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Notices

of the American Mathematical Society

April 1998

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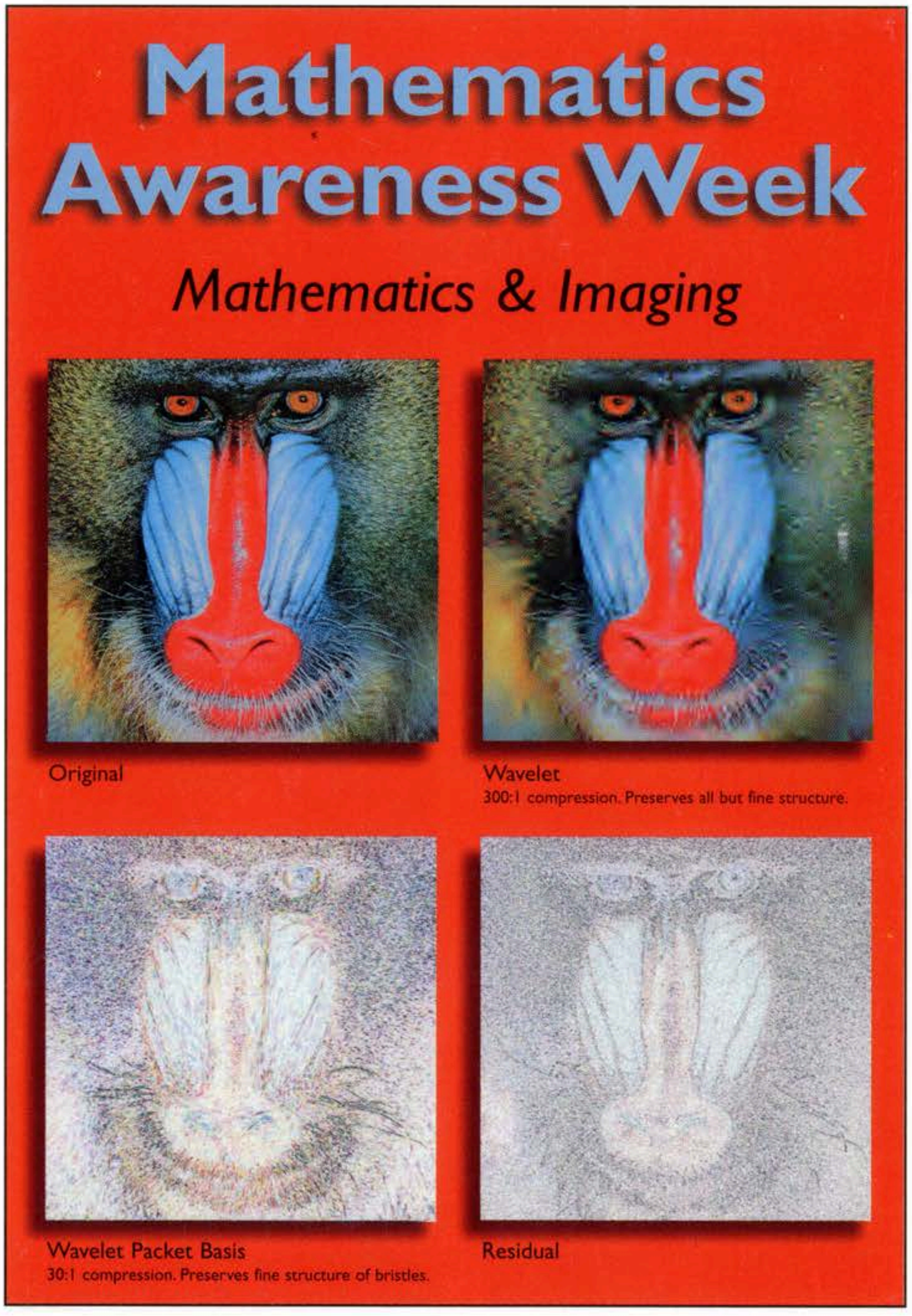
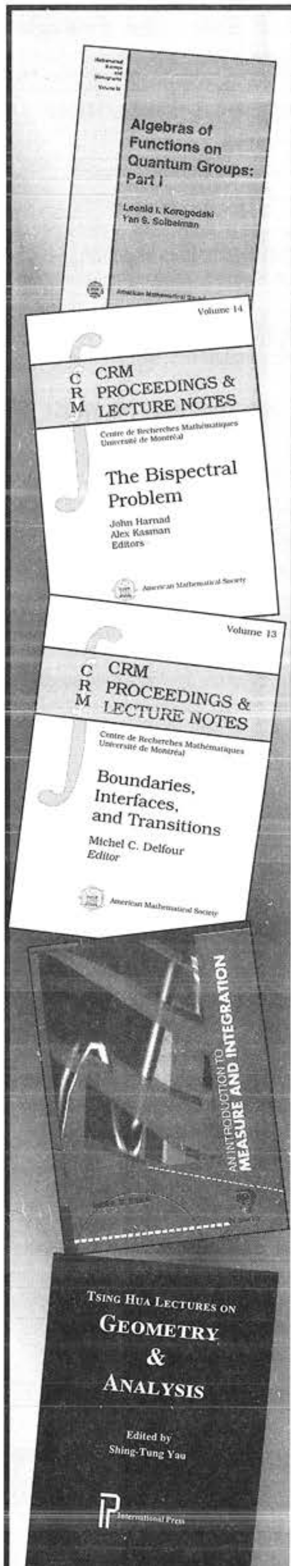


Mathematics Awareness Week 1998 *(See cover description on page 463)*



American Mathematical Society

New Titles from the AMS

Independent Study

Algebras of Functions on Quantum Groups: Part I

Leonid I. Korogodski and **Yan S. Soibelman**, *Institute for Advanced Study, Princeton, NJ*

The book is devoted to the study of algebras of functions on quantum groups. The authors' approach to the subject is based on the parallels with symplectic geometry, allowing the reader to use geometric intuition in the theory of quantum groups. The book includes the theory of Poisson-Lie algebras (quasi-classical version of algebras of functions on quantum groups), a description of representations of algebras of functions and the theory of quantum Weyl groups. This book can serve as a text for an introduction to the theory of quantum groups.

Mathematical Surveys and Monographs; 1998; 150 pages; Hardcover; ISBN 0-8218-0336-0; List $49; All AMS members $39; Order code SURV/56NT84

The Bispectral Problem

John Harnad and **Alex Kasman**, *Centre de Recherches Mathématiques, Université de Montréal, PQ, Canada*, Editors

Although originally posed in the context of mathematical problems related to medical imaging, the bispectral problem is now closely related to other topics and has connections to many areas of pure and applied mathematics. The central theme of this book is the search for solutions to eigenvalue problems that satisfy additional equations in the spectral parameter, for example, pairs of eigenvalue equations. This problem, which looks very simple at first, has turned out to be both deep and difficult. Moreover, this concept of bispectrality has been shown to be useful in many active areas of current research in mathematics and physics.

Following several years of exciting new results on the subject, in March 1997 the Centre de Recherces Mathématiques held the first scientific meeting devoted exclusively to the bispectral problem. Collected in this volume are contributions from the speakers at this meeting. The participants at this workshop included a majority of those researchers who have made significant contributions to the subject and many others working on related problems.

CRM Proceedings & Lecture Notes, Volume 14; 1998; 235 pages; Softcover; ISBN 0-8218-0949-0; List $65; Individual member $39; Order code CRMP/14NT84

Boundaries, Interfaces, and Transitions

Michel C. Delfour, *Centre de Recherches Mathématiques, Montréal, PQ, Canada*, Editor

There is currently considerable mathematical interest and very real potential for applications in using geometry in the design, identification and control of technological processes. Geometry plays the role of a design variable in the shape optimization of mechanical parts. It also appears as a control variable in optimal swimming, shape control of aircraft wings or stabilization of membranes and plates by periodic variations of the boundary. As it is used as a design or control variable, it often undergoes "mutations" as in the microstructures of materials, crystal growth, image processing or the texture of objects which involve relaxations of classical geometry and geometrical entities. In other areas, such as free and moving boundary problems, the understanding of the underlying phenomena is very much related to the geometric properties of the fronts and the nature of the nonlinearities involved.

This book brings together tools that have been developed in a priori distant areas of mathematics, mechanics and physics. It provides coverage of selected contemporary problems in the areas of optimal design, mathematical models in material sciences, hysteresis, superconductivity, phase transition, crystal growth, moving boundary problems, thin shells and some of the associated numerical issues.

CRM Proceedings & Lecture Notes, Volume 13; 1998; approximately 352 pages; Softcover; ISBN 0-8218-0505-3; List $95; Individual member $57; Order code CRMP/13NT84

Deformations of Galois Representations and Hecke Algebras

J. Tilouine, *Université de Paris Nord, Villetaneuse, France*

This book presents an expanded version of a course delivered at Hokkaïdo University (Sapporo, Japan) and at the Mehta Research Institute (Allahabad, India). Its aim is to examine aspects of the relationship connecting the local moduli space of deformations of a mod p "modular" Galois representation $\bar{\rho}$ to the corresponding local component of a p-adic Heck algebra.

Published by Narosa Publishing House and distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

1996; 108 pages; Softcover; ISBN 81-7319-106-9; List $24; All AMS members $19; Order code DGRNT84

Supplementary Reading

An Introduction to Measure and Integration

Inder K. Rana, *Indian Institute of Technology, Pawai, India*

This volume presents a motivated introduction to a subject that goes under various headings such as real analysis, Lebesgue measure and integration, measure theory, modern analysis, advanced analysis, etc.

Prerequisite for the text is a first course in mathematical analysis. The text can be used for a one-year course in the topic as indicated by the title. Due to the lecture-notes style of the text, it would also be appropriate to use for individual self-study. Included is a chart depicting the logical interdependence of the chapters.

Published by Narosa Publishing House and distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

1997; 380 pages; Hardcover; ISBN 81-7319-120-4; List $49; All AMS members $39; Order code IMINT84

Tsing Hua Lectures on Geometry & Analysis

Shing-Tung Yau, *Harvard University, Cambridge, MA*, Editor

This book presents lectures given during a seminar organized by S.-T. Yau at Tsing Hua University (Taiwan). Included are lectures by experts in the field and students who studied under Yau. Contributions by guest lecturers and students made this a lively and successful seminar.

International Press publications are distributed worldwide, except in Japan, by the American Mathematical Society.

International Press; 1997; 322 pages; Hardcover; ISBN 1-57146-042-X; List $42; All AMS members $34; Order code INPR/25NT84

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U. S., please include $6.50 per item. *Prepayment required.* Order from: **American Mathematical Society**, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax (401) 455-4046 or call toll free 800-321-4AMS (4267) in the U. S. and Canada, (401) 455-4000 worldwide. Or place your order through the AMS bookstore at www.ams.org/bookstore/. Residents of Canada, please include 7% GST.

AMS
American Mathematical Society

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SUBSCRIPTION INFORMATION: Subscription prices for Volume 45 (1998) are $300 list; $240 institutional member; $180 individual member. (The subscription price for members is included in the annual dues.) A late charge of 10% of the subscription price will be imposed upon orders received from nonmembers after January 1 of the subscription year. Add for postage: Surface delivery outside the United States and India—$15; in India—$36; expedited delivery to destinations in North America—$35; elsewhere—$70. Subscriptions and orders for AMS publications should be addressed to the American Mathematical Society, P.O. Box 5904, Boston, MA 02206-5904. All orders must be prepaid.

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NOTICES ON e-MATH: Most of this publication is available electronically through e-MATH, the Society's resource for delivering electronic products and services. To access the *Notices* on e-MATH, use the URL:

`http://www.ams.org/notices/`

Those with VT100-type terminals or without WWW browsing software can connect to e-MATH via Telnet (`telnet e-math.ams.org`; login and password are "e-math") and use the Lynx option from the main menu.

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Editorial

Cost of Publishing

Research mathematicians are used to working in comprehensive mathematics libraries, moving from source to source, confident that any references of interest may be tracked down without leaving the library. This system is now in jeopardy because of the spiraling unit costs of journals, books, and electronic products and because of the continual explosion of mathematical literature. What is to be done?

Many people offer simple solutions: increase library budgets, avoid expensive journals, go electronic. But the problem is not so simple, and it is likely that a combination of approaches will be needed. Different groups of people can help solve parts of the problem in different ways, and a necessary ingredient for this purpose is information. That is where the *Notices* can help.

Within the past three years the *Notices* has printed several articles on aspects of this problem, as well as a forum and a number of letters. Articles have explored copyright issues and electronic publishing, and letters have set forth hopes and cautions about electronic publishing.

With this issue we begin an occasional series on the cost of publishing from different points of view—including authors, publishers, librarians, and readers. The Branin-Case article in this issue addresses the cost of publishing from the point of view of library administrators, detailing the scope of the problem, partial solutions that are under way, and legal matters. Research librarians, as Branin and Case say, point to the growing commercialization of scholarship as a root cause. They look for solutions with authors, publishers, and librarians working in partnership, but at the same time they envision "bringing scientific scholarly publishing back into the academy" as part of the reform that is needed.

An article in a coming issue of the *Notices* will consider the question of the cost of publishing from the point of view of commercial publishers. What factors make commercial publishing so expensive? What can be done to reduce costs? Will commercial publishers continue to play a significant role in the publishing of mathematics? Stay tuned.

—*Anthony W. Knapp*

Current Events

Mathematics Awareness Week, April 26–May 2

Each year Mathematics Awareness Week (MAW) provides an opportunity to participate in a nationwide celebration of mathematics. The theme for MAW 1998 is "Mathematics and Imaging". Mathematics departments all over the country come up with their own ways of observing the week, from problem-solving contests to art exhibits to public lectures. In conjunction with this year's MAW events, the Public Broadcasting System will air a seven-part series about mathematics called "Life by the Numbers". Produced by WQED Pittsburgh, this series aims to reveal to viewers the fascination of mathematics by demonstrating how the field relates to many aspects of everyday life. The programs in the series would make an excellent springboard for MAW events. The series will begin April 8; call your local public television station for local broadcast dates and times. Ideas for MAW activities can be found at the Math Forum Web site, `http://forum.swarthmore.edu/maw/`.

—*Allyn Jackson*

Commentary

In My Opinion

Cryptography in Crisis

Rarely does mathematics reach the front pages of newspapers, yet for two decades some simple and elegant number theory has enjoyed a very public discussion—but this discussion has been political, not mathematical. The conflict is over the deployment of strong cryptography.[1]

In the mid-1970s Whitfield Diffie, Martin Hellman, and Ralph Merkle proposed that some computations might be of such great complexity that even though both halves of the computation were known (say, by an eavesdropper on the Internet), computing the inverse (decrypting) would not be possible in a reasonable amount of time, thus providing a way to communicate securely over insecure networks. Three MIT computer scientists—Ron Rivest, Len Adleman, and Adi Shamir—used elementary number theory to develop the public-key cryptography system RSA, which not only computes digital signatures (electronic signatures that provide nonrepudiable ratification) but also provides confidentiality.

It was a beautiful application; shortly afterwards the MIT professors found out just how interesting their solution was. As Rivest prepared the work to present at a meeting of the Institute of Electrical and Electronics Engineers in Ithaca, New York, the MIT professors received an odd letter from one J. A. Meyer of Bethesda, Maryland. Meyer claimed that since foreign nationals would be at the conference, discussion of the RSA cryptosystem would violate the International Trafficking in Arms Regulations. An enterprising *Science* reporter discovered Meyer was an employee of the National Security Agency (NSA), which quickly disavowed any connection with the letter, and Rivest gave the talk.

The letter was the precursor of twenty years of government policy. Through a variety of means including export control, the U.S. Government has delayed the deployment of strong cryptography. The latest government effort is key escrow (or key recovery, as it is currently called), in which private keys are stowed so that governments can get to them.

In 1998 the Internet is no longer a theory but a commercial enterprise. And electronic communications are at risk. FBI director Louis Freeh has testified that twenty-three foreign governments routinely target U.S. business for economic espionage. Increasingly, companies are seeking protection for their online operations. RSA Data Security is thriving. However, like all U.S. firms it is prohibited, with only narrow exceptions, from exporting codes with keys greater than 40 bits. These restrictions exist despite a clear demonstration of the inherent weakness of 40-bit cryptosystems: in under four hours a Berkeley graduate student, using the idle time of 250 workstations, was able to break a system encoded with a 40-bit key.

