematical Surveys and Monographs

	Victor W. Guillemin	1992
	David S. Kinderlehrer	1991
Chair	M. Susan Montgomery	1990
	Marc A. Rieffel	1991

4.2.12. Mathematics of Computation

Chair	Walter Gautschi	1992
	Donald Goldfarb	1990
	Andrew M. Odlyzko	1991
	Lars B. Wahlbin	1992

Associate Editors

James Bramble	1991	René Schoof	1992
James W. Demmel	1991	Larry L. Schumaker	1991
Eugene Isaacson	1992	Ridgway Scott	1992
Heinz-Otto Kreiss	1990	Daniel Shanks	1990
James N. Lyness	1990	Frank Stenger	1992
Harald Niederreiter	1990	Hans J. Stetter	1991
Syvert P. Nørsett	1990	G. W. Stewart	1992
Frank W. J. Olver	1990	Nico M. Temme	1992
John Osborn	1992	Vidar C. Thomée	1991
Stanley J. Osher	1992	Hugh C. Williams	1991
Carl Pomerance	1991	John W. Wrench, Jr.	1990

4.2.13. Notices

	Robert J. Blattner	1990
	Michael C. Crandall	1992
Chair	Robert M. Fossum	*ex officio*
	Lucy J. Garnett	1990
	D. J. Lewis	1992
	Nancy K. Stanton	1990
	Robert E. L. Turner	1992
	Donovan Van Osdol	*ex officio*

Associate Editors

Special Articles	Ronald L. Graham
	Jeffrey C. Lagarias

4.2.14. Proceedings

	William W. Adams	1992
	J. Marshall Ash	1992
	Maurice Auslander	1992
	Andreas Blass	1992
	Frederick R. Cohen	1991
Chair	William J. Davis	1991
	Clifford J. Earle, Jr.	1992
	Lawrence F. Gray	1993
	Palle E. T. Jorgensen	1992
	Jeff Kahn	1993
	Barbara Lee Keyfitz	1991
	Kenneth R. Meyer	1991
	Paul S. Muhly	1990
	George C. Papanicolaou	1991
	Louis J. Ratliff, Jr.	1991
	Jonathan M. Rosenberg	1991
	Franklin Tall	1993
	James E. West	1991
	Warren J. Wong	1991

4.2.15. Proceedings of Symposia in Applied Mathematics

Chair	Alexandre J. Chorin	1991
	Björn E. J. Dahlberg	1991
	Ronald L. Graham	1992

4.2.16. Transactions and Memoirs

	Avner D. Ash	1990
	James E. Baumgartner	1991
	James W. Cannon	1993
	Ralph L. Cohen	1990
	Burgess Davis	1992
	Eugene B. Fabes	1992
	Jerry L. Kazdan	1990
	Roger D. Nussbaum	1991
	Carl Pomerance	1991
	Judith D. Sally	1993
Chair	David J. Saltman	1990
	Masamichi Takesaki	1993
	Audrey A. Terras	1991

4.2.17. Translation from Chinese

	Sun-Yung Alice Chang
	S.-Y. Cheng
Chair	Tsit-Yuen Lam
	Tai-Ping Liu
	Chung-Chun Yang

4.2.18. Translation from Japanese

	Shoshichi Kobayashi
Chair	Katsumi Nomizu

Standing Committees

4.2.19. Advisory Committee for the Russian-English Dictionary

	Joseph N. Bernstein
Chair	Ralph P. Boas
	James R. Bunch
	Courtney S. Coleman
	Joseph L. Doob
	Bogdan Dudzik
	Eugene Dynkin
	Mark I. Freidlin
	Vladislav V. Goldberg
	Paul R. Halmos
	Edwin Hewitt
	John R. Isbell
	Anatole Katok
	George Mackey
	John McCarthy
	Boris Mityagin

	Eric John Fyfe Primrose	
	Boris Schein	
	Lawrence A. Shepp	
	Ben Silver	*ex officio*
	Smilka Zdrakovska	

4.2.20. History of Mathematics

	Richard A. Askey	1991
Chair	Peter L. Duren	1990
	Harold M. Edwards	1991

4.2.21. Subcommittee on Russian Mathematical History

	V. I. Arnol'd
	Richard A. Askey
	Igor Dolgachev
	S. G. Gindikin
	N. K. Nikol'skii

4.2.22. Reprinted Books

	Eugenio Calabi
	Charles W. Curtis
Chair	Oscar S. Rothaus

4.2.23. University Lecture Series

	Theodore W. Gamelin
	Donald S. Ornstein
Chair	Hugo Rossi
	Leonard L. Scott

4.3. Committees of the Board of Trustees

4.3.1. Agenda and Budget

All members of this committee serve *ex officio.*

	Steve Armentrout
	William Browder
	Robert M. Fossum
	Ronald L. Graham
	Irwin Kra
	Franklin P. Peterson

4.3.2. Appeals Committee on Discounted Subscriptions

Consultant	David Gregory	
	William H. Jaco	*ex officio*
Chair	Morton Lowengrub	
	Franklin P. Peterson	
	Paul J. Sally, Jr.	
Consultant	B. A. Taylor	

4.3.3. Audit

All members of this committee serve *ex officio.*

	Frederick W. Gehring
	Ronald L. Graham

4.3.4. Computer Operations and Facilities, Visiting Committee on

	Ronald L. Graham	*ex officio*
	Richard Mandelbaum	1992
	Jill P. Mesirov	1991
Chair	Peter J. Weinberger	1990

4.3.5. Corporate Relations

Chair	Ramesh A. Gangolli
	Maria M. Klawe
	Oscar S. Rothaus

4.3.6. Endowment

	Andrew M. Gleason
Chair	W. Ted Martin
	Cathleen S. Morawetz

4.3.7. Investment

All members of this committee serve *ex officio.*

	Steve Armentrout
	Frederick W. Gehring
Chair	Franklin P. Peterson

4.3.8. Legal Aid

	Steve Armentrout
	Todd Dupont
Chair	Murray Gerstenhaber

4.3.9. Liaison Committee

All members of this committee serve *ex officio.*

Chair	William Browder
	Robert M. Fossum
	Franklin P. Peterson

4.3.10. Long Range Planning

All members of this committee serve *ex officio.*

	Robert M. Fossum
	Ronald L. Graham
	William H. Jaco
	Franklin P. Peterson
	Hugo Rossi
Chair	William P. Thurston

4.3.11. Membership

	Susan Friedlander	1992
Chair	Frederick W. Gehring	1990
	Melvin Henriksen	1990
	Irwin Kra	1990
	Hugo Rossi	1991

4.3.12. The Publication Program

	Steve Armentrout	1990
	Robert Devaney	1992
	Robert M. Fossum	*ex officio*
	Eric Friedlander	1992
Chair	Ramesh A. Gangolli	1992
	William H. Jaco	*ex officio*
Consultant	Mary C. Lane	
	Cathleen S. Morawetz	1991
	Andrew M. Odlyzko	1992
	John C. Polking	*ex officio*
	Paul J. Sally, Jr.	*ex officio*

4.3.13. Salaries

All members of this committee serve *ex officio.*

	Steve Armentrout
	Frederick W. Gehring
Chair	Ronald L. Graham
	Franklin P. Peterson

4.3.14. Staff and Services

Chair	Steve Armentrout	*ex officio*
	Franklin P. Peterson	*ex officio*
	Paul J. Sally, Jr.	