Scientific freedom and human rights are in collision with current government policy. Papers and ideas circulate freely; programs on disks and over the Internet do not. While cryptography research involves collaborations amongst scientists on different continents, U.S. export regulations keep a University of Illinois professor from posting source code for his encryption algorithm on the Internet. And despite the value of the Internet as a communications venue, U.S. export control complicates its use for democratic organizations. An American Association for the Advancement of Science program advising human-rights groups on information security (e.g., on protecting sensitive e-mail from government investigators) cannot give the code to the organizations, but must instead point the groups to foreign Web sites for the information.

The United States Government argues that its policies, by keeping strong cryptography out of shrink-wrapped software (of which the U.S. remains the leading manufacturer), secures national objectives. Cryptography can hide evidence from government investigators, but the lack of strong cryptography leaves an online society dangerously vulnerable. A recent National Research Council panel on cryptography policy, whose members included a former U.S. attorney general and a former deputy director of the NSA, said "the advantages of more widespread use of cryptography outweigh the disadvantages" and recommended "broad availability" of cryptography to legitimate users in the U.S.[2]

U.S. key-recovery proposals are considered problematic at best. Key-recovery centers provide a rich target for those who seek to spy, and key recovery is easily circumvented by using additional forms of cryptography on top of the key-recovery scheme. Finally, it is difficult to implement key recovery internationally. U.S. proposals have received a poor reception, and their main effect has been to hobble industry. Meanwhile, other nations have stepped into the breach.

What exactly does the U.S. seek to export? Secure communications are needed by U.S. companies operating abroad and by scientists, inventors, politicians, and private citizens everywhere. Present U.S. cryptography policy was designed when the enemy was the Soviet Union. Mathematicians, computer scientists, policymakers, users of the Internet—all have a stake in moving U.S. policy to one that promotes communications privacy, economic security, scientific freedom, and human rights.

—Susan Landau
Associate Editor

[1] *A relative term meaning the cryptography is hard to break with current computational power.*

[2] *National Research Council, Commission on Physical Sciences, Mathematics, and Applications, Computer Science and Telecommunications Board, Committee to Study National Cryptography Policy,* Cryptography's Role in Securing the Information Society *(Kenneth Dam and Herbert Lin, eds.), National Academy Press, 1996.*

Letters

Response to Sadosky's "Forum"

I am writing in response to Professor Sadosky's "Forum" article, "On Issues of Immigration and Employment for Mathematicians" (*Notices*, December 1997).

Sadosky asks, "Since when are mathematicians selected on their ambition to make money?" This is intended to refute Geoff Davis's suggestion ("Mathematicians and the market," *Notices*, November 1997) that economic forces play a significant role in the mathematics labor market. Sadosky's rhetoric misses the point; one might rephrase her question as, "Since when are mathematicians selected on their desire for a full-time, tenure-track job?" It is bad for the field of mathematics if we are losing talented people before they even enter the field because prospects in the job market are so bad.

Sadosky asks, "Is it the American Way to give preference to less-qualified U.S. citizens?" The answer is, "Yes, absolutely." In just about every profession it is quite difficult to hire a nonresident alien as long as there is a qualified resident available for the job—not a more qualified resident, not an equally qualified one, but merely a qualified resident. This is true for doctors, lawyers, engineers, and practically every profession *except* for college and university professors. One might say that this gives unfair preference to permanent residents of the U.S., but removing such immigration barriers would have profound economic consequences. When discussing immigration issues, it is important to consider these potential consequences.

Sadosky doesn't ask, "If the U.S. had such a strong history of importing mathematicians before 1976, then why did the government feel it necessary to make it even easier to import them in 1976? And why again in 1990?" Before 1976 the same immigration restrictions applied to college and university professors as to everyone else; that year several of these restrictions were weakened, but only for academics. In 1990 several more of these restrictions were weakened and, again, primarily for academics. Were these changes beneficial to academia and to mathematics in particular?

Sadosky doesn't ask, "If you believe that U.S. immigration law is a factor in the employment market, what steps should be taken?" She seems to imply that various people (as reported in the *Boston Globe* and the *Wall Street Journal*) have suggested banning immigrants. That sort of suggestion is extreme and could be dismissed out of hand. Of course, I haven't heard that suggestion; instead, I've heard the proposal that the 1990 changes (and/or the 1976 changes) in the immigration law be repealed. This proposal, I think, deserves serious discussion and consideration, something completely lacking in Sadosky's article.

Sadosky doesn't ask, "What role do economic forces, such as immigration law, play in the academic job market? If you alter these forces, what effects should you expect?" Again, these are serious issues, and they deserve serious consideration. I hope the *Notices* will provide a forum for an open discussion of these and similar issues.

John H. Palmieri
Visiting Assistant Professor
University of Notre Dame

(Received December 18, 1997)

Defining Uniform Continuity First Does Not Help

At the risk of prolonging a discussion of pedagogy in the pages of an AMS publication, I wish to say a few things about Peter Lax's proposal in the January *Notices* that we use uniform continuity as an introduction to continuity and limits. The first text I know of that did this was John M. H. Olmsted's two-volume *Calculus with Analytic Geometry*, published in 1966 by Appleton-Century-Crofts. We used it in the late 1960s, but abandoned it about 1970 because our students weren't understanding limits or any kind of continuity any better than they had with other approaches, and they were having to work a lot harder. I think the reason it didn't succeed was that even though only two quantifiers were used in the definition of uniform continuity, that was still too complicated. That is, defining uniform continuity first did not lessen the difficulties with (ϵ, δ) definitions Leonard Gillman eloquently described in the September 1997 *Notices*.

The purpose of limits bears greatly on which definition of limits to use. If the purpose is to serve as the foundation for rigorous arguments in analysis, then the quantifiers in (ϵ, δ) are unavoidable. But the purpose of a limit in a beginning calculus course is to be the foundation for the definitions of the ideas studied, not the foundation of rigorous arguments, and so its definition need only be descriptive. The task is to devise for the student experiences such that having them and thinking about them will provide a foundation of meaning so that the description of a limit will make sense, as will the uses to which the limit is put. My own preference is to emphasize uses of graphs before getting to calculus. Then I can use graphs to describe limits. The test is for the student to tell correctly from the graph of a function whether limits of that function at various points exist, and if so, what they are. It's enough of a foundation for the limit for beginning students, and it's harder than it sounds. It may be that a numeric approach such as Lax's illustration can have meaning if the students have had to think about the accuracy of their input and output. Mine haven't. I've had even less luck with such things than with graphs, and I'm skeptical. But students' backgrounds change, so it's worth another try.

Albert W. Briggs Jr.
Washington College

(Received December 22, 1997)

Elevate the Level of Discussion of Educational Issues

"Calculus Reform — for the $Millions" by Klein and Rosen (*Notices*, November 1997) raises some points that are central to the improvement of mathematics education at every level. But the title and tone of their article almost guarantee that the issues they raise will be discussed only among groups of people who already agree with one another.

It's unlikely that the people signing this letter would be unanimous on any issue of substance in education except that sarcasm and insult have no place in the debate about mathematics education.

This is an extremely important time in mathematics education. Serious scholars are proposing theories that call for major revamping of educational practice. These theories need to be debated and discussed, and the foundations on which they rest need to be ruthlessly scrutinized by everyone involved in mathematics education, especially by the mathematics community. We call on the community to elevate the level of discussion so that the serious work of teaching mathematics can move forward.

Al Cuoco
Education Development Center, and 19 others

(Received December 22, 1997)

Editor's Note: Al Cuoco informed the *Notices* that the complete list of signatories is available at `http://www.edc.org/LTT/BOS/letter.html`.

Rota and the Theory of Commutative Rings

Gian-Carlo Rota's article "The Many Lives of Lattice Theory" (*Notices*, December 1997) is very interesting and also controversial. It is intended to be so!

May I point out that in spite of belonging to "the sect of algebraic geometers", the authors of *Commutative Algebra*—Oscar Zariski and I—did not hide the fact that for commutative rings the Chinese Remainder Theorem is equivalent with the distributive laws for ideals with respect to intersections and sums (vol. I, pp. 279–281). We even showed that one of the distributive laws implies the other one. The proofs are rather straightforward, much more so than what is proved in the following sections, culminating with the reciprocity law and Kummer's theorem.

On the other hand, I object to G.-C. Rota's saying that "The theory of commutative rings has been torn between two customers: number theory and geometry." On the contrary, by providing a common tool for (diophantine) number theory and algebraic geometry, commutative algebra was instrumental for the cross-fertilization of both theories. It began with Dedekind and Weber, and later the works of A. Weil, A. Grothendieck, P. Deligne, S. Arakelov, G. Faltings, A. Wiles, and many others were striking examples. Also, deep results about "complete-intersection" rings, proved by R. Taylor, provided the finishing touch to A. Wiles's proof of Fermat's theorem.

Pierre Samuel
Université de Paris-Sud, Orsay

(Received December 23, 1997)

Volunteer Work on Electronic Journals Vital

The September 1997 editorial by Steven G. Krantz covered an area, electronic math journals, where there are many important issues which need careful evaluation and investigation; it is therefore unfortunate that the potential problems he highlighted are ones that are comparatively well understood and that have already been solved, with the help of enlightened publishers such as the AMS, by the more thoughtful parts of the academic community. It is, however, your editorial prerogative to use space and time in this way.

Of far greater concern is the author's apparent dismissal of the excellent, pioneering work that many others are doing (paid or unpaid) in adapting the rapidly developing technology to serve the diverse needs of the mathematical community.

It is in particular the voluntary efforts, supported by the more explicitly financed activity of professional bodies and publishers, that keep the community alive and stimulate the necessary investigation into the best methods of achieving both the traditional and future goals of mathematical publishing. The independent, self-motivated nature of this work is essential to its originality and creativity and hence its vitality and utility.

Here are some questions pertinent to an editor of an AMS publication: Is the author aware that vital parts of the software systems used by the AMS in their publishing are also being developed and maintained by similar voluntary work, including much high-quality input from professional mathematicians and AMS employees? Is this also a waste of their time? And will he please apologize to all of his colleagues whose work he has thus disparaged as having a "negative impact"?

I very much hope that the real issues surrounding the purpose and practice of mathematical publishing in the modern world will continue to be covered by the *Notices* and that the AMS will keep its leading and progressive role in all aspects of the use of digital technology. But will you please avoid facile and derogatory editorials, on any subject.

—Chris A. Rowley
LaTeX3 Project

(Received January 20, 1998)

About the Cover

This month's cover image is adapted from the poster for Mathematics Awareness Week 1998 (April 26–May 2), the topic of which is "Mathematics and Imaging".

The original image (upper left) is the sum of the other three. Each pulls out different features of the original. We can think of the image as being synthesized by three different instruments, in a way similar to a musical orchestration where the final sound is the sum of the notes from each instrument.

This mathematical transcription is useful for a more efficient and accurate storage and processing of imaging data, but also provides tools for denoising and identifying structure in images. For example, it can sharpen detail in medical images, such as MRI, and be used to identify particular objects for diagnostic purposes.

Images provided by Ronald Coifman, Yale University.

AMERICAN MATHEMATICAL SOCIETY

Announcing searches for

TWO ASSOCIATE SECRETARIES

of the American Mathematical Society

Positions

The American Mathematical Society is seeking applications and nominations for candidates for two positions: Associate Secretary of the Southeastern Section and Associate Secretary of the Western Section. Robert Daverman, currently Associate Secretary of the Southeastern Section, has been elected Secretary and will assume that office on 01 February 1999. William Harris, Associate Secretary of the Western Section, passed away suddenly in early January.

An Associate Secretary is an officer of the Society and is appointed by the Council to a two-year term, beginning on 01 February. In the case of the Associate Secretary for the Southeastern Section, the term would begin on 01 February 1999. In the case of the Associate Secretary of the Western Section, the term would begin immediately and end on 31 January 2000. Reappointments are possible and desirable. All necessary expenses incurred by an Associate Secretary in performance of duties for the Society are reimbursed, including travel and communications.

Duties

The primary responsibility of an Associate Secretary is to oversee scientific meetings of the Society in the section. Once every four years an Associate Secretary has primary responsibility for the Society's Annual Meetings program at the January Joint Mathematics Meeting. An Associate Secretary is a member of the Secretariat, a committee consisting of all Associate Secretaries and the Secretary. The Secretariat approves all applications for membership in the Society and approves all sites and dates of meetings of the Society. Frequently an Associate Secretary is in charge of an international joint meeting. Associate Secretaries are the principal contact between the Society and its members in the various sections. They are invited to all Council meetings and have a vote on the Council on a revolving basis.

Applications

An Associate Secretary is appointed by the Council upon recommendation by the Executive Committee and Board of Trustees. Applications and nominations should be sent to: Professor Robert M. Fossum, Secretary, American Mathematical Society, Department of Mathematics, University of Illinois, 1409 W. Green Street, Urbana, IL 61801-2975, e-mail: `r-fossum@uiuc.edu`.

Applications received by 30 April 1998 will be assured full consideration.

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AMERICAN MATHEMATICAL SOCIETY

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Representations of Finite Groups: A Hundred Years, Part II

T. Y. Lam

Recapitulation

The origin of the representation theory of finite groups can be traced back to a correspondence between R. Dedekind and F. G. Frobenius that took place in April of 1896. The present article is based on several lectures given by the author in 1996 in commemoration of the centennial of this occasion.

In Part I of this article we recounted the story of how Dedekind proposed to Frobenius the problem of factoring a certain homogeneous polynomial arising from a determinant (called the "group determinant") associated with a finite group G. In the case when G is abelian, Dedekind was able to factor the group determinant into linear factors using the characters of G (namely, homomorphisms of G into the group of nonzero complex numbers). In a stroke of genius, Frobenius invented a general character theory for arbitrary finite groups, and used it to give a complete solution to Dedekind's group determinant problem. Interestingly, Frobenius's first definition of (nonabelian) characters was given in a rather ad hoc fashion, via the eigenvalues of a certain set of commuting matrices. This work led Frobenius to formulate, in 1897, the modern definition of a (matrix) representation of a group G as a homomorphism $D : G \to \mathrm{GL}_n(\mathbb{C})$ (for some n). With this definition in place, the character $\chi_D : G \to \mathbb{C}$ of the representation is simply defined by $\chi_D(g) = \mathrm{trace}(D(g))$ (for every $g \in G$). The idea of studying a group through its various representations opened the door to a whole new direction of research in group theory and its applications.

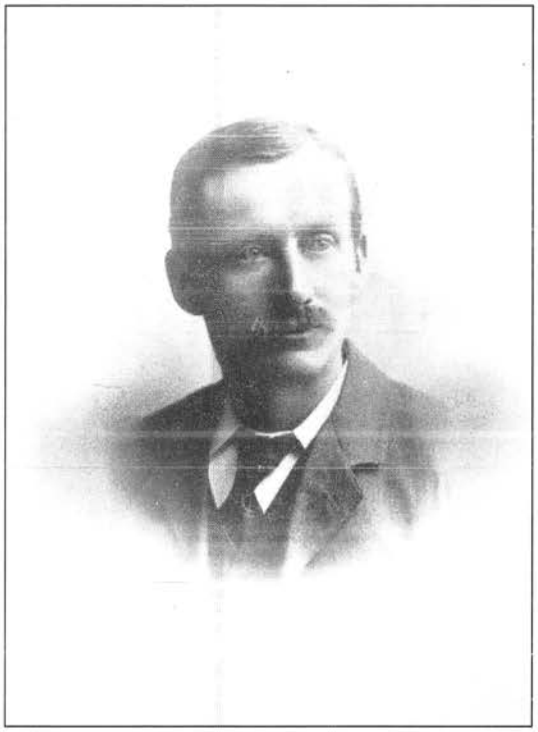
Having surveyed Frobenius's invention of character theory and his subsequent monumental contributions to representation theory in Part I of this article, we now move on to tell the story of another giant of the subject, the English group theorist W. Burnside. This comprises Part II of the article, which can be read largely independently of Part I. For the reader's convenience, the few bibliographical references needed from Part I are reproduced here, with the same letter codes for the sake of consistency. As in Part I, [F: (53)] refers to paper (53) in Frobenius's collected works [F]. Burnside's papers are referred to by the year of publication, from the master list compiled by Wagner and Mosenthal in [B]. Consultation of the original papers is, however, not necessary for following the general exposition in this article.