Ad Hoc Committee

4.3.15. Institutional Membership

Consultant	Carol-Ann Blackwood	
	Ramesh A. Gangolli	
Chair	Frederick W. Gehring	
	Donovan H. Van Osdol	*ex officio*
	William A. Veech	

4.4. Internal Organization of the American Mathematical Society

Standing Committees

4.4.1. Archives

	Andrew M. Gleason	
	Franklin P. Peterson	
Chair	Everett Pitcher	

4.4.2. Committee on Committees

	M. Salah Baouendi	1990
	William Browder	*ex officio*
	Robert M. Fossum	*ex officio*
	Morris W. Hirsch	1990
	Rhonda J. Hughes	1990
	Irwin Kra	1990
	Philip Kutzko	1990
Chair	Julius L. Shaneson	1990

4.4.3. Library Committee

	Nancy Anderson	
	Richard A. Askey	
	Robert S. Doran	
	Dorothy McGarry	
Chair	James Rovnyak	
	George Seligman	
	Mary Ann Southern	
	Jack Weigel	

Ad Hoc Committees

4.4.4. Applications of Mathematics

	Frederick J. Almgren, Jr.	
Chair	Jerry L. Bona	
	Hermann Flaschka	
	Barbara Lee Keyfitz	
	David Mumford	
	Ivar Stakgold	
	Hans F. Weinberger	

4.4.5. 1989 Election Tellers

	Leo P. Comerford	
	Robert E. Megginson	

4.5. Program and Meetings

Standing Committees

4.5.1. Program Committee for National Meetings

	James G. Arthur	1991
	Spencer Bloch	1992
	Robert M. Fossum	*ex officio*
	Peter B. Gilkey	1990
	George A. Hagedorn	1990
	Peter Sarnak	1991
Chair	Jean E. Taylor	1991

4.5.2. Central Section Program Committee

	Carolyn S. Gordon	1991
	Robert Griess	1991
	Dennis A. Hejhal	1990
	Andy Roy Magid	*ex officio*
Chair	Mark Mahowald	1990

4.5.3. Eastern Section Program Committee

	W. Wistar Comfort	*ex officio*
	Detlef Gromoll	1990
Chair	Jerry L. Kazdan	1990
	Richard N. Lyons	1991
	Walter A. Strauss	1990

4.5.4. Southeastern Section Program Committee

	Joseph A. Cima	*ex officio*
	Ronald F. Gariepy	1991
	Ray A. Kunze	1990
Chair	William Pardon	1990
	Edward B. Saff	1991

4.5.5. Western Section Program Committee

	Michael Aschbacher	1991
Chair	Sun-Yung Alice Chang	1990
	Michael Crandall	1991
	Lance W. Small	*ex officio*
	John R. Stallings	1990

4.5.6. Agenda for Business Meetings

	M. Salah Baouendi	1990
Chair	Robert M. Fossum	
	Carol L. Walker	1990

4.5.7. Gibbs Lecturer for 1991 and 1992, Committee to Select

Chair	Elliott H. Lieb	
	Karen Uhlenbeck	
	David A. Vogan, Jr.	

4.5.8. Progress in Mathematics

	Hyman Bass	1992
Chair	Armand Borel	1991
	Paul H. Rabinowitz	1990
	Hugo Rossi	1990
	Alan D. Weinstein	1991

4.6. Status of the Profession

Standing Committees

4.6.1. Academic Freedom, Tenure, and Employment Security

	Ellis Kolchin	1992
	Thomas G. Kurtz	1990
Chair	Barbara L. Osofsky	1990
	Charles E. Rickart	1991
	Mary Ellen Rudin	1992
	Gail S. Young	1992

4.6.2. Academic Review

	Frederick W. Gehring
	Frank L. Gilfeather
	Andrew M. Gleason
Chair	J. K. Goldhaber

4.6.3. Human Rights of Mathematicians

	Raymond Ayoub	1991
	Joan S. Birman	1992
	Michael I. Brin	1990
	Chandler Davis	1991
	Joel L. Lebowitz	1990
	Cora S. Sadosky	1992
Chair	Alice T. Schafer	1990
	Steven Weintraub	1992

4.6.4. Liaison Committee on Education in Mathematics

	John A. Dossey
	Melvin Hochster
	Rogers J. Newman
	Louise A. Raphael
Chair	Paul J. Sally, Jr.
	James D. Stasheff
	Lynn A. Steen

4.6.5. Pi Mu Epsilon Liaison Committee

	Henry Alder	1990
	Rhonda J. Hughes	1991
	Ivan Niven	1990
	Eileen Poiani	1992
	Bruce Reznick	1990
Chair	Carol L. Walker	1991
	Carol S. Wood	1992

4.6.6. Professional Ethics

	C. Edmund Burgess	1990
	Harold M. Edwards	1991
	Frank L. Gilfeather	1990
Chair	Everett Pitcher	1992
	George B. Seligman	1991

4.6.7. Science Policy

	Michael Artin	*ex officio*
	Hyman Bass	1990
	William Browder	*ex officio*
	Frank L. Gilfeather	1990
	William H. Jaco	*ex officio*
	Joseph J. Kohn	1992
	Joel L. Lebowitz	1992
	Jerrold E. Marsden	1991
	Cathleen S. Morawetz	1991
	John C. Polking	1990
Chair	Michael C. Reed	1992
	Oscar S. Rothaus	1991
	Paul J. Sally, Jr.	1992
	David A. Vogan, Jr.	1991
	Mary F. Wheeler	1992

4.6.8. Service to Mathematicians in Developing Countries

Chair	Raymond G. Ayoub
	James A. Donaldson
	James Eells
	Donald M. Hill

Ad Hoc Committees

4.6.9. Cooperation with Latin American Mathematicians

Chair	Charles Herbert Clemens
	Samuel Gitler
	Carlos E. Kenig
	Joseph J. Kohn
	Horacio A. Porta
	Cora S. Sadosky

4.6.10. Coordinating Committee for the Doctoral Program in Mathematics

Chair	R. Creighton Buck
	Franklin P. Peterson
	Murray H. Protter

4.6.11. Education

Terms expire on February 1

	William Browder	*ex officio*
	Ramesh A. Gangolli	1992
	Andrew M. Gleason	1992
	Fern Y. Hunt	1992
	William J. Jaco	*ex officio*
	Don J. Lewis	1992
	Michael C. Reed	*ex officio*
	Richard A. Tapia	1992