T. Y. Lam is professor of mathematics at the University of California, Berkeley. His e-mail address is `lam@math.berkeley.edu`.

This article, in two parts, is a slightly abridged version of an article appearing concurrently in the Proceedings of the "Aspects of Mathematics" conference *(N. Mok, ed.), University of Hong Kong, H.K., 1998. Part I, concerning the study of group determinants by Ferdinand Georg Frobenius and the resulting theory of characters and group representations, appeared in the March 1998 issue of the* Notices, *pages 361–372.*

William Burnside (1852–1927)

Remarks in this section about Burnside's life and work are mainly taken from A. R. Forsyth's obituary note [Fo] on Burnside published in the *Journal of the London Mathematical Society* the year after Burnside's death, and from the forthcoming book



Photograph courtesy of the Institut Mittag-Leffler.

William Burnside.

of C. Curtis on the pioneers of representation theory [Cu_2, Ch. 3].

Born in London of Scottish stock, William Burnside received a traditional university education in St. John's and Pembroke Colleges in Cambridge. In Pembroke he distinguished himself both as a mathematician and as an oarsman, graduating from Cambridge as Second Wrangler in the 1875 Mathematical Tripos. He took up a lectureship in Cambridge after that, and remained there for some ten years, teaching mathematics and acting as coach for both the Math Tripos and for the rowing crews. In 1885, at the instance of the Director of Naval Instruction (a former Cambridge man named William Niven), Burnside accepted the position of professor of mathematics in the Royal Naval College at Greenwich. He spent the rest of his career in Greenwich, but kept close ties with the Cambridge circles, and never ceased to take an active role in the affairs of the London Mathematical Society, serving long terms on its Council, including a two-year term as president (1906–08). In Greenwich he taught mathematics to naval personnel, which included gunnery and torpedo officers, civil and mechanical engineers, as well as cadets. The teaching task was not too demanding for Burnside, which was just fine, as it afforded him the time to pursue an active program of research. Although physically away from the major mathematical centers of England, he kept abreast of the current progress in research throughout his career, and published a total of some 150 papers in pure and applied mathematics. By all accounts, Burnside led a life of steadfast devotion to his science.

Burnside's early training was very much steeped in the tradition of applied mathematics in Cambridge.[1] At that time, applied mathematics meant essentially the applications of analysis (function theory, differential equations, etc.) to topics in theoretical physics such as kinematics, elasticity, electrostatics, hydrodynamics, and the theory of gases. So not surprisingly, in the first fifteen years of his career, Burnside's published papers were either in these applied areas, or else in elliptic and automorphic functions and differential geometry. On account of this work, he was elected Fellow of the Royal Society in 1893. Coincidentally, it was also around this time that Burnside's mathematical interests began to shift to group theory, a subject to which he was to devote his main creative energy in his mature years.

After authoring a series of papers entitled "Notes on the theory of groups of finite order" (and others), Burnside published his group theory book [B_1] in 1897, the first in the English language offering a comprehensive treatment of finite group theory. A second, expanded edition with new material on group representations appeared in 1911. For more than half a century, this book was without doubt the one most often referred to for a detailed exposition of basic material in group theory. Reprinted by Dover in 1955 (and sold for \$2.45), Burnside's book is now enshrined as one of the true classics of mathematics. We will have more to say about this book in the next section.[2]

Since group theory was not a popular subject in England at the turn of the century, Burnside's group-theoretic work was perhaps not as much appreciated as it could have been. When Burnside died in 1927, the *London Times* reported the passing of "one of the best known Cambridge athletes of his day".[3] We can blame this perhaps on the journalist's ignorance and lack of appreciation of mathematics. However, even in Forsyth's detailed obituary, which occupied seventeen pages of the *Journal of the London Math Society*, no more than a page was devoted to Burnside's work in group theory, even though Forsyth was fully aware that it was this work that would "provide the most continuous and most conspicuous of his contributions to his science." None of Burnside's greatest achievements that now make him a household

[1] *According to Forsyth [Fo], pure mathematics was then largely "left to Cayley's domain, unfrequented by aspirants for high place in the tripos."*

[2] *Those familiar with Dover publications will know that there are two other Dover reprints of books by "Burnside": one is* Theory of Probability, *and the other is* Theory of Equations. *The former was indeed written by William Burnside; published posthumously in 1928, it was also one of the earliest texts in probability theory written in English. However, the 2-volume work* Theory of Equations *was written (ca. 1904) by Panton and* another *Burnside. William Snow Burnside, professor of mathematics in Dublin, was a contemporary of William Burnside; they published papers in the same English journals, one as "W. S. Burnside" and the other simply as "W. Burnside". An earlier commentary on this was given by S. Abhyankar [Ab, footnote 43, p. 91].*

[3] *The full text of the* London Times *obituary on Burnside was quoted in [Cu_2, Ch. 3].*

name in group theory was even mentioned in Forsyth's article. I can think of two reasons for this. The first is perhaps that Forsyth did not have any real appreciation of group theory. While he was Sadlerian Professor of Mathematics in Cambridge, his major field was function theory and differential equations.[4] We cannot blame him for being more enthusiastic about Burnside's work in function theory and applied mathematics; after all, it was this work that won Burnside membership in the Royal Society. Second, Burnside's achievements in group theory were truly way ahead of his time; the deep significance of his ideas and the true power of his vision only became clear many a year after his death. Today, I do not hear my applied math colleagues talk about Burnside's work in hydrodynamics or the kinetic theory of gases, but I will definitely teach my students Burnside's great proof of the $p^a q^b$ theorem (that any group of order $p^a q^b$ is solvable) in my graduate course in group representation theory! In mathematics, as in other sciences, it is time that will tell what are the best and the most lasting human accomplishments.

Theory of Groups of Finite Order (1897, 1911)

Through his work on the automorphic functions of Klein and Poincaré, Burnside was knowledgeable about the theory of discontinuous groups. It was perhaps this connection that eventually steered him away from applied mathematics and toward research on the theory of groups of finite order. In the early 1890s, Burnside followed closely Hölder's work on groups of specific orders; soon he was publishing his own results on the nature of the order of finite simple groups. Frobenius's early papers in group theory apparently first aroused his interest in finite solvable groups.[5]

The first edition of Burnside's masterpiece *Theory of Groups of Finite Order* appeared in 1897; it was clearly the most important book in group theory written around the turn of the century. While intended as an introduction to finite group theory for English readers, the book happened to contain some of the latest research results in the area at that time. For instance, groups of order $p^a q^b$ were shown to be solvable if either $a \leq 2$ or if the Sylow groups were abelian, and (nonabelian) simple groups were shown to have even order if the order was the product of fewer than six primes.[6] It is clear that Burnside realized that these results were not in their final form, for he wrote in [B_1, 1st ed., p. 344]:

> If the results appear fragmentary, it must be mentioned that this branch of the subject has only recently received attention: it should be regarded as a promising field of investigation than as one which is thoroughly explored.

Burnside was right on target in his perception that much more was in store for this line of research. However, Burnside's assessment at that time of the possible role of groups of linear substitutions was a bit tentative. Since the theory of permutation groups occupied a large part of [B_1] while groups of linear substitutions hardly received any attention, Burnside felt obliged to give an explanation to his readers. In the preface to the first edition of [B_1], he wrote:

> My answer to this question is that while, in the present state of our knowledge, many results in the pure theory are arrived at most readily by dealing with properties of substitution groups, it would be difficult to find a result that could be most directly obtained by the consideration of groups of linear transformations.

Little did he know that, just as his book was going to press, Frobenius on the continent had just made his breakthroughs in the invention of group characters, and was in fact writing up his first memoir [F: (56)] on the new representation theory of groups! As it turned out, the next decade witnessed some of the most spectacular successes in applying representation theory to the study of the structure of finite groups—and Burnside himself was to be a primary figure responsible for these successes. There was no question that Burnside wanted his readers to be brought up to date on this exciting development. When the second edition of [B_1] came out in 1911 (fourteen years after the first), it was a very different book, with much more definitive results and with six brand new chapters introducing his readers to the methods of group representation theory! In the preface to this new edition, Burnside wrote:

> In particular the theory of groups of linear substitutions has been the subject of numerous and important investigations by several writers; and the reason given in the original preface for omitting any account of it no longer holds good. In fact it is now more true to say that for further advances in the abstract theory one must look largely to the representation of a group as a group of linear substitutions.

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[4] *His 2-volume work on the former and 6-volume work on the latter were quite popular in his day.*

[5] *A group G is* solvable *if it can be constructed from abelian groups via a finite number of group extensions. In case G is finite, an equivalent definition is that the composition factors of G are all of prime order.*

[6] *Burnside showed that the order must be 60, 168, 660, or 1,092.*

With these words, Burnside brought the subject of group theory into the twentieth century, and he went on to present 500 pages of great mathematics in his elegant and masterful style. Though later authors have found an occasional mistake in [B_1], and there are certainly some typographical errors,[7] Burnside's book has remained as valuable a reference today as it has been throughout this century. I myself have developed such a fondness for Burnside's book that every time I walk into a used book store and have the good fortune to find a copy of the Dover edition on the shelf, I would buy it. By now I have acquired seven (or is it eight?) copies. True book connoisseurs would go instead for the first edition of Burnside's book, because of its scarcity and historical value. Apparently, a good copy could command a few hundred dollars in the rare book market.

Burnside's Work in Representation Theory

After reading Frobenius's papers [F: (53), (54)], Burnside saw almost immediately the relevance of Frobenius's new theory to his own research on finite groups. What he tried to do first was to understand Frobenius's results in his own way. In the 1890s Burnside had also followed closely the work of Sophus Lie on continuous groups of transformations, so, unlike Frobenius, he was conversant with the methods of Lie groups and Lie algebras. Given a finite group G, he was soon able to define a Lie group from G whose Lie algebra is the group algebra $\mathbb{C}G$ endowed with the bracket operation $[A, B] = AB - BA$. Analyzing the structure of this Lie algebra, he succeeded in deriving Frobenius's principal results both on characters and on the group determinant. (For more details on this, see [Cu_2] and [H_2].) He published these results in several parts, in [B: 1898a, 1900b], etc. Burnside certainly was not claiming that he had anything new; he wrote in [B: 1900b]:

> The present paper has been written with the intention of introducing this new development to English readers. It is not original, as the results arrived at are, with one or two slight exceptions, due to Herr Frobenius. The modes of proof, however, are in general quite distinct from those used by Herr Frobenius.

Actually, while Burnside's methods were different from Frobenius's, what he did was close in spirit to what was done by Molien [M_1] in 1893. Both used the idea of the regular representation, the only difference being, that Molien worked with $\mathbb{C}G$ as an associative algebra (or "hypercomplex system") while Burnside worked with $\mathbb{C}G$ as a Lie algebra. However, Molien's paper [M_1] was understood by few, which was perhaps why it did not receive the recognition that it deserved. Burnside, for one, was apparently frustrated by the exposition in Molien's paper. In a later work [B: 1902f], in referring to [M_1], Burnside lamented openly:

> It is not, in fact, very easy to find exactly what is and what is not contained in Herr Molien's memoir.

Later, the methods of both Molien and Burnside were superseded by those of Emmy Noether [N]. As was noted in the section "Factorization of $\Theta(G)$ for Modern Readers" in Part I of this article, a quick application of the theorems of Maschke and Wedderburn à la Noether yields all there is to know about representations at the basic level.

The next stage of Burnside's work consists of his detailed investigation into the nature of irreducible representations and their applications. Recall that, for Frobenius, the irreducibility (or "primitivity") of a representation was originally defined by the irreducibility of its associated determinant. Since this was clearly a rather unwieldy definition, a more direct alternative definition was desirable. Burnside [B: 1898a] and Frobenius [F: (56)] had both given definitions for the irreducibility of a representation in terms of the representing matrices, although, as Charles Curtis pointed out to me, these early definitions seemed to amount to what we now call *indecomposable* representations. By 1898, E. H. Moore (and independently A. Loewy) had obtained the result that any finite group of linear substitutions admits a nondegenerate invariant hermitian form, and in 1899, Maschke used Moore's result to prove the "splitting" of any subrepresentation of a representation of a finite group (now called "Maschke's Theorem"). With these new results, whatever confusion that might have existed in the definition of the irreducibility of a representation became immaterial. By 1901 (if not earlier), Burnside was able to describe an irreducible representation in no uncertain terms [B: 1900b, p. 147]: "A group G of finite order is said to be represented as an irreducible group of linear substitutions on m variables when G is simply or multiply isomorphic with the group of linear substitutions, and when it is impossible to choose m' ($< m$) linear functions of the variables which are transformed among themselves by every operation of the group." Aside from its long-windedness, this *is* basically the definition of irreducibility of a matrix representation we use today.

With credit duly given to Maschke (and Frobenius), Burnside went on to prove the "complete reducibility" of representations of finite groups in [B: 1904c], and used it to give a self-contained ac-

[7] *The most glaring one appeared in the General Index, p. 510, where Burnside "blew" his own great theorem with an amusing entry "Groups of order $p^a q^b$, where p, q are primes, are simple" (which even survived the 1955 Dover edition). Who did the proofreading? Oh, dear ....*

count of basic character theory in [B: 1903d], independently of the continuous group approach he initiated in [B: 1898a]. One year later in [B: 1905b], Burnside arrived at a beautiful characterization of an irreducible representation that is still in use today:

Theorem 4.1. A representation $D : G \longrightarrow \mathrm{GL}_n(\mathbb{C})$ is irreducible if and only if the matrices in $D(G)$ span $\mathbb{M}_n(\mathbb{C})$.

Burnside proved this result for arbitrary (not just finite) groups (and used it later in [B: 1905c] for possibly infinite groups). Subsequently, Frobenius and Schur extended this theorem to "semigroups" of linear transformations. With this hindsight, we can state Burnside's main result in the following ring-theoretic fashion: *a subalgebra A of $\mathbb{M}_n(\mathbb{C})$ has no nontrivial invariant subspaces in $\mathbb{C}^n$ if and only if $A = \mathbb{M}_n(\mathbb{C})$.* Stated in this form, Burnside's result is of current interest to workers in operator algebras and invariant subspaces. Some generalizations to an infinite-dimensional setting have been obtained, for instance, in Chapter 8 of [HR]. We should also point out that Burnside's result holds in any characteristic; the only necessary assumption is that the ground field be algebraically closed (see [L, p. 109]).

Burnside had a keen eye for the arithmetic of characters (which he called "group characteristics"); many of his contributions to character theory were derived from his unerring sense of the arithmetic behavior of the values of characters. The following are some typical samples of his results proved in this spirit:

1. Every irreducible character χ with $\chi(1) > 1$ has a zero value.

2. The number of real-valued irreducible characters of a group G is equal to the number of real conjugacy classes[8] in G.

3. (Consequences of (2)) If $|G|$ is even, there must exist a real-valued irreducible character other than the trivial character (and conversely). If $|G|$ is odd, then the number of conjugacy classes in G is congruent to $|G|$ (mod 16).

4. If χ is the character of a faithful representation of G, then any irreducible character is a constituent of some power of χ. (This result is usually attributed to Burnside, although, as Hawkins pointed out in [H_3, p. 241], it was proved earlier by Molien. A quantitative version of the result was found later by R. Brauer.)

Burnside's most lasting result in group representations is, of course, his great $p^a q^b$ theorem, which we have already mentioned. Again, the approach he took to reach this theorem was purely arithmetic. Using arguments involving roots of unity and Galois conjugates, he proved the following result in [B: 1904a]:

Theorem 4.2. Let $g \in G$ and χ be an irreducible character of G. If $\chi(1)$ is relatively prime to the cardinality of the conjugacy class of g, then $|\chi(g)|$ is equal to either 0 or $\chi(1)$.

Combining this result with the Second Orthogonality Relation (given in the display box in Part I, p. 368), he obtained a very remarkable sufficient condition for the *nonsimplicity* of a (finite) group:

Theorem 4.3. If a (finite) group G has a conjugacy class with cardinality p^k where p is a prime and $k \geq 1$, then G is not a simple group.

This sufficient condition for nonsimplicity is so powerful that, from it, Burnside obtained immediately the $p^a q^b$ theorem, a coveted goal of group theorists for more than ten years.[9] It is interesting to point out that, in [B_1, 2nd ed., p. 323], after proving the powerful theorem (4.2), Burnside simply stated the $p^a q^b$ theorem as "Corollary 3":

Theorem 4.4. For any primes p, q, any group G of order $p^a q^b$ is solvable.

The proof is so easy and pleasant by means of Sylow theory that we have to repeat it here. We may assume $p \neq q$. By induction on $|G|$, it suffices to show that G is not a simple group. Fix a subgroup Q of order q^b (which exists by Sylow's Theorem), and take an element $g \neq 1$ in the center of Q. If g is central in G, G is clearly nonsimple. If otherwise, $C_G(g)$ (the centralizer of g in G) is a proper subgroup of G containing Q. Then the conjugacy class of g has cardinality $[G : C_G(g)] = p^k$ for some $k \geq 1$, so G is again nonsimple by (4.3), as desired!

At first sight, (4.4) may not look like such a deep result. However, for many years, it defied the group theorists' effort to find a purely group-theoretic proof. It was only in 1970 that, following up on ideas of J. G. Thompson, D. Goldschmidt [Go] gave the first group-theoretic proof for the case when p, q are *odd* primes. Goldschmidt's proof used a rather deep result in group theory, called Glauberman's $Z(J)$-theorem. A couple of years later, Matsuyama [Mat] completed Goldschmidt's work by supplying a group-theoretic proof for (4.4) in the remaining case $p = 2$. Slightly ahead of [Mat], Bender [Be] also gave a proof of (4.4) *for all p, q*, using (among other things) a variant of the notion of the "Thompson subgroup" of a p-group. While these group-theoretic proofs are not long, they involve technical ad hoc arguments, and certainly do not come close to the compelling simplicity and the striking beauty of Burnside's original character theoretic proof. As for the more general The-

[8] *A conjugacy class is said to be* real *if it is closed under the inverse map.*

[9] *As we indicated in the previous section, in his earlier papers Burnside had proved many special cases of this theorem without using representation theory; much of this was summarized in the first edition of [B_1].*

orem 4.3, which led to the $p^a q^b$ theorem, a purely group-theoretic proof has not been found to date.

Burnside: Visionary and Prophet

If one traces Burnside's group-theoretic work back to its very beginning, it should be clear that one of his main objectives from the start was to understand finite simple groups. Burnside knew the role of finite simple groups from the work of Galois and from the Jordan-Hölder Theorem, but in the 1890s, there was very little to go on. The only known finite simple groups were Galois's alternating groups A_n ($n \geq 5$), Jordan's projective special linear groups $\mathrm{PSL}_2(p)$ ($p \geq 5$), some of the Mathieu groups, and Cole's simple group of order 504. The latter group is now recognized as $\mathrm{PSL}_2(8)$, but finite fields were hardly known in the early 1890s, so in 1893, Cole [Co] had to construct this group "by bare hands" as a permutation group of degree nine.[10]

By 1892, Hölder found all simple groups of order ≤ 200. In another year, with his construction of the simple group of order 504, Cole pushed Hölder's work to the order $660 = |\mathrm{PSL}_2(11)|$, and in another two years, Burnside further extended this work to the order $1{,}092 = |\mathrm{PSL}_2(13)|$. He also proved some of the earliest theorems on the orders of simple groups, showing, for instance, that if they are even, they must be divisible by 12, 16, or 56. With the aid of these theoretical results, which he summarized in the first edition of [B$_1$], Burnside was confident that Hölder's program could be pushed to at least the order 2,000. He observed with premonition, however, that: "As the limit of the order is increased, such investigations as these rapidly become more laborious, as a continually increasing number of special cases have to be dealt with." Clearly, stronger general results would be desirable! With what we can now appreciate as truly uncanny foresight, Burnside finished the first edition of his book with the following closing remark:[11]

> No simple group of odd order is at present known to exist. An investigation as to the existence or nonexistence of such groups would undoubtedly lead, whatever the conclusion might be, to results of importance; it may be recommended to the reader as well worth his attention. Also, there is no known simple group whose order contains fewer than three different primes.... Investigation in this direction is also likely to lead to results of interest and importance.

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Thus, in one single paragraph, Burnside managed to lay down two of the most important research problems in finite group theory to be reckoned with in the next century.

The second one was not to remain open for very long. As we know, Burnside's tour de force[B: 1904a] solved this problem: the solvability of groups of order $p^a q^b$ (Theorem 4.4) implied their nonsimplicity (and conversely, of course). The proof of this great result depended critically on the newly invented tools of character theory. However, the first problem, equivalent to the solvability of groups of odd order, proved to be very difficult. Burnside's odd-order papers [B: 1900c] were clearly aimed at solving this problem, and he obtained many positive results. For instance, he showed that odd-order groups of order $< 40{,}000$ were solvable, and ditto for odd-order transitive permutation groups of degree either a prime, or < 100. The fact that some of the proofs involved character theoretic arguments prompted Burnside to make the following prescient comment at the end of the introduction to [B: 1900c]:

> The results obtained in this paper, partial as they necessarily are, appear to me to indicate that an answer to the interesting question as to the existence or nonexistence of simple groups of odd composite order may be arrived at by a further study of the theory of group characteristics.

By the time he published the second edition of [B$_1$], it was clear that Burnside was morally convinced that odd-order groups should be solvable. Short of making a conjecture, he summarized the situation by stating (in Note M, p. 503) that: "The contrast that these results shew between groups of odd

[10] *Five years later, Burnside gave a presentation of Cole's group by generators and relations, and observed that it is isomorphic to $PSL_2(8)$ in [B: 1898d].*

[11] *Notes to §260 in [B$_1$, 1st ed., p. 379].*

and even order suggests inevitably that simple groups of odd order do not exist."

Burnside was not to see a solution of the odd-order problem in his lifetime; in fact, there was not much progress on the problem to speak of for at least another forty-five years. Then, with Brauer's new idea of studying simple groups via the centralizers of involutions gradually taking hold, new positive results began to emerge on the horizon. Finally, building on work of M. Suzuki, M. Hall and themselves, Feit and Thompson succeeded in proving the solvability of all odd-order groups in 1963. Their closely reasoned work [FT] of 255 pages occupied a single issue of the *Pacific Journal of Mathematics*. Burnside was proved to be right not only in "conjecturing" the theorem, but also in predicting the important role that character theory would play in its proof. Indeed, Chapter V of the Feit-Thompson paper, almost 60 pages in length, relies almost totally on working with characters and Frobenius groups. Feit and Thompson received the Cole Prize for this work in 1965, and Thompson was awarded the Fields Medal in 1970 for his subsequent work on minimal simple groups. All of this work culminated later in the classification program of finite simple groups in the early 1980s.

"The contrast that these results shew between groups of odd and even order suggests inevitably that simple groups of odd order do not exist."

The spectacular successes of this program have apparently exceeded even Burnside's dreams, for he had stated on page 370 in the first edition of [B_1] that "a complete solution of this latter problem is not to be expected." That was, however, in the "dark ages" of the 1890s. Burnside would probably have felt very differently if he had known the $p^a q^b$ theorem, the odd-order theorem, and the existence of some of the sporadic simple groups found in the 1960s and 1970s. Today I think it is generally agreed that the classification program of finite simple groups could not have been possible without the pioneering efforts of Burnside.

Another well-known group-theoretic problem that came from Burnside's work in 1902–05 concerns the structure of torsion groups (groups all of whose elements have finite order). There are two (obviously related) versions of this problem, which may be stated as follows:

Burnside Problem (1). Let G be a finitely generated torsion group. Is G necessarily finite?

Burnside Problem (2). Let G be a finitely generated group of finite exponent N (that is, $g^N = 1$ for any $g \in G$). Is G necessarily finite?

Working in the setting of representation theory, Burnside was able to give an affirmative answer to (2) *in the case of complex linear groups*. In fact, his methods showed that, if G is a subgroup of $\mathrm{GL}_n(\mathbb{C})$ for some n, and G has exponent N, then $|G| \leq N^3$. This result was proved by a trace argument, obviously inspired by Burnside's then ongoing work on characters. Burnside also showed that the answer to (2) is yes for any group G with exponent $N \leq 3$. Later, Schur gave an affirmative answer to (1) for any $G \subseteq \mathrm{GL}_n(\mathbb{C})$, and Kaplansky extended Schur's result to $G \subseteq \mathrm{GL}_n(k)$ for any field k; details of the proofs can be found in [L, §9].

Progress on Burnside's Problems (1) and (2) was at first very slow. A positive solution for (2) was furnished for $N = 4$ by I. N. Sanov in 1948, and for $N = 6$ by M. Hall in 1958. For $N \geq 72$, P. S. Novikov announced a negative answer to (2) in 1959; however, the details were never published. Finally, for N odd and ≥ 4381, the negative answer to (2) appeared in the joint work of P. S. Novikov and S. I. Adian in 1968. For small values of $N \notin \{2, 3, 4, 6\}$ or N even, apparently not much is known. In particular, the cases $N = 5, 8$ seem to be still open. As for Problem (1), the answer turned out to be much easier. In 1964, E. S. Golod produced for every prime p an *infinite* group on two generators in which every element has order a finite power of p; this disposed of Burnside's Problem (1) in the negative.

This was, however, not the end of the story. Since the 1930s, group theorists have considered another variant of the Burnside Problems, which we can formulate as follows. For given natural numbers r and N, let $B(r, N)$ be the "universal Burnside group" with r generators and exponent N; in other words, $B(r, N)$ is the quotient of the free group on r generators by the normal subgroup generated by all Nth powers. Burnside's Problem (2) above amounts to asking whether $B(r, N)$ is a finite group. The following variant of this problem is called

The Restricted Burnside Problem. For given natural numbers r and N, are there only finitely many finite quotients of $B(r, N)$?

The point is that, even if the universal group $B(r, N)$ is infinite, one would hope that there are only finitely many ways of "specializing" it into finite quotients (and therefore a unique way to specialize it into a *largest possible* finite quotient). In

1959, A. I. Kostrikin announced a positive solution to this problem for all prime exponents; much of his work (and that of the Russian school) is reported in his subsequent book *Around Burnside*. After the partial negative solution of the Burnside Problem (2) was known, the interest in the Restricted Burnside Problem intensified. The breakthrough came in the early 1990s when E. Zelmanov came up with an affirmative solution to this problem, *for all r and all N*. Surprisingly (to others if not to experts), Zelmanov's solution depends heavily on the methods of Lie algebras and Jordan algebras. Another ingredient in Zelmanov's solution is the classification of finite simple groups: some consequences of the classification theorem were used in reducing the general exponent case to the case of prime power exponent via the earlier results of Hall and Higman. Zelmanov's main work was then to affirm the Restricted Burnside Problem first for $N = p^k$ with p odd [Z_1], and then for the (much harder) case $N = 2^k$ [Z_2]. For this work, Zelmanov received the Fields Medal in 1994. Looking back, I think it is quite remarkable that Burnside's work in representation theory and the open problems he proposed actually spawned the later work of two Fields Medalists. What a tremendous legacy to mathematics!

Some of my teachers and mentors have always urged me to "read the masters": they taught me that the great insight of the masters, implicit or explicit in their original writing, is not to be missed at any cost. In closing this section, I think I'll pass on this cogent piece of advice to our younger colleagues, using Burnside's book [B_1] again as a case in point. There is so much valuable information packed into this classic that sometimes it is left to later generations to unearth the "treasures" that the great master (knowingly or sometimes even unknowingly) left behind. In §§184–185 in the second edition of [B_1], Burnside discussed the characters of transitive permutation representations of a group G by making a "table of marks" (their character values), and showed how to "compound" such marks and resolve the results into integral combinations of the said marks. More than a half century later, L. Solomon resurrected this idea in [So], and formally constructed the commutative Grothendieck ring of the isomorphism classes of finite G-sets, which he appropriately christened the "Burnside ring" of the group. Today this Burnside ring $\mathfrak{B}(G)$ is an important object not only in representation theory, but also in combinatorics and topology (especially homotopy theory).[12] Some of the connections between $\mathfrak{B}(G)$ and the group G itself found by later authors are rather amazing. For instance, A. Dress [Dr] has shown that *G is a solvable group if and only if the Zariski prime spectrum of $\mathfrak{B}(G)$ is connected*, and there is even a similar characterization of minimal simple groups G in terms of $\mathfrak{B}(G)$. When I saw Louis Solomon in April 1997 at an MSRI workshop on the interface of representation theory and combinatorics, I asked him if the term "Burnside ring" originated with his paper [So]. He confirmed this, but added emphatically, "It is all in Burnside!"

A Tale of Two Mathematicians

As I contemplated and wrote about the career and work of F. G. Frobenius and W. Burnside, I could not help noticing the many interesting parallels between these two brilliant mathematicians. There was as much difference in style between them as one would expect between a German and an Englishman, and yet there were so many remarkable similarities in their mathematical lives that it is tempting for us to venture a direct comparison.

Burnside was three years Frobenius's junior, and survived him by ten, so they were truly contemporaries. Coincidentally, they were elected to the highest learned society of their respective countries in the same year, 1893: Frobenius to the Prussian Academy of Sciences, and Burnside to the Royal Society of England. Mathematically, both started with analysis and found group theory as the subject of their true love in their mature years. Both got into group theory via the Sylow Theorems, and published their own proofs of these theorems for abstract groups: Frobenius in 1887, and Burnside in 1894. Other group theory papers of Burnside in the period 1893–96 also in part duplicated results obtained earlier by Frobenius. Obviously, Frobenius had the priority in all of these, and Burnside felt embarrassed about not having checked the literature sufficiently before he published his own work. Burnside learned a valuable lesson from this experience, and from that time on, he was to follow Frobenius's publications very closely. In his subsequent papers, he made frequent references to Frobenius's work, always referring to him politely as "Herr Frobenius" or "Professor Frobenius". In Burnside's group theory book [B_1], Frobenius received more citations than any other author, including Jordan and Hölder. Frobenius was, however, less enthused about Burnside's work, at least at the outset. In his May 7, 1896, letter to Dedekind, Frobenius wrote,[13] after mentioning an 1893 paper of Burnside on the group determinant:

> This is the same Herr Burnside who annoyed me several years ago by quickly rediscovering all the theorems I had published on the theory of groups, in the same order and without exception: first my proof of Sylow's Theorems, then the theorem on groups with square-free orders, on groups of order

[12] *A good reference for this topic is [CR], where the entire last chapter is devoted to the study of Burnside rings and their modern analogues, the representation rings.*

[13] *English translation following [H_3, p. 242].*

$p^a q$, on groups whose order is a product of four or five prime numbers, etc. etc.

If the above sentiment was expressed in 1896, we can imagine how Frobenius felt later when he saw Burnside's papers [B: 1898a, 1900b], etc., in which Burnside re-derived practically all of Frobenius's results on the group determinant, group characters, and orthogonality relations! At least once or twice (e.g., on page 269 of the second edition of [B_1]), Burnside had stated that in [B: 1898a] he had "obtained independently the chief results of Professor Frobenius' earlier memoirs." For an expert analysis of this claim of Burnside, we refer the reader to [H_2, p. 278].

It was perhaps a stroke of fate that the group-theoretic work of Frobenius and Burnside remained perennially intertwined: they were interested in the same problems, and in many cases they strived to get exactly the same results. The following are some interesting comparisons.

1. Both Frobenius and Burnside worked on the question of the *existence of normal p-complements in finite groups*, and each obtained significant conditions for the existence of such complements. Their conditions are different, and the results they obtained are both standard results in finite group theory today. Frobenius's result seems stronger here, since it gives a necessary and sufficient condition, while Burnside's result offers only a sufficient condition.

2. *On transitive groups of prime degree*: a topic of great interest to Frobenius. Here, Burnside had the scoop, as he proved in [B: 1900c] that any such group is either doubly transitive or metacyclic, from which it follows that there are no simple groups of odd (composite) order and prime degree. The paper [B: 1900c] appeared heel-to-heel following Burnside's paper [B: 1900b] on "group-characteristics", and represented the first applications of group characters to group theory proper, a fact acknowledged by Frobenius himself.