4.6.12. Sigma Xi Liaison Committee

James Glimm
Mary Wheeler

4.6.13. Soviet Mathematicians, Committee to Study Relations with

	Chandler Davis
Chair	Robert MacPherson
	Hugo Rossi
	Lance W. Small

4.7. Prizes and Awards

Standing Committees

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

	Ronald G. Douglas	
Chair	Robert M. Fossum	*ex officio*
	John C. Polking	

	David P. Roselle	
	———	

4.7.2. Centennial Fellowships

Terms expire on June 30

	Robert L. Bryant	1992
	Joseph Lipman	1992
Chair	Dusa McDuff	1991
	Alexander J. Nagel	1991
	Raghavan Narasimhan	1992
	Karl Rubin	1991
	John B. Wagoner	1992

4.7.3. National Awards and Public Representation

	Michael Artin	*ex officio*
Chair	William Browder	*ex officio*
	Robert M. Fossum	*ex officio*
	Louis Nirenberg	1991

4.7.4. Subcommittee on Appointments of the Committee on National Awards and Public Representation

	Robert M. Fossum	*ex officio*
Chair	Irwin Kra	
	John C. Polking	

4.7.5. Satter Prize for 1991, Committee to Select the Winner of the

	Joan S. Birman
Chair	Linda Keen
	Karen Uhlenbeck

4.7.6. Steele Prizes

Terms expire on June 30

	Alexandre J. Chorin	1992
	Charles L. Fefferman	1991
	William J. Haboush	1992
	Jun-ichi Igusa	1991
	Arthur M. Jaffe	1992
	George Lusztig	1992
	Mark Mahowald	1992
	———	1993
	———	1993
	———	1993

Ad Hoc Committees

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

Chair	David Mumford
	Jacob T. Schwartz
	John L. Selfridge

4.7.8. Cole Prize, Committee to Select the Winner

	Michael Artin
	Walter Feit
Chair	Melvin Hochster

4.7.9. Veblen Prize, Committee to Select the Winner

	Edgar H. Brown, Jr.
Chair	Michael H. Freedman
	Mikhael Gromov

4.8. Institutes and Symposia

Standing Committee

4.8.1. Cooperative Symposia

	Robert M. Thrall
	Daniel H. Wagner

4.8.2. Liaison Committee with AAAS

	Richard A. Askey	*ex officio*
	Hyman Bass	1991
Chair	Jerry L. Bona	*ex officio*
	Cathleen S. Morawetz	*ex officio*
	Warren Page	1991
	Gian-Carlo Rota	1991
	Clifford Taubes	*ex officio*
	Alan D. Weinstein	1991

4.8.3. Summer Institutes and Special Symposia

Terms expire on February 28

	Nicholas Katz	1993
	Barbara Lee Keyfitz	1992
	Haynes R. Miller	1991
Chair	Raghavan Narasimhan	1991
	Brian Parshall	1992
	Francois Treves	1993

4.9. Joint Committees

4.9.1. AMS Liaison Committee with Deutsche Mathematiker Vereinigung

	Robert M. Fossum
	Dale Husemoller
	Bernd Ulrich

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

	Sylvia T. Bozeman	1992
	Claudette Bradley	1992
	Johnny E. Brown	1992
Chair	Gloria F. Gilmer	1992
	Shirley Malcom	*ex officio*
Consultant	Argelia Veléz-Rodriguez	

4.9.3. AMS-ASA-IMS-MAA-NCTM-SIAM Committee on Women in the Mathematical Sciences

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

	Marsha J. Berger (SIAM)	1992
	Grace M. Burton (NCTM)	1990
	Marjorie M. Enneking (NCTM)	1992
	Nancy Flournoy (IMS)	1992
Chair	Susan Geller (AMS)	1991
	Susan Goodman (AMS)	1992
	Mary Hesselgrave (MAA)	1991
	Patricia A. Jacobs (IMS)	1990
	Patricia Kenschaft (AWM)	
	Jeanne W. Kerr (AMS)	1992
	Edith Luchins (MAA)	1991
	Joyce R. McLaughlin (SIAM)	1990
	Anne Parkhurst (ASA)	

	Magda Peligrad (IMS)	1991
	Linda R. Petzold (SIAM)	1992
	Frances Rosamond (MAA)	1992
	M. Beth Ruskai (AMS)	1992
	Alice T. Schafer (MAA)	1991

4.9.4. AMS-ASL-IMS-SIAM Committee on Translations from Russian and Other Slavic Languages

Chair	Peter Landweber (AMS)	1991

AMS Subcommittee Members

Consultant	V. I. Arnol'd	
	Joseph N. Bernstein	1990
	David G. Ebin	1991
Consultant	S. G. Gindikin	
	Anatole Katok	1990
Consultant	Askol'd Georgievic Khovanskii	
Chair	Peter Landweber (AMS)	1991
	Alexander Lichtman	1991
Consultant	N. K. Nikol'skii	

ASL Subcommittee Members

	Vladimir Lifschitz	1990
Chair	Elliott Mendelson	1992
	Gregory Mints	1990
	Benjamin F. Wells	1992

IMS Subcommittee Members

Chair	M. I. Freidlin
	B. Pittel
	A. Rukhin
	W. J. Studden

4.9.5. AMS-IMS-SIAM Committee on Joint Summer Research Conferences in the Mathematical Sciences

Terms expire on June 30

	Fan R. K. Chung (AMS)	1993
	Leonard Evens (AMS)	1993
Chair	Martin Golubitsky (SIAM)	1994
	Anthony W. Knapp (AMS)	1992
	Peter W. K. Li (AMS)	1993
	Emanuel Parzen (IMS)	1991
	Stewart B. Priddy (AMS)	1994
	Gregg J. Zuckerman (AMS)	1992
	________(SIAM)	1994
	________(IMS)	1994
	________(AMS)	1994

4.9.6. AMS-LMS Joint Program Committee

William Abikoff
Hyman Bass
Robert M. Fossum

4.9.7. AMS-MAA Joint Archives Committee

	Leonard Gillman
	Uta C. Merzbach
	Everett Pitcher
Chair	Sanford L. Segal

4.9.8. AMS-MAA Arrangements Committee for the San Francisco Meeting January 16–19, 1991

	William Chinn	
	Guy M. De Primo	
	Judith Ekstrand	
Chair	Newman Fisher	
	William H. Jaco	*ex officio*
	Millianne Lehman	
	Andy Roy Magid	*ex officio*
	Peter S. Pacheco	
	Kenneth A. Ross	*ex officio*
	Franklin Sheehan	
	Tom Walsh	

4.9.9. AMS-MAA Joint Program Committee for the San Francisco Meeting

	Peter B. Gilkey (AMS)
Chair	George A. Hagedorn (AMS)
	David P. Roselle (MAA)
	Audrey A. Terras (MAA)

4.9.10. AMS-MAA Arrangements Committee for the Orono Meeting August 8-11, 1991

	Joseph A. Cima	*ex officio*
	William H. Jaco	*ex officio*
Chair	Grattan Murphy	
	Kenneth A. Ross	*ex officio*

4.9.11. AMS-MAA Joint Meetings Committee

All members of this committee serve *ex officio.*

Consultant	H. Hope Daly
	Robert M. Fossum
Chair	William H. Jaco
	Kenneth A. Ross
	Marcia P. Sward