3. *On Frobenius groups*: Burnside had been keenly interested in these groups, and devoted pages 141–144 in [B_1, 1st ed.] and subsequently [B: 1900a] to their study. He was obviously trying to prove that the Frobenius kernel is a subgroup, and by 1901, he was able to prove this in case the Frobenius complement has even order or is solvable. If one assumes the Feit-Thompson Theorem, this would give a de facto proof of the desired conclusion in all cases. Maybe this was one of the reasons that fueled Burnside's belief that odd order groups are solvable? We do not know for sure. Anyway, on the Frobenius group problem, it was Frobenius who had the scoop, as he proved that the Frobenius kernel is a subgroup in *all* cases in 1901. Frobenius's great expertise with induced characters gave him the edge in this race.

4. *Solvability of $p^a q^b$ groups*: This was clearly a common goal that both Frobenius and Burnside had very much hoped to attain. If m is the exponent of p modulo q, Burnside furnished a positive solution in case $a < 2m$ [B_1, 1st ed., p. 345], and Frobenius later relaxed Burnside's hypothesis to $a \leq 2m$. The truth of the result in *all* cases was proved by Burnside in 1904 (Theorem 4.4 above); here, Burnside's acumen with the arithmetic of characters gave him the winning edge.

Since Frobenius and Burnside worked on many common problems and obtained related results on them, it is perhaps not surprising that posterity sometimes got confused about which result is due to which author. One of the most conspicuous examples of this is the famous counting formula, which says that, with a finite group G acting on a finite set S, the average number of fixed points of the elements of G is given by the number of orbits of the action (see box). Starting in the mid-1960s, more and more authors began to refer to this counting formula as "Burnside's Lemma". According to P. M. Neumann [Ne], S. Golomb and N. G. de Bruijn first made references and attributions to Burnside for this result in 1961 and 1963–64, after which the name "Burnside's Lemma" began to take hold. While Burnside did have this result in his group theory book [B_1, p. 191], he had basically little to do with the lemma. In his paper "A lemma that is not Burnside's" [Ne], Neumann reported that Cauchy was the first to use the idea of the said lemma in the setting of multiply transitive groups, and it was Frobenius who formulated the lemma explicitly in [F: (36), p. 287], and who first understood its importance in applications. Neumann's recommended attribution "Cauchy-Frobenius Lemma" was lauded by de Bruijn in a quotation at the end of [Ne]; however, in his group theory book [NST] with Stoy and Thompson, Neu-

"A lemma that is not Burnside's"

$$\#(G\text{-orbits on } S) = \frac{1}{|G|} \sum_{g \in G} \pi(g)$$

where $\pi(g)$ is the number of points in S fixed by g. According to R. C. Read [PR, p. 101], "this lemma has been likened to the country yokel's method of counting cows, namely count the legs and divide by four." Ironically, it is sometimes easier to count legs than to count cows! For instance, to count the number of different necklaces a jeweler can make using six beads of two colors (say green and white), we can get the answer, 13, by applying the above formula to the dihedral group of twelve elements acting on a set of $2^6 = 64$ "formal necklaces". Burnside deserved credit for popularizing the Cauchy-Frobenius formula by including it in his book. Later, a far-reaching generalization of this formula known as Pólya's Fundamental Theorem became a major landmark in the field of enumerative combinatorics.

From the viewpoint of representation theory, π is the character of the permutation representation associated with the action of G on S. In case this action is doubly transitive, Burnside showed in his book that π is the sum of the trivial character and an irreducible character of G.

mann somehow decided to refer to the result as "Not Burnside's Lemma"!

Another case in point is the theorem, mentioned already in Part I, that the degree of an irreducible (complex) representation of a group G divides the order of G. Some authors have attributed this theorem to Burnside, but again it was Frobenius who first proved this result, as one can readily check by reading the last page of his classical group determinant paper [F: (54)].[14] Burnside supplied a proof of this result in his own terms, but the theorem was definitely Frobenius's. Issai Schur, a student of Frobenius, proved later that the degree of an irreducible representation divides the index of the center of G, and N. Itô was to prove eventually that this degree in fact divides the index of any abelian normal subgroup.

With such little tales on attributions, we conclude our discussion of the life and work of Frobenius and Burnside. Although their work was so closely linked, there seemed to have been no evidence that they had either met, or even corresponded with each other. Would the history of the representation theory of finite groups be any different if these two great mathematicians had known each other, or if there had been a *Briefwechsel* between them, like that between Frobenius and Dedekind?

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[14] *The result was also proved independently by Molien, as pointed out by Hawkins [H_2, p. 271].*

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Reforming Scholarly Publishing in the Sciences: A Librarian Perspective

Joseph J. Branin and Mary Case

Introduction: The Librarian's View of the Scholarly Publication System

Research librarians—that is, librarians who work in large college, university, and private research libraries—today face the difficult challenge of managing their collections and information services during a period of crisis and profound change in scholarly publications. This crisis and change affect all fields of knowledge, but the sciences, including mathematics, are front and center in defining the stresses and innovations that are shaking the foundations of the established, scholarly publication system. Research librarians at present are particularly concerned about three issues in scholarly publishing. First, there is the very specific but seemingly intractable problem of reversing, or at least containing, the rapidly rising cost of scientific journal subscriptions. Librarians often describe this as the "serials crisis" in scholarly publications. Second, there is growing concern among research librarians that revisions to local, national, and international information policies and procedures governing intellectual property rights may threaten the free flow of information in scholarly communications. And finally, there is the overriding librarian preoccupation with the applications and effects of new information technology. Will the new digital information system fundamentally change the scholarly publication system and the research librarian's role in it? Will new information technology help solve troubling current economic and structural problems in scholarly publication or merely exacerbate these problems?

The sheer volume of scholarly publication, the rising cost of this scholarship (particularly in the sciences), and the dizzying array of new options brought about by advances in information technology all conspire to make this an exciting and difficult time to be a research librarian. Underlying this tumultuous change and challenge is the fundamental question of who owns scholarly publications. Ownership is key to both the cost and accessibility of scholarship in the traditional print information system as well as in the emerging digital information system. Research librarians, as this essay will document, are increasingly troubled by the growing commercialization of scholarship in the sciences, where authors assign their copyrights to commercial publishers. By placing ownership of publications outside the circle of the academy, scholars run the risk of making their works unaffordable and unavailable to research libraries.

Research librarians and their concerns, of course, form only a subset of the players and issues in the overall scholarly publication system. The librarian perspective on problems and solutions in scholarly publication is important, but this perspective must be viewed in the context of an overall system which, at least until the present time, has depended on the interplay of authors, publishers, librarians, and readers in a highly interdependent process. The potential, in light of the new digital information system, for changing the roles of the respective players in the process is, in fact, one of the underlying stresses in scholarly

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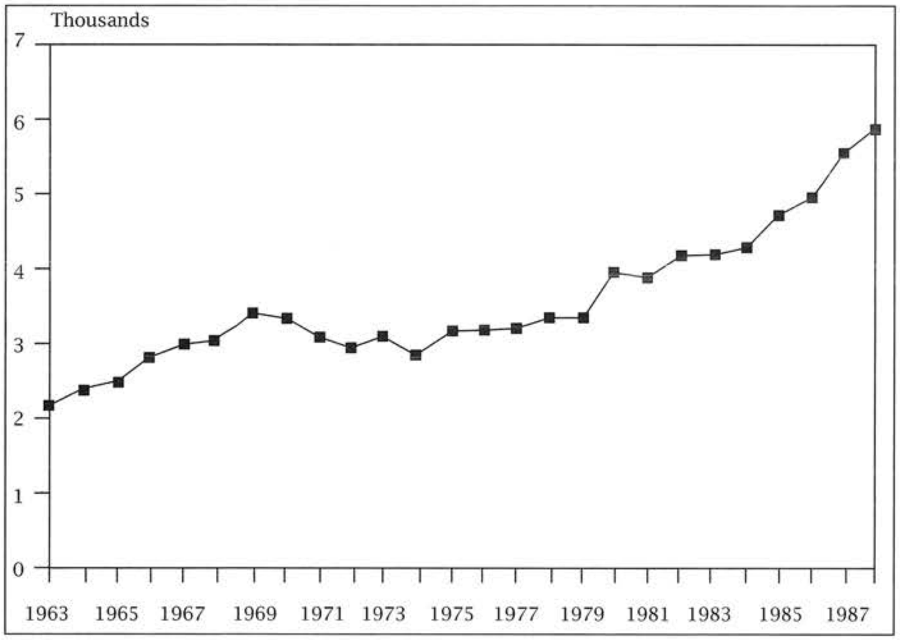


Chart 1. Number of university press books published annually.

publishing today. With desktop publishing software, client-server technology, and the Internet, do authors need publishers to produce and distribute their scholarship anymore? With mass digital storage, broadband telecommunications, and electronic document delivery to the desktop, what is to become of traditional library services to readers that have been built around decentralized, local print collections?

Defining the Crisis in Scholarly Publishing: Too Much at Too High a Cost

Whose Crisis Is It?

To oversimplify, the established formal scholarly publication system is made up of three major constituents: scholars who create, describe, and use new knowledge; publishers who evaluate, edit, package, and distribute this knowledge; and librarians who collect, organize, preserve, and share this published knowledge. Depending on your constituency group, you may or may not believe there is a crisis in scholarly publishing. Research librarians certainly think there is one, for they have been finding it increasingly difficult to keep up with the quantity and cost of new scholarship in the last quarter of the twentieth century. These may be the boom years for scholars and for certain types of publishers, but for research librarians, who collectively have the responsibility for preserving and sharing the complete record of scholarship, the overload of information is crushing. Rutherford D. Rogers, the retired director of the Yale University libraries, observed a number of years ago that information overload was the number one challenge facing scholars and research librarians. In a *New York Times* article entitled "Torrent of print strains the fabric of libraries" [1], Rogers commented that "we're drowning in information and starving for knowledge."

The Growing Imbalance between Scholarly Output and Library Resources

Starting about twenty years ago, research librarians in the United States began complaining about the growing imbalance between scholarly output and the resources necessary to collect, preserve, and share this output. In 1979 a Board of National Enquiry composed of publishers, librarians, and university faculty and administrators issued a report entitled "Scholarly Communication" [2]. In it the board describes how librarians in major research centers are "facing the difficult task of allocating increasingly scarce dollars among the vast and steadily growing number of books, journals, microforms, and other materials of scholarship." According to the Board of National Enquiry major research libraries are "no longer able to develop or maintain comprehensive, self-contained collections". In 1991 the Andrew W. Mellon Foundation sponsored a study and report entitled "University Libraries and Scholarly Communication" [3]. The report documents the tremendous growth in the number of scholarly books and articles published over the last forty years. For example, Charts 1 and 2, which are reproduced from the Mellon study, show the increase in book titles issued by American university presses between 1963 and 1987. Except for some dips in the 1970s, university presses have generally issued more new titles annually, on average 3% more each year. In 1994 the Association of American Universities (AAU) in cooperation with the Association of Research Libraries (ARL) shared the results of its analysis of current challenges in scholarly communication. Again, the system is described as being out of kilter. According to the "AAU/ARL Research Libraries Project Report" [4] worldwide book production increased by 45% between 1980 and 1990, yet during the same period there was an "aggregate decline in the number of titles acquired by libraries."

Growth of Journal Literature in the Sciences

While the growth of scholarship can be seen in all fields of knowledge and in all formats of publication, increases are most dramatic in the sciences and in the journal literature of the sciences. Chart 3, which is drawn from *Science Citation Index* source publications, illustrates the number of new scientific journals founded from 1700 to the end of the 1980s [3]. Since World War II there has been an explosion of scholarly information published in journals, particularly in scientific and technical journals. John Naisbitt, author of *Megatrends* [5], estimates that 6,000 to 7,000 new articles are written each day and that scientific and technical information increases by 13% per year, which means a doubling in output every 5.5 years. Andrew Odlyzko, a mathematician at AT&T Bell Laboratories, believes scientific scholarly literature is growing at an exponential rate, in the mathematical meaning of the word. He estimates that the number of scientific papers published annually has been doubling every 10 to 15 years for the last two centuries. According to Odlyzko, in 1870 there were 840 papers published in mathematics; by the middle of the 1990s, there were 50,000 new mathematics articles being published annually [6].

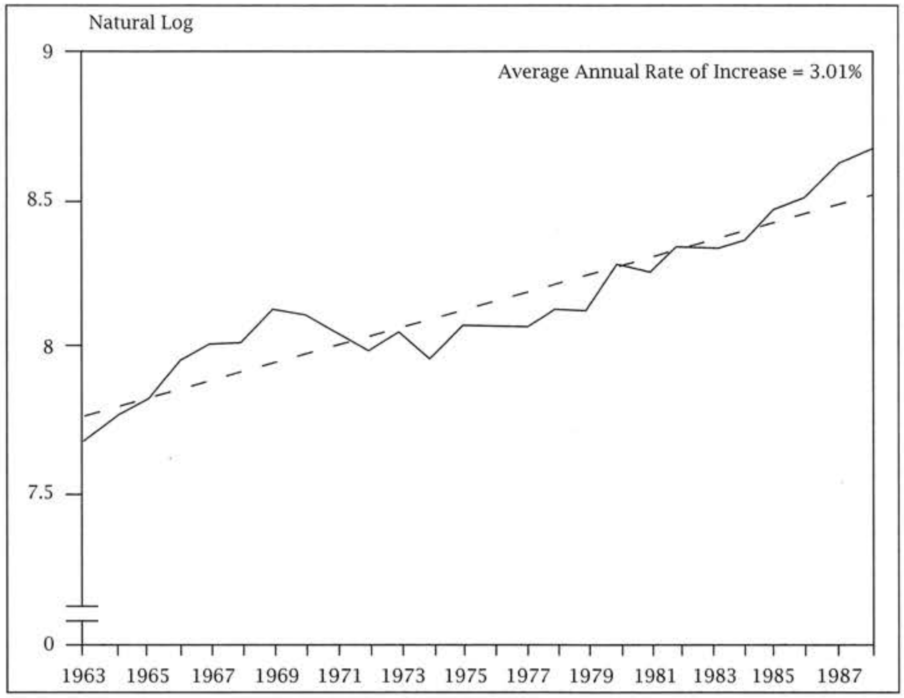


Chart 2. University press books, average annual rate of increase.

The High and Rising Cost of Scientific Journals

The statistics on the volume of scholarly publishing may not be exact, but the trend is clear: more is being published each year, especially in scientific fields where the journal article is the formal medium of choice. This has severe implications for research libraries, because scientific journal subscriptions are expensive and the cost for these subscriptions is rising rapidly. The annual "Periodicals Price Survey", published in *Library Journal* [7], lists the recent price history and average cost of journal subscriptions in different disciplines (see Chart 4). According to the survey the most costly journals in 1997 are all in scientific fields. Physics journals, at an average price of $1,494.47 for a library subscription, are the most expensive, followed by journals in chemistry, astronomy, biology, math and computer science, engineering, technology, geology, botany, and zoology. Journals in the humanities and social science fields on average cost much less: $89.73 for journals in language and literature, $96.46 for journals in history, and $238.09 for journals in psychology. Not only are prices higher for scientific journals, but their costs are rising faster than in many other fields. Between 1996 and 1997 library subscription prices increased by 11.41% in physics, 11% in chemistry, and 10.04% in math and computer science, while language and literature increased by only 3.97%, history by 3.88%, and music by 7.57%. Some fields in the social sciences, such as psychology, which saw a rise of 11.43%, and business and economics, which increased by 13.7%, are beginning to rival the sciences for annual price increases in journal subscriptions.

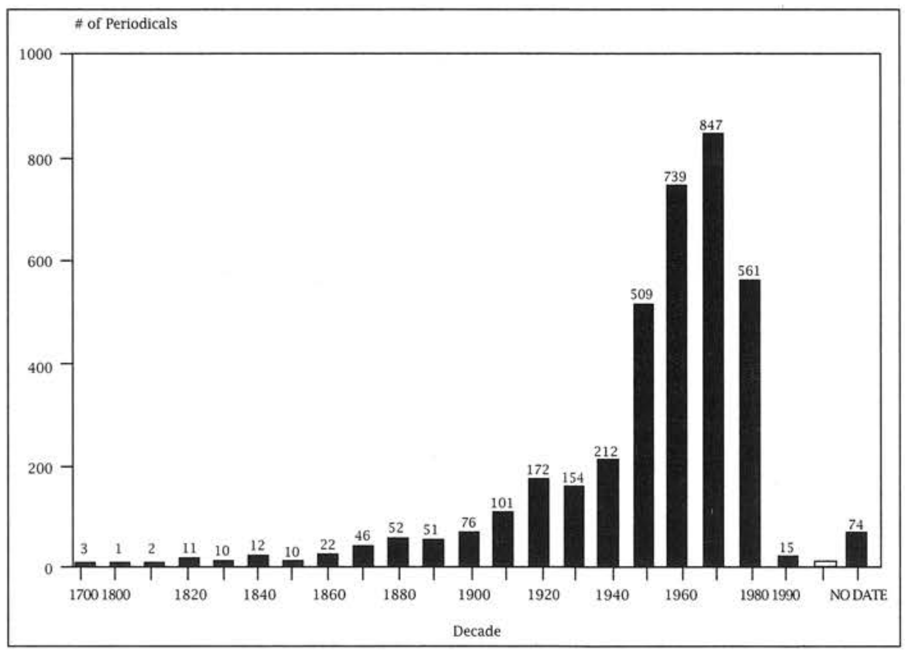


Chart 3. Growth of scientific journals.

Research Libraries Are Acquiring Less Each Year

Library budgets are simply not keeping pace with the increasing volume and cost of scholarship. At a time when research libraries should be acquiring more books and journals to keep pace with the growth of scholarship, they are actually acquiring fewer. Each year the Association of Research Libraries (ARL), which is composed of the 121 largest research libraries in North America, gathers statistics on its members' activities and expenditures. Chart 5 plots the general trend research libraries have found themselves in over the last decade [8].

Subject	Average No. of Titles 1993-97	Average Cost Per Title 1993	Average Cost Per Title 1994	% of Change '93-'94	Average Cost Per Title 1995	% of Change '94-'95	Average Cost Per Title 1996	% of Change '96-'97	Average Cost Per Title 1997	% of Change '96-'97	'93-'97 % of Change
Agriculture	197	$274.98	$286.91	4.34	318.68	11.07	$373.34	17.15	$402.49	7.81	46.37
Anthropology	38	127.18	138.93	9.24	155.55	11.96	174.08	11.91	186.44	7.10	46.60
Art & Architecture	67	91.46	93.01	1.69	98.14	5.52	103.88	5.85	108.21	4.17	18.31
Astronomy	22	829.55	755.95	-8.87	855.81	13.21	1,005.71	17.52	1,084.32	7.82	30.71
Biology	231	536.19	555.75	3.65	621.64	11.86	732.98	17.91	824.05	12.42	53.69
Botany	58	416.02	427.85	2.84	482.01	12.66	560.97	16.38	612.78	9.24	47.30
Business & Economics	238	190.95	204.90	7.31	236.64	15.49	280.80	18.66	319.26	13.70	67.20
Chemistry	186	933.88	940.88	0.75	1,035.01	10.00	1,224.50	18.31	1,359.22	11.00	45.55
Education	89	123.33	128.76	4.40	140.58	9.18	155.29	10.46	169.12	8.91	37.13
Engineering	241	491.36	534.98	8.88	591.13	10.50	718.91	21.62	814.38	13.28	65.74
Food Science	16	328.07	351.00	6.99	398.09	13.42	456.60	14.70	501.73	9.88	52.93
General Science	76	342.47	368.10	7.48	410.11	11.41	471.40	14.94	530.39	12.51	54.87
General Works	76	61.68	67.40	9.27	72.98	8.28	84.04	15.15	89.73	6.77	45.48
Geography	62	277.62	297.58	7.19	334.51	12.41	382.52	14.35	442.90	15.78	59.53
Geology	81	444.69	461.13	3.70	511.99	11.03	615.08	20.14	692.83	12.64	55.80
Health Sciences	1373	355.34	372.29	4.77	414.75	11.41	487.34	17.50	543.32	11.49	52.90
History	198	73.31	77.86	6.21	85.40	9.68	92.86	8.74	96.46	3.88	31.58
Language & Literature	328	67.48	69.37	2.80	75.87	9.37	86.30	13.75	89.73	3.97	32.97
Law	87	93.39	95.85	2.63	103.49	7.97	115.75	11.85	119.83	3.52	28.31
Library & Information Science	59	144.34	152.94	5.96	170.30	11.35	187.99	10.39	198.04	5.35	37.20
Math & Computer Science	169	526.84	582.34	10.53	631.04	8.36	743.09	17.76	817.72	10.04	55.21
Military & Naval Science	9	99.00	111.44	12.57	129.33	16.05	142.00	9.80	154.67	8.92	56.23
Music	45	53.59	55.07	2.76	59.24	7.57	62.59	5.65	67.33	7.57	25.64
Philosophy & Religion	140	86.28	87.21	1.08	97.55	11.86	108.28	11.00	112.70	4.08	30.62
Physics	184	994.93	1,020.57	2.58	1,130.57	10.78	1,341.46	18.65	1,494.47	11.41	50.21
Political Science	57	117.52	123.55	5.13	139.89	13.23	161.71	15.60	178.30	10.26	51.72
Psychology	134	152.87	167.98	9.88	188.67	12.32	213.67	13.25	238.09	11.43	55.75
Recreation	18	71.44	76.73	7.40	79.14	3.14	88.45	11.76	92.72	4.83	29.79
Sociology	242	145.64	155.83	7.00	172.63	10.78	196.90	14.06	215.20	9.29	47.76
Technology	196	430.22	474.47	10.29	531.37	11.99	631.07	18.76	706.95	12.02	64.32
Zoology	106	402.83	424.30	5.33	474.57	11.85	545.88	15.03	599.11	9.75	48.73

Chart 4. Cost history of periodicals by subject.

Between 1986 and 1996 the largest research libraries in the United States and Canada saw their serials purchases decline by 7% and monograph purchases decline by 21%. (In librarian terminology, "serials" are publications that are issued in successive parts, usually at regular intervals. Publications such as periodicals, newspapers, annuals, memoirs, proceedings, and transactions of societies are "serials". "Monographs" are single books on specific subjects.) While the number of scholarly serials and monographs purchased declined, research libraries spent 29% more on monographs and 124% more for serials during this same time period. The monograph unit price rose by 63%, and the serial unit price by 147%. These numbers are not adjusted for inflation, but since 1986 the annual average increase for a serial subscription has been 9.5% and for a monograph purchase 5.0%, both of which are higher than the general inflation trends in North America during this same period. In the last decade research libraries purchased fewer books each year than they did in 1986, and by 1991 serials subscription cancellation projects were becoming standard operating procedure.

The Commercialization of Scholarly Publication in the Sciences: At the Core of the Economic Problem

Blame the Publishers

As a result of the high cost and continuing double-digit annual price increases for scientific journals, research librarians have had to shift ever-larger portions of their acquisitions budgets into science journal subscriptions, even as they cancel journal titles and buy fewer books. With growing frustration and boldness, librarians are blaming the scientific community, particularly the commercial publishers of scientific journals, for this unfortunate situation. Librarians write about the expensive science journal as a "Doomsday Machine" or as "The Journal That Ate the Library" [9]. A headline in a recent issue of the *Wisconsin State Journal* proclaims, "Librarians rebel against publisher" [10]. The publisher in question is Reed Elsevier, the world's largest commercial publisher of academic and scientific journals. Its most expensive journals, such as *Brain Research* and *The Journal of Chromatography*, can cost as much as $15,000 a year for a library subscription. According to the news report in the *Wisconsin State Journal*, librarians are "fed up" and "quite desperate" over the high and rising prices that Reed Elsevier and other scientific publishers are charging for their journals. In a recent *New York Times* article entitled "Concerns about an aggressive publishing giant" [11], a group of professors and librarians at Purdue University is reported as telling Reed Elsevier that its "must have" journals had become "can't afford", and "don't need" journals. Research libraries have simply not been able to retain their purchasing power for acquisitions in the face of these high costs for scientific journals. The result has been massive cancellation of library subscriptions and the steady erosion of new book purchasing. For example, the University of Wisconsin at Madison library, the fourteenth largest research library in North America, has cancelled more than 7,000 subscriptions to academic journals over the last ten years.

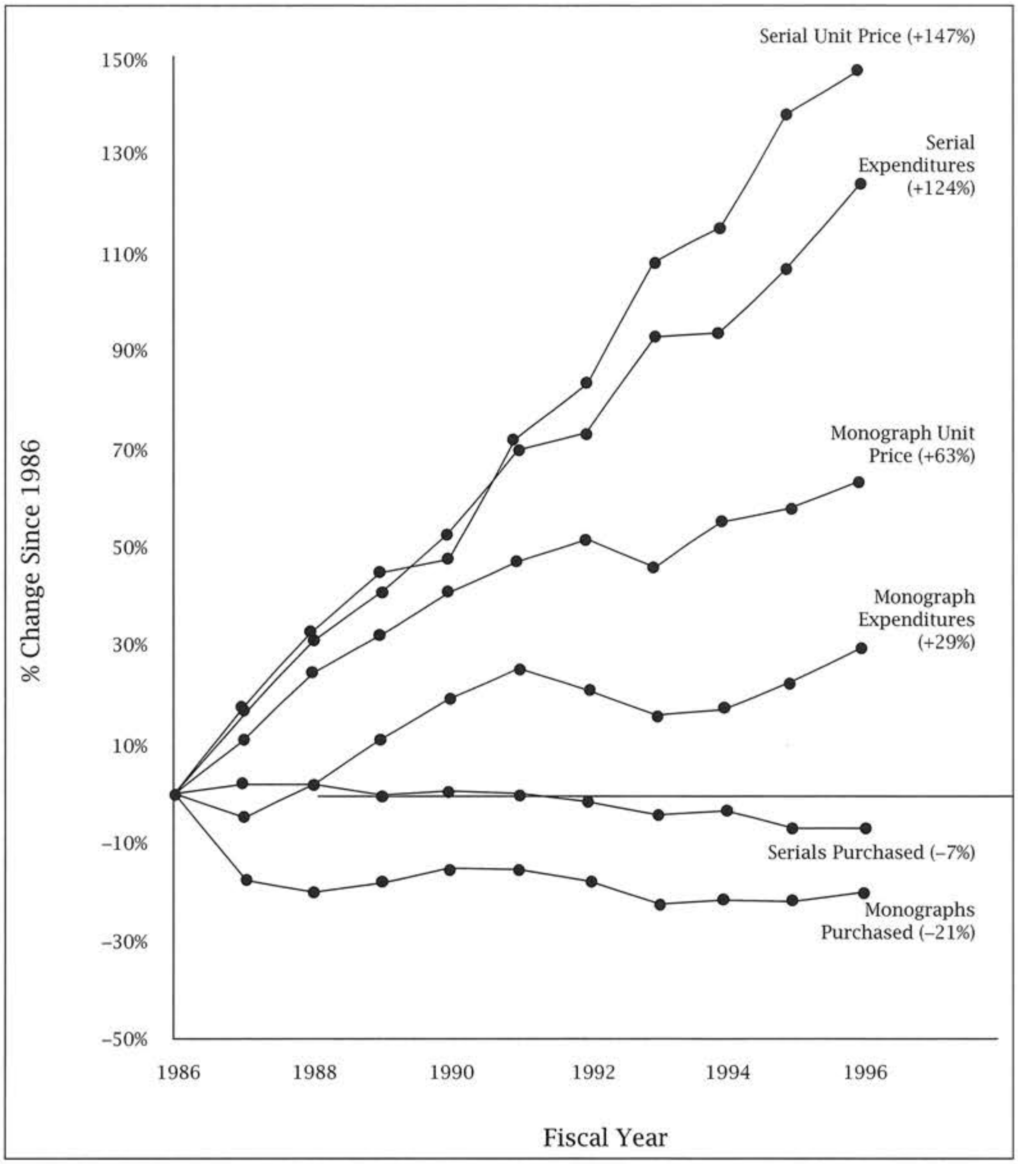
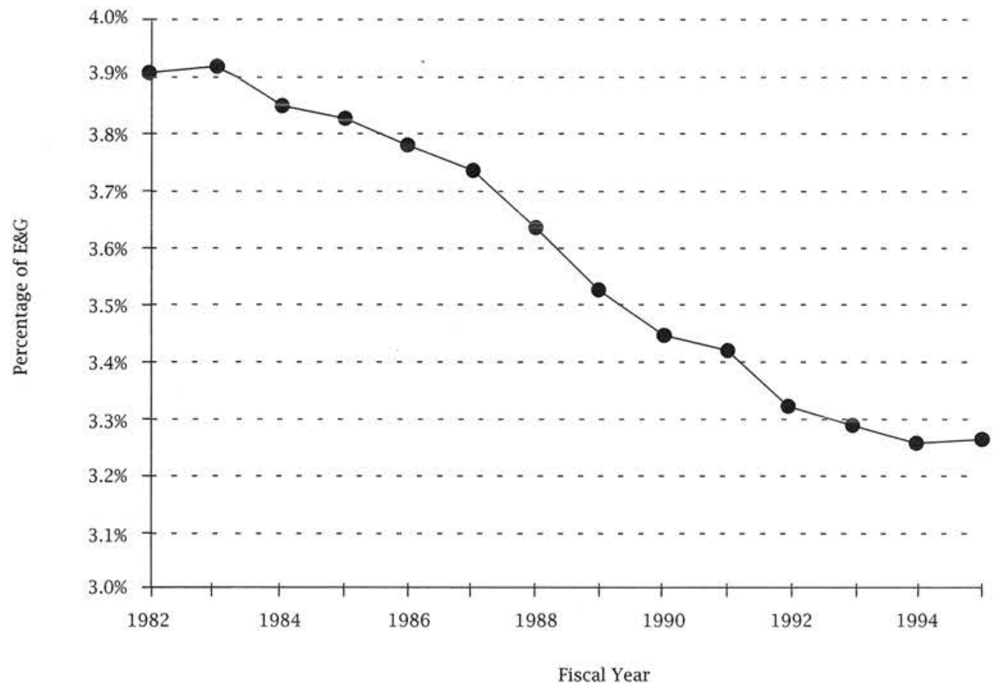


Chart 5. Monograph and serial costs in ARL libraries, 1986–1996.

Blame the Librarians

While research librarians complain, some scholars and publishers express differing sentiments about the state of scholarly publishing in the sciences. Albert Henderson, editor of *Publishing Research Quarterly*, in a recent letter to *The Chronicle of Higher Education* [12], took issue with Robion Kirby, a mathematics professor at the University of California, Berkeley, over who is to blame for declining library acquisitions. Kirby, in April of 1997, sent an e-mail survey report on the cost of mathematics journals to his colleagues around the country [20]. Kirby describes the plight of mathematics libraries like that at Berkeley, where acquisitions funds are not keeping pace with the 13% rise in annual subscription costs for mathematics journals. Kirby points a finger at high-priced, commercially published mathematics journals and predicts that if the current situation continues, Berkeley's math library will see its purchasing power cut in half in three years. While Kirby urges mathematicians to start publishing their work in less expensive journals, Henderson makes a different recommendation: simply increase library funding. According to Henderson, "If library budgets matched the growth of research expenditures, we would not be having this discussion." Henderson is right about the anemic state of research library budgets. As Chart 6 shows, the library percentage of university education and general expenditures has decreased almost 17%, from 3.91% in 1982 to 3.26% in 1995 [13].