4.9.12. AMS-MAA Data Committee

Chair	Edward A. Connors (AMS)	1990
Consultant	Lincoln K. Durst	
	John D. Fulton (MAA)	1991
	James F. Hurley (AMS)	1991
	Charlotte Lin (AMS)	1992
	Don O. Loftsgaarden (MAA)	1990
	David J. Lutzer (MAA)	1990
	James W. Maxwell (AMS)	*ex officio*
	Donald E. McClure (AMS)	1990
	Donald C. Rung (AMS)	1992

4.9.13. AMS-MAA Committee on Employment and Educational Policy

	Donna L. Beers (AMS)	1991
	Morton Brown (MAA)	1992
Chair	Edward A. Connors (AMS)	1991
	Philip C. Curtis, Jr. (MAA)	1990
	David J. Lutzer (MAA)	1992
	Bernard L. Madison (AMS)	1992
	James W. Maxwell	*ex officio*
	James J. Tattersall (MAA)	1990

4.9.14. Short Course Subcommittee

Chair	Stefan A. Burr	1992
	R. Peter DeLong	1991
	Lisl Novak Gaal	1992
	Robert P. Kurshan	1990
	Barbara L. Osofsky	1991
	Marjorie L. Stein	1990
	James J. Tattersall	1990

4.9.15. AMS-MAA Committee on Teaching Assistants and Part Time Instructors (TA/PTI)

	Thomas F. Banchoff (AMS)	1992
	Edward A. Connors (AMS)	1991
	Stephen A. Doblin (MAA)	1991
Chair	John P. Huneke (MAA)	1992
	Don R. Lick (MAA)	1991
	Shelba J. Morman (MAA)	1992
	Thomas T. Read (AMS)	1991
	Robert H. Szczarba (AMS)	1990

4.9.16. AMS-MAA-SIAM Joint Committee on Employment Opportunities

	Peter E. Castro (SIAM)	1992
	Ronald M. Davis (MAA)	1990
	James W. Maxwell	*ex officio*
	S. Brent Morris (AMS)	1991
	Marc A. Rieffel (MAA)	1991
Chair	Donald C. Rung (AMS)	1990
	Leon H. Seitelman (SIAM)	1991

4.9.17. AMS-MAA-SIAM Joint Administrative Committee

All members of this committee serve *ex officio*.

	Gerald L. Alexanderson (MAA)
	I. Edward Block (SIAM)
Chair	Robert M. Fossum (AMS)
	Samuel Gubins (SIAM)
	William H. Jaco (AMS)
	Donald L. Kreider (MAA)
	Franklin P. Peterson (AMS)
	Ivar Stakgold (SIAM)
	Marcia P. Sward (MAA)

4.9.18. AMS-MAA-SIAM Joint Policy Board for Mathematics (see 1990 Mathematical Sciences Professional Directory, page 27)

4.9.19. AMS-SIAM Committee on Applied Mathematics

	James M. Hyman	1990
	Andrew J. Majda	1992
	Lawrence A. Shepp	1991
	Joel Spencer	1992
Chair	Gilbert Strang	1991
	Robert F. Warming	1990

4.9.20. AMS-SIAM Committee to Screen Applicants for Graduate Study from the People's Republic of China

David Benney
Robert Bryant

4.9.21. AMS-SIAM Committee to Select the Winner of the Wiener Prize of 1990

	Elliott H. Lieb
Chair	I. M. Singer
	Stephen Smale

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

	Jack D. Cowan	1991
	James W. Curran	1993
	Marcus B. Feldman	1991
	Eric S. Lander	1993
Chair	Marc Mangel	1992
	James Murray	1992

5. Representatives

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

Ralph P. Boas

5.0.2. American Association for the Advancement of Science

Terms expire on February 12

Section A	Cathleen S. Morawetz	1992
Section B	Clifford Taubes	1992
Section L	Richard A. Askey	1992
Section Q	Jerry L. Bona	1992
Section T	Martin D. Davis	1992

5.0.3. Commission on Professionals in Science and Technology

Edward A. Connors

5.0.4. Committee on the American Mathematics Competition

Term expires on June 30

Guido L. Weiss 1990

5.0.5. Conference Board of the Mathematical Sciences

William Browder 1990

5.0.6. Fulkerson Prize Committee

Alan J. Hoffman

5.0.7. U.S. National Committee on Theoretical and Applied Mechanics

Term expires on October 31

Constantine M. Dafermos 1992

6. Index

Miscellaneous

Deaths

V.W. Adkisson, of Fayetteville, Arkansas, died on April 15, 1988, at the age of 83. He was a member of the Society for 58 years.

Harold E. Benzinger, of the University of Illinois, died on June 25, 1990, at the age of 49. He was a member of the Society for 26 years.

Michael C. Blad, of the University of Sydney, died on March 26, 1990, at the age of 41. He was a member of the Society for 9 years.

Esther Comegys, of Needham, Massachusetts, died on April 10, 1990, at the age of 91. She was a member of the Society for 65 years.

Michael Goldberg, of Washington, D.C., died on March 9, 1990, at the age of 87. He was a member of the Society for 61 years.

Marshall Hall, Jr., of Emory University, died on July 4, 1990, at the age of 79. He was a member of the Society for 59 years.

Richard A. Roice, of the University of Montana, died on February 3, 1990, at the age of 35. He was a member of the Society for 9 years.

Hans Schwerdtfeger, of the University of Adelaide, died on June 26, 1990, at the age of 87. He was a member of the Society for 46 years.

Visiting Mathematicians

(Supplementary List)

The list of visiting mathematicians includes both foreign mathematicians visiting in the United States and Canada, and Americans visiting abroad. Note that there are two separate lists.

American Mathematicians Visiting Abroad

Name and Home Country	Host Institution	Field of Special Interest	Period of Visit
Dinculeanu, Nicolae (U.S.A.)	Université de Paris	Vector Measures and Integration Theory, Functional Analysis	7/90 - 12/90

Visiting Foreign Mathematicians

Name and Home Country	Host Institution	Field of Special Interest	Period of Visit
Baker, Roger C. (England)	Brigham Young University	Analytic Number Theory	8/90 - 12/90
Burdzy, Krzysztof (U.S.A., Poland)	York University	Probability Theory	9/90 - 12/90
Gouvea, Fernando (Brazil)	Queen's University	Number Theory	9/90 - 8/91
Jensen, Christian (Denmark)	Queen's University	Algebra and Number Theory	9/90 - 10/90
Landver, Avner (Israel)	University of Kansas	Logic, Set-Theory Topology	8/90 - 7/92
Lin, Zongzhu (China)	University of Washington	Algebraic Groups	9/89 - 6/92
Macedonska-Nosalska, Olga (Poland)	York University	Group Theory	9/90 - 5/91
Miyaoka, Yoichi (Japan)	Johns Hopkins University	Algebraic Geometry	11/90 - 12/90
Moran, William (Australia)	Brigham Young University	Analytic Number Theory	1/91 - 5/91
Morgan, Charles (England)	Auburn University	Set Theory	9/90 - 9/91
Myerson, Gerald (Australia)	Brigham Young University	Analytic Number Theory	8/90 - 12/90
Pol, Roman (Poland)	University of Washington	∞-dim Topology	9/90 - 6/91
Pumplün, H.-Dieter (West Germany)	York University	Category Theory, Analysis	9/90 - 12/90
Putinar, Mihai (Romania)	University of Kansas	Operator Theory	1/91 - 5/91
Schinazi, Rinaldo (Brazil)	York University	Probability Theory	7/90 - 6/91
Shephard, Geoffrey (England)	University of Washington	Geometry, Combinatorics, Group Theory	9/90 - 12/90
Sitaram, Alladi (India)	University of Washington	Harmonic Analysis	12/90 - 6/91
Solomyak, Boris (U.S.S.R.)	University of Washington	Functional Analysis	9/90 - 6/91
Spiez, Stanislaw (Poland)	University of Washington	Topology	9/90 - 6/91
Stettner, Lukasz (Poland)	University of Kansas	Stochastic Control Theory	8/90 - 12/90
Szmigielski, Jacek (Poland)	University of Kansas	Differential Geometry	9/90 - 7/92
Weil, Wolfgang (Germany)	University of Oklahoma	Convexity	9/90 - 12/90