But can research librarians and the academic community realistically expect that library acquisitions budgets will increase by 10% to 15% a year? At Berkeley, for example, where the expenditure for mathematics journals was approximately $250,000 in 1997 and subscription increases are averaging 13% a year, the institution will have to commit over $360,000 to math journal subscriptions in the year 2000 just to retain the same purchasing power. The provost at the University of Kansas recently told the Kansas faculty that the uni-



Year	Percent
1982	3.9100%
1983	3.9200%
1984	3.8500%
1985	3.8300%
1986	3.7800%
1987	3.7400%
1988	3.6400%
1989	3.5300%
1990	3.4500%
1991	3.4200%
1992	3.3200%
1993	3.2869%
1994	3.2589%
1995	3.2604%

Chart 6. ARL library percentage of university education and general (E&G) expenditures.

versity library there would need an acquisitions budget of $9.4 million to purchase the same proportion of published scholarship as it did in 1986 [14]. This is 2.5 times more than its current acquisitions budget. To have achieved this total, the acquisitions budget at the University of Kansas libraries would have had to increase by 9.6% a year during a time when the university's operating budget increased by only 2.6% a year. Research librarians certainly want to strengthen the library economy, but few would expect, in either public or private universities, the massive infusions of funds necessary to keep pace with current inflation rates for scholarly scientific publications.

Why Do Science Journals Cost So Much?

Why do science journals cost so much, and why do subscription prices for these journals continue to rise at double-digit rates each year? Could the reasons be the growth of science literature, fewer subscribers, and higher production costs or profits for publishers? These are not easy questions to answer, because publishing data are notoriously slippery and sensitive. As one publishing industry analyst put it, "Book industry statistics may be likened to a handful of wet spaghetti. They may be more or less digestible, even a bit nourishing; but they are messy, slippery, elusive, never tidy" [15]. One scientist who tried to get a better handle on the cost of science journals paid dearly for his efforts.

The Barschall Study

In 1986 and again in 1988 Henry Barschall, now deceased but at the time a physics professor at the University of Wisconsin and an editor of *Physical Review*, published a series of studies on the cost and cost effectiveness of scholarly journals in several scientific disciplines [16, 17]. Barschall determined the cost, based on library subscription price, per 1,000 characters for a sampling of journals in physics, optics, mathematics, and philosophy. He found that the cost-per-character ratio could be more than 40 between the most expensive commercially published journals and the least expensive scientific society- or association-published journals. In physics, for instance, Barschall's study revealed that in 1985 the *Journal of Applied Physics*, published by the American Institute of Physics, cost .7 cents per 1,000 characters, while *Particle Accelerators*, published by Gordon and Breach, cost 31 cents per 1,000 characters. In mathematics, using the American Mathematical Society's (AMS) "Survey of American Research Journals" of 1982, Barschall found that a library subscription to the *Journal of the American Statistical Association* cost .8 cents per 1,000 characters, while *Applicable Analysis*, published by Gordon and Breach, cost 35 cents per 1,000 characters [16].

Barschall then went on to add another factor to his analysis: "impact", the frequency with which articles in journals are cited, as measured in *Science Citation Index*. By combining cost and impact Barschall developed a cost-effectiveness test which he applied to 200 journals in physics. His analysis led him to conclude that "All the publishers whose journals have low average costs per character or low ratios of cost to impact are scientific societies or associations, while the publishers whose journals have high costs per character or high ratios of cost to impact are commercial firms" [17].

Blame the Commercial Publishers of Science Journals

Barschall's findings confirmed the experience of many research librarians: commercial publishers in the scientific disciplines were at the core of their economic woes. One commercial publisher, Gordon and Breach, who came out at the bottom of Barschall's survey of cost effectiveness, disagreed and sued Barschall, the American Physical Society (APS), and the American Institute of Physics (AIP) in West Germany, Switzerland, France, and the United States over the publication of the journal cost surveys [18]. Gordon and Breach later obtained an injunction in West Germany, barring the AMS from distributing surveys in which Gordon and Breach journals were included. The injunction still stands. Gordon and Breach contended these surveys were conducted in a poor manner and constituted unfair comparative advertising. Nevertheless, courts in West Germany, Switzerland, and the United States upheld Barschall's right to say what he did and the rights of the APS, AIP, and AMS to publish surveys on journal cost. A French trial court did find in favor of Gordon and Breach under strict French comparative advertising laws. The AIP/APS is appealing that decision. In the U.S. case, decided on August 26, 1997, Judge Leonard B. Sand found in favor of AIP/APS, affirming that "Barschall's methodology has demonstrated to establish reliably precisely the proposition for which defendants cited it—that defendants' physics journals, as measured by cost per character and cost per character divided by impact factor, are substantially more cost-effective than those published by plaintiffs" [19]. When notified of Judge Sand's decision, Gordon and Breach immediately announced their intention to appeal the decision.

Gordon and Breach's legal tactics are a disappointment to the scholarly community, and they have not stopped further analysis of cost differentials among science journals. As mentioned earlier, in the spring of 1997 Robion Kirby distributed widely an e-mail message to his colleagues [20] that reported on a survey he conducted on the cost of mathematics journals in the University of California, Berkeley, library. Kirby's findings are similar to Barschall's: prices, in this case cost per page, charged for journals in mathematics can vary greatly. Kirby's exact figures are subject to more dispute than his qualitative conclusion: commercial publishers, such as Gordon & Breach, Elsevier, Springer-Verlag, Birkhäuser, Wiley-Interscience, de Gruyter, Baltzer, Kluwer, and Academic Press account for most of the expensive journal titles published in mathematics. In his e-mail Kirby encourages "all mathematicians to pledge that they will not submit papers to, nor edit for, nor referee for, high priced journals." Kirby characterizes the current situation in mathematics scholarly publishing as "crazy." He states that "even if we can survive with the status quo, we owe it to the math community at large to vastly improve our efficiency in disseminating mathematics."

Finding Solutions: Owning and Sharing Scholarly Publications in the Digital Age

Who Owns Scholarly Publications?

Research librarians share Professor Kirby's view that the current situation in scholarly publishing in mathematics and in all the sciences is untenable and must be changed, but how? In the current system scholars, in most cases supported by a university and in many cases also supported by governmental grants, do research and write manuscripts about their research findings. They submit their manuscripts to nonprofit academic publishers—that is, university presses, scholarly societies, or scientific association publishers—or to commercial publishers who evaluate, edit, package, and distribute worthwhile articles in their journals. Publishers usually ask or demand that authors give copyright ownership of their articles to them. Publishers then sell their journals to individual scholars and to research libraries. North America's largest universities, through their research libraries, spent more than $386 million on current serials in 1996 to buy from publishers this record of scholarship produced by their faculty of scholars [21]. In this cycle of writing, editing, and archiving scholarly information, universities and their libraries spend a great deal of money at the front and back end. Scholars, who create the articles, make little or no profit and in some cases pay the publisher through a practice of "page charges" to package their work. Scholarly publishing may be a precarious occupation, but to librarians publishers seem to end up in control of this cycle, with the ownership of scholarship and with the right to sell it as a commodity.

Scholarship As a Specialized Commodity

Scholarship is an interesting type of information commodity in that it has a very limited market and no "elasticity of demand", which means that without competition owners can charge what they want [22]. Occasionally a scholarly article or book will appeal to a broad audience and even become a best seller, but in most cases scholarship is highly specialized, obtuse, and meant for a small target audience. Andrew Odlyzko makes this point in his article "Tragic Loss or Good Riddance? The Impending Demise of Traditional Scholarly Journals" [6]. According to Odlyzko, "Research papers are written by specialists for specialists," and the typical number of serious readers for any given research paper is under twenty. Because of the sheer size (number of pages issued annually) and the high subscription cost of many scientific journals, library or institutional subscriptions have largely replaced individual subscriptions. Research librarians then are primary buyers of science journals and other specialized scholarly publications.

High-Cost, Low-Use Scholarship

Research librarians have known for some time that portions of their collections receive very limited use. In 1979 Allen Kent issued a rather controversial study on the use of library material in the University of Pittsburgh library [23]. Kent examined circulation records and in-house use of library material over a seven-year period at Pittsburgh and found "that any given book purchased had only slightly better than one chance in two of ever being borrowed." As books on the shelves aged and did not circulate, their likelihood of ever circulating diminished to as low as one chance in fifty. Journal use was also discovered to be low. Subsequent use studies have confirmed Kent's general finding of underutilization of scholarship in research libraries. In 1991 and 1992 staff at the State University of New York at Albany library gathered data on the use of their journal collection [24]. In science and mathematics they found that of the 1,403 current journal titles in their collection, 229 could be described as "low-use" titles, that is, titles for which there were five or fewer uses in a year. These 229 low-use titles were tracked as having 522 uses during the year. Their total subscription cost to the library was $103,758; therefore, cost per use—and this excludes any overhead cost for processing, managing, and storing these titles—was $198.77.

Journal Cancellation Projects As a Coping Strategy

Scholarship may have no "elasticity of demand", but under the current scholarly publication system research librarians are finding it necessary to say no to a growing number of high-cost, low-use journals and monographs. Tina Chrzastowski and Karen Schmidt, librarians at the University of Illinois at Urbana-Champaign, tracked the cancellation of journal subscriptions in five Midwestern research libraries (Illinois, Iowa, Michigan State, Ohio State, and Wisconsin) over the five-year period from 1988 to 1992 [25]. During this period the five libraries canceled a total of 13,021 serials titles, which represented a 5.7% reduction in total serials holdings. Science titles and non-U.S.-published titles dominated the serials cancellation lists. One approach then to managing the scholarly publication system is to follow a marketplace model. This is what research librarians are doing: buying what they can afford and cutting back where necessary. Scholarship that is expensive or that has a small readership is the first to go. As a result, specialized science journals and foreign-language material are becoming less available in research libraries.

Canceling journals and buying fewer monographs are just coping strategies and not really solutions to the crisis in scholarly publications. In fact, buying fewer items only deepens the crisis for publishers and scholars. Publishers raise their prices as revenues decline with fewer sales, and scholars find it harder to locate the scholarship they need in their less robust local library collections. What research librarians would ideally like to see is a reform, a restructuring, of the scholarly publication system itself. Such reform revolves around two issues: the digitization and the ownership of scholarly information. Moving from print to digital will be much more than just a format change for scholarly publication. The way information is created, organized, stored, and retrieved will be transformed. But more fundamental than the potential of technological transformation will be the perennial question of ownership, for in the digital age owners will exert greater control over the access to and cost of scholarly information than they ever did in the print environment.

Reform through New Information Technology

The digital information system is still quite immature, but its potential as a vehicle or tool for revolutionary change in library service and in scholarly publishing is becoming clear and startling. While print is place and time bound, networked digital information is not. With a computer workstation networked to the Internet and with the proper passwords or clearances, scholars from any location and at any time of the day can now gain access to a growing array of online library catalogs, reference works, newspapers, business and government reports, and electronic journals. Scientific scholarly publishers are leading the way in this transition from print to electronic communications. The AMS, the American Physical Society, the American Institute of Physics, the American Chemical Society, Elsevier, Springer-Verlag, and Academic Press have been some of the first scholarly publishers to offer many of their journals online. The AMS is now publishing three journals in electronic form only: *Conformal Geometry and Dynamics*, *Representation Theory*, and *Electronic Research Announcements*.[1]

A recent survey of the penetration of online journals into the core of scholarly literature uncovered that 24% (665 of 2,729) of journals listed in *Science Citation Index*, 19% (546 of 2,866) of journals listed in *Social Science Citation Index*, and 10% (118 of 1,135) of journals listed in *Arts and Humanities Citation Index* were available online [7]. Web sites on the Internet abound with gateways to scientific information in the digital medium. In mathematics several such interesting Web sites can be found at the

[1] *These electronic journals can be found at the AMS home page,* `http://e-math.ams.org/`.

AMS home page (`http://e-math.ams.org/`), the European Mathematical Information Service (`http://www.emis.ams.org/`), and Web-based Mathematics Sources maintained by the University of Pennsylvania (`http://www.math.upenn.edu/MathSources.html`). Not only is current literature becoming available in the electronic medium, but older information is also being digitized. The J-STOR Project, a nonprofit organization with initial sponsorship from the Mellon Foundation, is digitizing complete backfiles of scholarly journals and making them available to its customers over the Internet.[2] Thus far the backfiles of 34 journals have been converted, including 6 in mathematics (*Annals of Mathematics, Journal of the AMS, Mathematics of Computation, Proceedings of the AMS, SIAM Review*, and *Translations of the AMS*).

The Beginning of More Fundamental Change in Scholarly Publishing

In these early days of the emerging digital information system, digital formats are serving primarily as substitutes for or enhancements of print formats. The fundamental structure of the scholarly publications system has yet to be altered in any significant way. Authors still submit their manuscripts, now more often than not in electronic form, to publishers. Publishers take ownership of the manuscripts, turn them into both print and electronic books and articles, and sell them to individuals and libraries. Research librarians are loath to give up their print collections and journal subscriptions until the digital information system, particularly in its archival function, is more stable and mature, so libraries tend to use electronic resources as access enhancements to their local print collections. But more fundamental changes are certainly in store. The traditional book and journal as organizing frames for scholarship will likely change, as will basic production, distribution, and archiving functions.

Paul Ginsparg, a physicist at the Los Alamos National Laboratory; Andrew Odlyzko, a mathematician at AT&T Bell Laboratories; and Ross Atkinson, a research librarian at Cornell University, have all written provocatively about the demise of the traditional scholarly communication system and what its replacement might look like. Taking full advantage of desktop publishing capabilities, networking, and powerful computer servers, Ginsparg envisions the development of an electronic "global raw research archive" managed by a consortium of professional societies and research libraries [26]. Odlyzko believes the new digital information system will allow scholars to become their own publishers and archivists. According to Odlyzko, "publishers and librarians have been the middlemen between the scholars as producers of information and the scholars as consumers, and are likely to be largely squeezed out of this business" [6]. Atkinson predicts the design of new network-based hypertext document structures that may "represent fundamental revisions in the very modality of communications" and that "may affect and alter some of our basic assumptions about the nature of information itself" [27].

Scholars, publishers, and librarians, of course, may not agree with all or part of these future scenarios, and they will strongly resist any diminished role in a newly evolving digital scholarly publication system. But these futurists should not be dismissed out of hand, for they point to some potentially fundamental changes that can help reform scholarly publishing. The nature and structure of scholarly archives, for example, need to be changed to manage better the growing quantity, specialization, and cost of scholarship. Rather than a highly decentralized system as exists today, with duplicative print collections spread across the country, digital technology can be used to centralize information storage and distribute access quickly and cost effectively when and where it is needed by scholars. Digital technology can also foster the integration of the various components and sources of scholarly publication. Researchers will no doubt use hyperlinks to move quickly online from index or bibliographic citations to abstracts to full multimedia documents with the click of a button. Such integration is already happening on the Internet's World Wide Web platform and through the efforts of library and scientific information services such as the Online Computer Library Center's (OCLC) *FirstSearch* (`http://www.oclc.org/`) and the Institute of Scientific Information's (ISI) *Web of Science* (`http://www.isinet.com/`). The ability to use hyperlinks to integrate scholarship online is an extraordinary driving force for the adoption of the new digital information system, a force with which the print format cannot compete.

Restructuring the Scholarly Archive

Research librarians are just at the beginning of making broad, organizational change in the management of the archives of scholarship. Librarians are starting to provide more access to digital information not from files stored in their own libraries or on their own campuses but from centralized servers that are networked to publishers, government agencies, universities, and scholarly societies that can be located anywhere around the world. Rather than selecting scholarly resources on an item-by-item basis, librarians are turning to a new breed of "aggregators" for collection development at a macro and integrated level. Reference tools, electronic journals, and digital archives of historical material now come in a variety of bundled packages. Johns Hopkins University Press, Elsevier, Academic Press, and the American Chem-

[2] *J-STOR*, `http://www.jstor.org/`.

ical Society, for example, now all market their entire line of electronic journals as a complete package to individual libraries, local library consortia, and even statewide or regionwide groups of libraries. And libraries are beginning to aggregate themselves by creating "virtual libraries" at the state or regional level to pool resources and services. The Ohio Library and Information Network, Georgia Library Learning Online, and the Midwest's Committee on Institutional Cooperation (CIC) Virtual Library are just three examples of the new virtual library consortia that are emerging across the country.[3]

What these new organizational developments in libraries have in common is the strategy of using digital information services to gain economies of scale, end unnecessary duplication, and provide scholars with more information resources at less cost. This pattern of networked, integrated access to central stores of electronic scholarly material seems inevitable in the new digital scholarly communication system. Finally the limitations of print collections may be overcome: self-sufficiency was never really possible in the traditional campus or departmental library, and at the same time there was always a great deal of waste in the form of underutilized material in these decentralized archives. The new is affecting the old too. Research librarians, running out of space for local collection storage and seeing new access opportunities through improvements in document delivery services, are beginning to consolidate their print archives both on and off campus, with regional storage facilities in operation or under construction in many parts of the country [28]. Scholars accustomed to having their separate discipline-based libraries in their departmental buildings—and mathematicians are an exemplar of this approach—are finding it disconcerting to see this convenient approach to library-collection organization end. But the high cost of maintaining decentralized archives along with the new approaches to access that digital information technology offers are making the traditional departmental library an anachronism. A recent report on "Mathematics Research Libraries at the End of the Twentieth Century" in *Notices of the AMS* [29] found that the number of mathematics libraries that are part of a general library or science and engineering library is increasing, while the number of mathematics libraries located in the same building as the mathematics faculty is declining.