Classified Advertisements

SUGGESTED USES for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

THE 1990 RATE IS \$50.00 per inch on a single column (one-inch minimum), calculated from the top of the type; \$22 for each additional 1/2 inch or fraction thereof. No discounts for multiple ads or the same ad in consecutive issues. For an additional \$10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Advertisements in other sections of the classified pages will be set according to the advertisement insertion. Headlines will be centered in boldface at no extra charge. Classified rates are calculated from top of type in headline to bottom of type in body copy, including lines and spaces within. Any fractional text will be charged at the next 1/2 inch rate. Ads will appear in the language in which they are submitted.

Prepayment is required of individuals but not of institutions. There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified advertising.

DEADLINES are listed on the inside front cover or may be obtained from the AMS Advertising Department.

U. S. LAWS PROHIBIT discrimination in employment on the basis of color, age, sex, race, religion or national origin. "Positions Available" advertisements from institutions outside the U. S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U. S. laws. Details and specific wording may be found near the Classified Advertisements in the February and July/August issues of the *Notices*.

SITUATIONS WANTED ADVERTISEMENTS from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada for further information.

SEND AD AND CHECK TO: Advertising Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Individuals are requested to pay in advance, institutions are not required to do so. AMS FAX 401-331-3842.

POSITIONS AVAILABLE

CALIFORNIA

HARVEY MUDD COLLEGE
Clare Booth Luce Professorship
Department of Mathematics

Harvey Mudd College invites applications from outstanding women candidates for appointment to a **Clare Boothe Luce** Assistant/Associate Professorship in the Department of Mathematics starting in 1991/1992. Preference will be given to applicants whose research and teaching interests are in differential equations, dynamical systems, or applied analysis.

The successful candidate will be expected to teach courses in her area of specialization, as well as general introductory calculus and differential equations courses, and to pursue an active research program. The **Clare Boothe Luce Professorship** provides substantial supplemental funds for five years which can be used to cover professionally related expenses.

Harvey Mudd College is a selective institution specializing in Engineering, Mathematics and the Sciences. It is a member of the Claremont Colleges, an internationally renowned group of five independent undergraduate Colleges plus a Graduate School which offers a Ph.D. program in Mathematics and provides opportunities for graduate level teaching and thesis supervision. The applied mathematics program includes the Mathematic Clinic, a mode of instruction pioneered in Claremont which attracts projects funded by industrial organizations.

Interested women should send a **curriculum vitae**, a statement of current research interests, and information on teaching experience. Candidates should arrange to have three letters of reference sent and those candidates at the beginning assistant professor level should also arrange for official transcripts to be sent. All application materials should be sent or mailed as soon as possible but, at the latest, to meet an October 1, 1990 deadline. Please address inquiries and applications to:

Dr. H. Krieger, Chair, Department of Mathematics,
Harvey Mudd College, Claremont, CA 91711
(714) 621-8000 ext.3618/8023
FAX: (714) 621-8465

Harvey Mudd College is an equal opportunity, affirmative action employer.

DISTRICT OF COLUMBIA

HOWARD UNIVERSITY

Mathematics: Both visiting and tenure track positions are anticipated (rank open) for 1991-92. Ph.D., demonstrated excellence in teaching and active participation in research required. We encourage applicants in statistics, algebra and in algebraic geometry, but other applications are welcome. Send resume and direct three letters of reference to: Chairman, Mathematics Department, Howard University, Washington, D.C. 20059. Deadline: December 31, 1990. Howard University is an Equal Opportunity Employer.

FLORIDA

THE UNIVERSITY OF FLORIDA
Department of Mathematics

In each of the next several years, the Department of Mathematics intends to fill a number of tenure-track faculty positions with mathematicians of exceptional caliber. In the coming year, special consideration will be given to filling positions in the following areas of research: algebraic geometry and number theory, topology, numerical analysis, and probability theory. However, outstanding candidates from all areas of pure and applied mathematics are invited to apply for these positions.

Candidates at all ranks will receive serious consideration, but it is expected that most positions will be filled at the level of assistant professor. Applications from junior candidates with post-doctoral experience are especially welcome.

Senior candidates should have distinguished research records, and junior candidates are expected to have made significant research contributions. Every candidate is expected to possess a strong commitment to teaching. Candidates should forward a resume (including a list of publications) and should arrange for at least four letters of recommendation to be sent to:

David A. Drake, Chair
Department of Mathematics
University of Florida
201 Walker Hall
Gainesville, FL 32611-2082

All applications for the academic year 1991-92 should be complete by December 31, 1990. The University of Florida is an equal opportunity employer and energetically solicites applications from women and minority candidates.

GEORGIA

ITERATED SYSTEMS, INC.
of
Norcross, Georgia

is seeking six mathematicians to do creative, challenging research on fractal image compression in an entreprenurial setting. Salaries are extremely competitive. Some positions available immediately. Applicants should show some computing experience and a record of innovative, beautiful research. Send resume to:

Mary Heagle
Iterated Systems, Inc.
5550A Peachtree Parkway, Suite 545
Norcross, GA 30092

EO/AAE

ILLINOIS

NORTHWESTERN UNIVERSITY
Department of Mathematics
2033 Sheridan Road
Evanston, Illinois 60208-2730

Applications are invited for one or more tenure-track positions starting September 1991. Although priority will be given to young, exceptional research mathematicians (no more than several years after Ph.D.), more senior candidates with very exceptional credentials may be considered for a tenured position. Fields of interest of the department include Algebra, Analysis, Dynamical Systems, Probability, Partial Differential Equations, and Topology. Northwestern is an affirmative action, equal opportunity employer committed to fostering a diverse faculty, so women and minority candidates are especially encouraged to apply. Candidates should arrange that at least three letters of recommendation be sent to Chair, Personnel Committee, Department of Mathematics, Northwestern University, Evanston, Illinois 60208. In order to receive full consideration, applications should be received by January 7, 1991. Hiring is contingent upon eligibility to work in the United States.

NORTHWESTERN UNIVERSITY
Department of Mathematics
2033 Sheridan Road
Evanston, Illinois 60208-2730

The Mathematics Department will sponsor an Emphasis Year in algebraic topology, cohomology of groups, and related topics. This program will include 2-year Assistant Professorship positions starting September 1991 and possible visiting positions for more senior mathematicians for part or all of the academic year.

Applications should be sent to Prof. Mark E. Mahowald at the department address and include a curriculum vitae and three letters of recommendation. In order to ensure full consideration, an application must be received by January 30, 1991.

Northwestern University is an Affirmative Action/Equal Opportunity employer. Hiring is contingent upon eligibility to work in the United States.

MARYLAND

THE JOHNS HOPKINS UNIVERSITY
Mathematics Department

Applications are invited for two positions beginning July 1991 in analysis, at least one of which is at the full professor level. Areas of particular interest are partial differential equations and geometric analysis. Outstanding research accomplishments and commitment to teaching are required. These positions represent part of the Department's commitment to increase its representation in analysis.

Minority and women candidates are encouraged to apply. The Johns Hopkins University is an affirmative action/equal opportunity employer.

Applications should be sent to Search Committee, Department of Mathematics, The Johns Hopkins University, Baltimore, Maryland 21218.

MICHIGAN

FERRIS STATE UNIVERSITY
HEAD, DEPARTMENT OF MATHEMATICS

Ferris State University invites nominations and applications for the position of Head of the Department of Mathematics. The Department of Mathematics has 23 faculty and is responsible for undergraduate education in math and computer science and for baccalaureate programs in Applied Mathematics and Actuarial Science. QUALIFICATIONS: An earned doctorate in Mathematics or Applied Mathematics, or an earned doctorate in Mathematics Education with a Master's in Mathematics; professional development and teaching experience appropriate to senior rank; familiarity with a broad spectrum of math instruction; ability to work with others in a broad array of disciplines; and personal qualities of integrity, industriousness, organization, leadership and interpersonal skills.

Ferris State University is a career-oriented, open-admissions, state-funded institution in western Michigan with 11,800 students and over 120 degree programs. Its Schools include Allied Health, Arts and Sciences, Business, Education, Pharmacy, Technology, and the College of Optometry.

Review of applications will begin August 30, 1990, with tentative start date of December 1, 1990. Send letter of interest, curriculum vita, 3 letters of reference, and official transcripts to: George Wales, Search Committee Chair, Starr 120, Ferris State University, Big Rapids, MI 49307. EO/AAE

MICHIGAN STATE UNIVERSITY
CHAIRPERSON
Department of Mathematics

Michigan State University invites applications for the position of Chairperson of the Department of Mathematics. The Department has more than 70 regular faculty; over 125 graduate students are enrolled in its Ph.D. and Masters degree programs.

Applicants should have an outstanding record of research and scholarly activity in mathematics. Applicants should also possess the leadership and administrative skills necessary to chair a department with major research, teaching, and service responsibilities.

To apply, please send a vita and have at least three letters of recommendation sent to Professor Sheldon Axler, Chair Search Committee, Department of Mathematics, Michigan State University, East Lansing, MI 48824. Applications and recommendation letters should arrive by 31 December 1990. Inquiries and nominations should also be sent to the above address (or via e-mail to axler@msu.bitnet).

The position of Chairperson carries tenure at the rank of Professor and is available on 1 September 1991. Salary is competitive and will be commensurate with qualifications.

Applications are strongly encouraged from groups that are traditionally underrepresented in mathematics. MSU is an Affirmative Action/Equal Opportunity Institution.

OHIO

OBERLIN COLLEGE
Department of Mathematics
Oberlin, OH 44074

Four-year, full-time, continuing position at the level of Instructor, Assistant Professor, or higher, starting 1991-92. Ph.D. in hand or expected by September 1991. Background in modern applied analysis essential. **All specialities considered** but preference given to chaotic dynamical systems, numerical analysis, and approximation theory. Excellence in teaching and productive scholarship required. Five courses per year, including at least one advanced course in modern applied analysis. Salary commensurate with qualifications and experience. Vita, transcripts, and three letters of reference to be received by November 9, 1990. Send to Michael Henle, Department of Mathematics, Oberlin College, Oberlin, Ohio 44074. Affirmative Action Equal/Opportunity Employer. Applications will continue to be accepted until the position is filled.

OBERLIN COLLEGE
Department of Mathematics
Oberlin, OH 44074

Four-year, full-time, continuing position at the level of Instructor, Assistant Professor, or higher, starting 1991-92. Ph.D. in hand or expected by September 1991. Background in Operations Research and interest in applied mathematics essential. Excellence in teaching and productive scholarship required. Five courses per year, including a two-course OR sequence. Salary commensurate with qualifications and experience. Vita, transcripts, and three letters of reference to be received by November 9, 1990. Send to Michael Henle, Department of Mathematics, Oberlin College, Oberlin, Ohio 44074. Affirmative Action/Equal Opportunity Employer. Applications will continue to be accepted until the position is filled.

THE OHIO STATE UNIVERSITY
Department of Mathematics

The Department of Mathematics of The Ohio State University hopes to have available several positions, both visiting and permanent, effective Autumn Quarter 1991. Candidates in all areas of applied and pure mathematics, including those with demonstrated interest in pedagogical matters, are invited to apply. Significant mathematical research accomplishments or exceptional promise, and evidence of good teaching ability, will be expected of successful applicants.

Please send credentials and have letters of recommendation sent to Professor Dijen Ray-Chaudhuri, Department of Mathematics, The Ohio State University, 231 W. 18th Avenue, Columbus, Ohio 43210. Review of resumes will begin immediately.

The Ohio State University is an Equal Opportunity/Affirmative Action employer. Qualified women and minority candidates are encouraged to apply.

THE OHIO STATE UNIVERSITY
Department of Mathematics
Research Instructorships in Mathematics

The Department of Mathematics of The Ohio State University hopes to have available a few research instructor positions for the academic year 1991-92. Candidates should hold a Ph.D. (or equivalent) in mathematics and show strong research promise.

Please send credentials and have letters of recommendation sent to Professor Dijen Ray-Chaudhuri, Department of Mathematics, The Ohio State University, 231 W. 18th Avenue, Columbus, Ohio 43210. The Ohio State University is an Equal Opportunity/Affirmative Action Employer.

OREGON

OREGON STATE UNIVERSITY

Assistant Professor positions in Algebra, Differential Geometry, Differential Equations, Dynamical Systems, Geometric Measure Theory and other fields will become available September 16, 1991. Salary depends on qualifications. Closing date is December 1, 1990. Write to:

Professor Bent Petersen, Chair
Staff Selection Committee
Department of Mathematics
Oregon State University
Corvallis, Oregon 97331-4605

OSU is an Affirmative Action/Equal Opportunity Employer and complies with Section 504 of the Rehabilitation Act of 1973. OSU has a policy of being responsive to the needs of dual-career couples.

OREGON STATE UNIVERSITY

The Andreotti Assistant Professor position in mathematics will become available September 16, 1991. The Andreotti position is a tenure-track position. Teaching duties consist of one course per term for the first two years. The position includes summer research support for the first two summers. It is restricted to individuals who have held a Ph.D. for at most three years. Salary depends on qualifications. Closing date is December 1, 1990. Write to:

Professor Bent Petersen, Chair
Staff Selection Committee
Department of Mathematics
Oregon State University
Corvallis, Oregon 97331-4605

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PENNSYLVANIA

BRYN MAWR COLLEGE
Department of Mathematics

Bryn Mawr College invites applications for a tenure track assistant professorship in Mathematics, to start September 1991. Candidates should have a doctorate in a mathematical science, or expect to have completed it by Sept. 1, 1991. Candidates are expected to show promise in research and a commitment to teaching. All fields are acceptable, with a preference for algebra or applied mathematics. Bryn Mawr is an Equal Opportunity/Affirmative Action employer, and seeks faculty and staff knowledgable about and concerned with multicultural and international issues. Minority candidates and women are especially encouraged to apply. Closing date January 1, 1991. (Late applications may be considered.) Send application and three letters of recommendation to:

Search Committee
Department of Mathematics
Bryn Mawr College
Bryn Mawr, PA 19019

Telephone: (215)526 5348.
Email: MSEARCH@BRYNMAWR.

CARNEGIE MELLON UNIVERSITY
Zeev Nehari Assistant Professorship in Mathematics

The Zeev Nehari Assistant Professorships have been instituted in the Department of Mathematics of Carnegie Mellon University to honor the memory of Professor Zeev Nehari, a member of the Department from 1954 to his death in 1978. The position available is for an initial period of one or two academic years, beginning in September 1991, and extendable for one additional year when mutually agreeable. It carries a reduced academic year teaching load of six hours per week during one semester and three hours per week during the other. Applicants are expected to show exceptional research promise, as well as clear evidence of achievement and should have research interests which intersect those of current faculty of the Department. Applicants should arrange to have three letters of recommendation sent to the Appointments Committee, send a vita, a list of publications and a statement describing current and planned research. It is important that the latter explain the relation of the proposed work to that currently done in the Department. All communications should be addressed to: Appointments Committee, Department of Mathematics, Carnegie Mellon University, Pittsburgh, PA 15213. Carnegie Mellon University is an Affirmative Action/Equal Opportunity Employer.

CARNEGIE MELLON UNIVERSITY
Department of Mathematics

The Department expects to make one tenure-track appointment, to begin in the Fall of 1991, at the Assistant Professor level. We particularly seek candidates in the area of computational mathematics, but also will consider other areas of research which strongly intersect those of the current faculty of the Department. Applicants should send a vita, list of publications, and a statement describing current and planned research, and arrange to have at least three letters of recommendation sent to the committee. All communications should be addressed to: Appointments Committee, Department of Mathematics, Carnegie Mellon University, Pittsburgh, PA 15213. Carnegie Mellon University is an Affirmative Action/Equal Opportunity Employer.

CARNEGIE MELLON UNIVERSITY
Department of Mathematics

The Department expects to make at least one Post-Doctoral appointment for 1991-1992 in the area of applied analysis. This is a one-year (twelve-month) appointment. Applicants should send a vita, list of publications, and a statement describing current and planned research, and arrange to have at least three letters of recommendation sent to the committee. All communications should be addressed to: Appointments Committee, Department of Mathematics, Carnegie Mellon University, Pittsburgh, PA 15213. Carnegie Mellon University is an Affirmative Action/Equal Opportunity Employer.

RHODE ISLAND

BROWN UNIVERSITY
Providence, RI 02919

One professorship at the Associate Professor level or above, with tenure to begin July 1, 1991. Salary to be negotiated. Preference to be given to applicants with research interests consonant with those of the present members of the Department. Preference will be given to those applicants with research interests in differential geometry and related fields. Candidates should have a distinguished research record and a strong commitment to teaching. Qualified individuals are invited to send a vita and at least three letters of recommendation, no later than October 31, 1990, to Professor Robert D. M. Accola (Senior Search), Executive Officer, Department of Mathematics, Brown University, Providence, Rhode Island 02912. Brown University is an Equal Opportunity/Affirmative Action employer.

TEXAS

SOUTHERN METHODIST UNIVERSITY
Department of Mathematics

The Department of Mathematics seeks applications for a full professor, with the appointment to begin in Fall 1991. This appointment is subject to final budgetary approval. Applicants must have a distinguished research record in some area of applied mathematics. Experience in supervising doctoral dissertations, a successful grant record and commitment to teaching are essential. The successful candidate will teach undergraduate and graduate students and will be expected to supervise students in our doctoral program in applied mathematics.

Thirteen of the sixteen full-time faculty in the Department of Mathematics are applied or numerical mathematicians. Departmental research interests include fluid mechanics, asymptotic and perturbation methods, nonlinear waves, chaotic dynamics, bifurcation theory, combustion theory, mathematical biology, numerical analysis of differential equations and mathematical software.

Application deadline is November 1, 1990. Applications should be sent to Professor Ian Gladwell, Chair, Department of Mathematics, Southern Methodist University, Dallas, Texas 75275; phone: (214) 692-2506, Fax: (214) 692-4099. Professor Gladwell may also be contacted with enquiries about the position. His email addresses are:

h5nr1001@smuvm1 (on bitnet)
gladwell11@seas.csevax.smu.edu

SMU is an equal opportunity/affirmative action/Title IX employer.

UNIVERSITY OF TEXAS AT EL PASO
Department of Mathematical Sciences

The Department of Mathematical Sciences invites applications for three or four tenure track Assistant Professorships (subject to final budgetary approval) to begin duties in Fall 1991. Research interests in the Department include analysis, logic programming/non-monotonic reasoning, numerical analysis, number theory, probability, statistics, topology and ordered algebraic systems. Candidates with research interests in numerical analysis, applied analysis, logic/artificial intelligence, discrete mathematics, (or which match current research in the department) will receive some preference, but all areas will be considered. The department offers Bachelors and Masters degrees in Mathematics, Applied Mathematics and Statistics and is developing an Actuarial Science concentration. Salaries are competitive. Candidates must show strong potential for excellence in teaching and research. Women and minority candidates are especially encouraged to apply. Send complete Curriculum Vitae (with e-mail address if available) and arrange for three letters of reference to be sent to James E. Nymann, Chairman, Faculty Recruiting Committee, Department of Mathematical Sciences, The University of Texas at El Paso, El Paso, Texas 79968-0514. E-mail inquiries may be made to DS00@UTEP.BITNET. Consideration of applications will begin November 19. Applications received after this date may be considered until the positions are filled or the search abandoned. The right to leave positions unfilled is reserved.

The University of Texas at El Paso is an Affirmative Action/Equal Opportunity Employer.

VIRGINIA

UNIVERSITY OF VIRGINIA
FACULTY POSITION

The Department of Applied Mathematics at the University of Virginia seeks a new faculty member committed to teaching and research, with interests in the formulation, analysis, and solution of partial differential equations. Such interests should intersect at least one of the three areas of expertise in the Department: Continuum Mechanics, Control Theory, and Numerical Analysis/Scientific Computing. Rank and salary will be commensurate with experience and qualifications.

The Department, which currently has eleven faculty, 27 undergraduates, and 33 graduate students, is part of the School of Engineering and Applied Science, and also maintains close ties with the Mathematics Department in the College of Arts and Sciences.

The University of Virginia is an equal opportunity/affirmative action employer. Women and minorities are especially encouraged to apply.

Applications should be sent to:
James G. Simmonds, Chair
Department of Applied Mathematics
Thornton Hall
University of Virginia
Charlottesville, VA 22903

WASHINGTON AND LEE UNIVERSITY
Department of Mathematics
Lexington, VA 24450

RADFORD PROFESSOR/DEPT. HEAD

The Radford Chair of Mathematics will be filled in September, 1991. An applicant should have a background that warrants tenure and the rank of full professor, a record of effective teaching and scholarship, and a commitment to mathematics education in a liberal-arts setting. The Radford Professor will assume the position of department head for a five-year term.

The mathematics faculty numbers seven, all with PhD's. The University is primarily a liberal-arts college with 1600 undergraduates. It is 240 years old and is located in the lower Shenandoah Valley. *Address inquiries to Prof. R. S. Johnson, Search Committee, Mathematics Department. The selection process will begin in November, 1990.* AA/EOE

CANADA

UNIVERSITY OF TORONTO
Department of Mathematics

The Department of Mathematics, University of Toronto is looking for strong female applicants in pure or applied mathematics to nominate as candidates for NSERC Research Fellowships for 1991-92. These fellowships constitute a new programme, in many ways similar to the recently discontinued University Research Fellowships, but are restricted to women applicants. They are five year research positions (subject to a review in the third year) with a teaching load of one course per year. One of the five years may usually be taken as a sabbatical. Successful candidates may, in special circumstances, be considered directly for a tenure-stream position.

Applicants should have a relatively recent doctorate and have demonstrated their ability with some substantive post-thesis research. They must be Canadian citizens or landed immigrants by October 15, 1990.

Applicants should send an up-to-date curriculum vitae, a short description of their research program and arrange to have three letters of reference sent directly to Professor J. Repka, Associate Chairman, Department of Mathematics, University of Toronto, Toronto, Ontario, Canada M5S 1A1. This material should arrive before October 1, 1990. The Department's choice of candidates will be made in the first week of October and the final decision will subsequently be announced by NSERC.

JAMAICA

UNIVERSITY OF THE WEST INDIES
MONA, JAMAICA

The University of the West Indies is seeking candidates for two CHAIRS, one in MATHEMATICS and one in COMPUTER SCIENCE, at its Mona Campus. The appointments will be on tenure or tenure track. The Professors are expected to contribute significantly to the development of the disciplines and to lead major research programmes. The University will make every effort to provide the appointees with funding for postdoctoral fellowships, research assistants, research students, and for conference travel. Fund raising through grants will be encouraged. Comfortable housing will be provided at nominal rentals and other attractive perquisites are offered. Consultancies are allowed within the University rules. Detailed applications including full curriculum vitae, outline of present main field of research, programmes the applicants would wish to pursue at UWI, and names and addresses of three referees should be sent as soon as possible to the UNIVERSITY REGISTRAR, UWI, MONA, KINGSTON 7, JAMAICA, from whom further particulars are available. To expedite the appointment procedure applicants are advised to ask their referees to send confidential reports direct to the University without waiting to be contacted.

NEW ZEALAND

VICTORIA UNIVERSITY OF WELLINGTON
LECTURESHIP/SENIOR LECTURESHIP IN MATHEMATICS

Applications are invited from suitably qualified persons for the above position in the Department of Mathematics. Applications in all areas of mathematics will be considered seriously, and are particularly welcome in fields relevant to modern applications of mathematics, or computational mathematics. Applicants are expected to show strong potential in both teaching and research.

Enquiries about academic aspects of the position may be directed to Professor Rob Goldblatt, Department of Mathematics, e-mail (Internet):rob@math.vuw.ac.nz.

Salary scale for Lecturers is $NZ36,000–$NZ47,200 per annum; for Senior Lecturers $NZ50,000–$NZ64,500 per annum.

Conditions of appointment and method of application available from the Appointments Administrator, Victoria University of Wellington, PO Box 600, Wellington, New Zealand (fax:04-711 700) with whom applications close on **1 October 1990**.

THE UNIVERSITY IS AN EQUAL OPPORTUNITY EMPLOYER

PUBLICATIONS

GEOMETRY NEWSLETTER

In an attempt to more rapidly disseminate new results in differential geometry, global analysis, analysis on manifolds and related topics we are starting a newsletter whose entries list title, author, publication and address of author responsible for handling preprint requests. To have papers listed please send preprints to

Della C. Duncan
Department of Mathematics
California State University
Fresno, CA 93740-0108

Copies will be sent upon request.

PROCEEDINGS OF THE SECOND SOVIET-JAPAN JOINT SYMPOSIUM OF TOPOLOGY

held in Khabarovsk, USSR in 1989. Topics are: Dimension theory, General topology, Algebraic topology and Theory of low-dimensional manifolds. Price: $60.- per copy. Write to Prof. J. Nagata, Dep. of Math. Osaka Dentsu University, Neyagawa, Osaka, 572 Japan.

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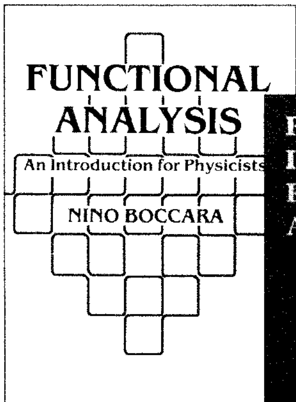

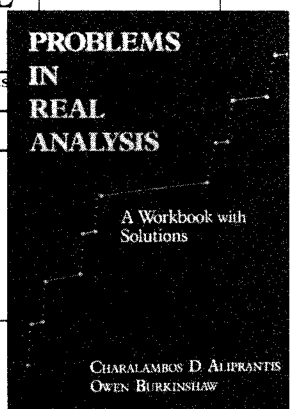

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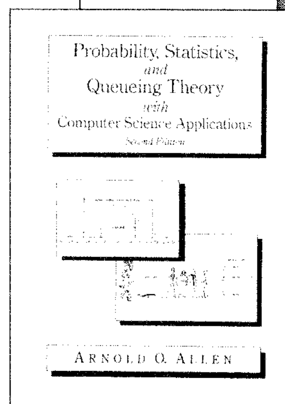

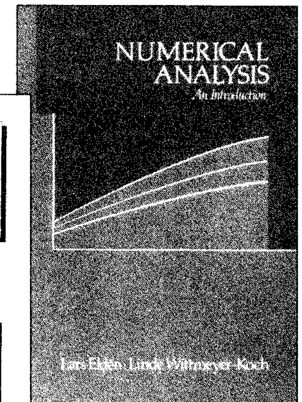

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