[3]*Information about these virtual library projects can be found at* `http://www.ohiolink.edu/` *for Ohiolink;* `http://galileo.galib.uga.edu/Homepage.cgi/` *for Galileo; and* `http://ntx2.cso.uiuc.edu/cic/cli/velnew.html` *for the CIC Virtual Library.*

The Library Model in the Digital Scholarly Publication System

The new opportunities for improved access to scholarly information, from a technical standpoint, look wonderful in the digital networked environment. However, ownership issues and their effect on the control and cost of scholarship are still quite problematic for research librarians. Libraries are usually thought of as places, collections, and services that provide needed information, but underlying this construct is an economic model for funding and sharing information services that is often taken for granted. In the print information system, libraries buy books and journals that can be borrowed any number of times or that can be copied within the limits of copyright law and fair-use guidelines. This traditional library model for the central funding and communal sharing of information, depending on your perspective, can be seen as either a key advantage or a serious obstacle to scholarly communication in the new digital environment.

Both access to and control over information take on powerful new dimensions in the digital age. The "circle of gifts" model that characterized the first years of the Internet was an idyllic time for pioneering electronic citizens. Information was freely shared over the network, and those with proprietary interest in their writing or databases stayed away. Some of the early electronic journals such as *Psycoloquy* and the *Electronic Journal of Combinatorics* and Paul Ginsparg's groundbreaking *Los Alamos Physics E-Print Archive* were, and in some cases continue to be, gifts to the scholarly Internet community [30]. And why not? If scholars receive no compensation for their work in traditional publishing, they might as well spread their own word for free through electronic self-publishing.

For those who wanted to conduct commerce on the Internet and receive payment for their work, the "circle of gifts" model was unacceptable. Through the development of firewalls, encryption techniques, authentication devices, and cybercash the Internet has become a much more secure environment today for a marketplace model of scholarly publishing. In fact, controls on the use of information can be much more powerful in the digital information system than they were in the print system. The Association of American Publishers in partnership with the Corporation for National Research Initiatives has designed a new persistent identification device called the "Digital Object Identifier (DOI) System" [31]. The DOI System, by identifying digital content and the content owner, is intended to enable easy customer and publisher communication and payment exchange over the Internet.

As the digital information system has evolved from a free-for-all into a highly controllable environment, librarians have become more concerned about restrictions on the sharing of scholarly information. The library model is not the same as a "circle of gifts", for it assumes that publications are not free. On behalf of a community—in the case of research libraries on behalf of the scholarly community—the library compensates the owner of information for the right to share it. This economic model can be carried forward into the digital environment if authors, publishers, and librarians cooperate with each other. But if the owners of scholarly publications limit sharing by charging high prices or by restricting fair-use copying, all the advantages of a more effective digital scholarly archive will be blocked.

Research librarians are trying to preserve the best of the library model by being proactive when it comes to funding and ownership issues of scholarly publishing in the digital age. In North Carolina, for instance, librarians in 1993 led an effort to engage scholars in the Research Triangle universities in the development of a policy regarding faculty publication in scientific and technical scholarly journals [32]. Concerned about the "relatively small number of very large commercial publishing conglomerates, many based in Europe" that dominate science scholarship and believing that there is "incompatibility between [the] non-economic goals of academic researchers and the largely economic goals of commercial and some not-for-profit publishers," the North Carolina group urged scholars to consider initial publication of peer-reviewed and edited research in "journals supported by universities, scholarly associations, or other organizations sharing the mission to promote widespread, reasonable-cost access to research information." At Johns Hopkins University and at Stanford University, librarians have pushed efforts to keep science publishing within the circle of the academy. Johns Hopkins developed Project Muse, which was one of the first university press efforts to publish established science journals on the World Wide Web.[4] HighWire Press, the Internet imprint of the Stanford University Libraries,[5] has as one of its aims to "insure that the nascent marketplace for electronic communication among scholars does not develop along the semi-monopolistic lines of current STM [Science, Technical, and Medical] publishing." HighWire's first project has been the digital publication of *The Journal of Biological Chemistry*. And finally, the Association of Research Libraries has mounted an aggressive lobbying effort among scholars, scholarly societies, higher education associations, and federal government agencies to influence both intellectual property rights policies and the structure of scholarly publishing in the digital environment. These efforts culminated in 1997 in the Association's creation of the Scholarly Publishing and Academic Resources Coalition [33], whose mission is to be a catalyst:

- to create a more competitive marketplace for research information by providing opportunities for new publishing ventures; endorsing new publications and information products; and recruiting authors, editors, and advisory board members;
- to promote academic values of access to information for research and teaching; the continuation of Fair Use and other library and educational uses in an electronic information environment; and the ethical use of scholarly information;
- to encourage innovative uses of technology to improve scholarly communications by collaborating in the design and testing of new products; advancing new publishing models as appropriate applications of electronic networks, such as Internet2; and developing systems and standards for the archiving and management of research findings.

Sharing Scholarship: The Scholar's Choice

Will the promise of improved access to scholarship in the digital age be blocked by restrictions to fair use or by the high cost placed on publication by its owners? Scholars themselves are really the only ones who can answer this question, for it is scholars who create and have first ownership rights to their own scholarship. If they pass their ownership rights to their scholarship to publishers outside the circle of the academy, they must realize that they have turned their work into a commercial commodity. If scholars keep their publications within the academy, they should also realize that some nonprofit organizations use publication revenues to support more than publication based expenses. In either case, scholars may be placing their works and the ownership rights to their publications with publishers who will limit access to their scholarship through high cost or restrictions to library sharing or educational uses of these works. Publishers, of course, serve a critical function in the scholarly publication system, but the best edited, produced, and marketed publication can be severely limited or useless if it cannot be widely shared with other scholars and students. If it is true that one of the fundamental missions of the modern university and the scholarly community is to promote the free exchange of ideas and research results, then authors, publishers, and librarians must work more in partnership to ensure that this happens. At the end of the twentieth century many research libraries are in serious trouble because they can no longer afford to acquire scholarship they need to share with their communities. The commercialization of science publication is at the core of this problem for research librarians. By bringing scientific scholarly publishing back into

[4] *Project Muse*, `http://muse.jhu.edu/`.

[5] *Highwire Press*, `http://www-jbc.stanford.edu/`.

the circle of the academy, the scholarly publication system can be reformed to take full advantage of the archival and distribution potential of new digital information technology.

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[33] *SPARC: The Scholarly Publishing and Academic Resources Coalition*, Draft, Association of Research Libraries, Washington, DC, 1997.

The State of Mathematics Education: Building a Strong Foundation for the 21st Century

Richard W. Riley

I have to say that it is somewhat intimidating speaking to such an intellectually impressive group. When I saw that I was speaking among powerhouse lectures with titles like "Kleene algebra with tests" and "Non-linear wavelet image processing", I got a little worried that perhaps I should add some words like "algorithm", "derivatives", or "integrals" to the title of my speech.

This is just as bad as one of the first speeches I gave as secretary of education. I was squeezed between two very well-known Ph.D.s: Bill Cosby and Dr. Ruth, the sex therapist.

Now, I am sure there is a connection between Dr. Ruth and what I want to talk about today. Maybe it is that, in this information age, mathematics is sexy.

Suffice it to say that when I saw the kinds of topics being discussed at this conference, I knew that this would be an audience that would be particularly receptive to a discussion about the need to reach for high standards of learning in mathematics as an ever more important part of preparing our students to compete and succeed in an increasingly complex global economy.

Quite simply, a quality mathematics education *must* be an integral part of today's learning experience. In order to succeed in our information-based society, students must have a solid understanding of the basics—reading, science, history, the arts—and smack at the center of this base of essential knowledge, must be mathematics. As William James wrote, "The union of the mathematician with the poet, fervor with measure, passion with correctness, this surely is the ideal."

It should come as no surprise then that almost 90 percent of new jobs require more than a high school level of literacy and math skills. An entry-level automobile worker, for instance, according to an industry-wide standard, needs to be able to apply formulas from algebra and physics to properly wire the electrical circuits of a car. Indeed, almost every job today increasingly demands a combination of theoretical knowledge and skills that require learning throughout a lifetime.

That is why it is so important that we make sure that all students master the traditional basics of arithmetic early on as well as the more challenging courses that will prepare them to take physics, statistics, and calculus in much larger numbers in high school and college.

A recent U.S. Department of Education report demonstrates that a challenging mathematics education can build real opportunities for students who might not otherwise have them.

It found, for example, that young people who have taken gateway courses like Algebra I and Geometry go on to college at much higher rates than those who do not—83 percent to 36 percent. The difference is particularly stark for low-income students. These students are almost three times as likely—71 percent versus 27 percent—to attend college.

In fact, taking the tough courses, including challenging mathematics, is a more important factor in determining college attendance than is either a student's family background or income. This is the kind of direct link on which we need to build.

This undeniable and critical increase in the value of challenging mathematics for both indi-

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Richard W. Riley is the U.S. Secretary of Education. This is the text of a speech he presented at the invitation of the AMS Committee on Science Policy and the AMS Committee on Education. The speech was presented on January 8, 1998, at the Joint Mathematics Meetings in Baltimore.

Introduction by AMS President Arthur Jaffe

It is a great pleasure to welcome the Secretary of Education, The Honorable Richard Riley. This is a historic event, publicly symbolizing the interest of our Society, as well as of our sister societies, in education and also pointing to the synergy between our specialty, research in mathematics, with education at all levels. I am proud that our Committee on Education has concentrated not only on graduate and postgraduate education, but also on the involvement of research mathematicians in K-12 issues. For our members, mathematics education means cradle to the grave. We are all "perpetual students".

We originally invited Secretary Riley when it appeared that his department would bear full responsibility for the development of the proposed eighth-grade mathematics test. Since the time of our invitation, the agreement between President Clinton and Congress has moved the primary responsibility elsewhere, but it is clear that the Department of Education will have considerable influence.

Coming on the heels of the mediocre performance in mathematics by our fourth- and eighth-grade children as measured by the international TIMSS study, the proposal for a national test is viewed by many mathematicians as an opportunity to bootstrap the level of school mathematics onto a higher plane. However, others worry that such a test would become an upper bound to mathematics skills, a political football, so that to ensure good performance the test would be content light and would make a bad situation worse.

We couple this concern about average performance with another central worry in our community: our schools do not pay adequate attention to our gifted students. We need to look up to the ceiling as well as down to the floor. Not doing so, we run the risk of losing our capability to regenerate our scientific population in the future. In the past we have been helped so much by immigration. With the changes in the world, we cannot rely on that in the future.

So we await your talk with great interest! Secretary Richard Riley was born in South Carolina just 65 years and 2 days ago today. So we can think of his visit as a special birthday party. Secretary Riley served in the Navy on a minesweeper. Later he served as a distinguished governor of South Carolina. He is known for launching initiatives to raise academic standards. We are extremely grateful that he has taken the time and effort to join us. We look forward to hearing Secretary Riley's insights and plans.

vidual opportunities and our society's long-term economic growth leads me to an issue about which I am very troubled—and that is the increasing polarization and fighting about how mathematics is taught and what mathematics should be taught.

I will talk in more detail shortly about these so-called "math wars" in California and elsewhere. But let me say right now that this is a very disturbing trend, and it is very wrong for anyone addressing education to be attacking another in ways that are neither constructive nor productive.

It is perfectly appropriate to disagree on teaching methodologies and curriculum content. But what we need is a civil and constructive discourse. I am hopeful that we can have a "cease-fire" in this war and instead harness the energies employed on these battles for a crusade for excellence in mathematics for every American student.

One way to begin such a crusade is to start with the facts. Building on these facts, we can begin to spread the "gospel" of challenging mathematics—not just to students, but to parents, teachers, and business and community leaders, who, like you, can and should play a critical role in building a culture of learning.

To begin with, we need to focus on raising the standards of teaching and learning in our K-12 schools, placing particular emphasis on improving the quality of mathematics education during these years. The payoff here affects all levels of society, and we cannot afford to give it short shrift.

Let me say that while our students are not yet performing at the level we want, they are in fact doing better than many Americans think. Mathematics scores from the National Assessment of Education Progress (NAEP), the nation's report card, increased significantly from 1990 to 1996 at all levels tested. In addition, over the past two decades, more students are taking Advanced Placement mathematics courses, SAT and ACT mathematics scores are up, and more high school graduates are taking more years of mathematics—in 1994, 51 percent of students completed three years, compared to only 13 percent in 1982.

There is also some positive news when you compare our students with those of other nations. Here I am speaking about the recent Third International Mathematics and Science Study (TIMSS), the most extensive international comparison of education ever undertaken. TIMSS compared the United States with up to forty other nations in curriculum, teaching, and student performance at the fourth-, eighth-, and twelfth-grade levels and provides us with some real opportunities to reflect on and improve our own practices.

The good news is that U.S. fourth-graders scored above the international average in mathematics and science; in fact, they are near the very top in achievement in science and can compete with the best in the world.

TIMSS also revealed some areas where we need to improve and concentrate our efforts. Most troubling was the drop-off experienced by our nation's eighth-graders. The United States was the only country in TIMSS whose students dropped from above-average performance in mathematics in the fourth grade to below-average performance in mathematics in the eighth grade.

This is disappointing. But I believe the evidence of this "math gap" and the careful analysis TIMSS provides about why it has occurred give us not only a wake-up call but also a road map for improvement.

While the curriculum in our classrooms continues to focus on basic arithmetic in the years after fourth grade—fractions, decimals, and whole number operations—classrooms in Japan and Germany have shifted their emphasis to more advanced concepts, including algebra, geometry, and probability. Unfortunately, in too many cases our eighth-grade curriculum looks like the curriculum of seventh grades elsewhere.

Why is our competitive position dropping in the middle grades? It is surely not because our kids cannot master challenging material. And it is not because most do not know the basic skills of arithmetic. In fact, NAEP trend data, released in August of this year, shows that fully 79 percent of eighth-graders "can add, subtract, multiply, and divide using whole numbers, and solve one-step problems," up from 65 percent in 1978.

These students are ready to move ahead to more challenging concepts. Of course, we should do whatever it takes to increase that 79-percent mastery of basic arithmetic concepts by the middle school years. Students should get the extra help they need, whether it is in after-school tutoring or some other way. But at the same time we need to raise our standards higher and ensure that all students are learning more challenging concepts in addition to the traditional basics.

That is one reason why we encourage the development of a voluntary national test in eighth-grade mathematics. This test, which is based on NAEP but which will provide individual student results, will help give all teachers, parents, and students the knowledge to evaluate achievement and develop challenging course work at world-class levels of performance in the basics as well as at more advanced levels of study.

States that have developed challenging standards of learning, aligned their assessments to those standards, and provided substantial professional development for teachers have demonstrated improvement in student achievement.

In North Carolina, for example, students improved dramatically after development of challenging standards of learning and a statewide assessment system aligned to those standards. After beginning the decade near the bottom of the state NAEP mathematics rankings, North Carolina posted the greatest achievement gain of any state in the nation.

U.S. Secretary of Education Richard W. Riley.

Indeed, how we engage larger numbers of students in challenging mathematics courses is an area worthy of discussion for scholars like you. Whether high school students should take calculus classes or focus on statistics, how to best integrate technology into the mathematics curriculum—these are issues of real importance as opposed to politically inspired debates that will serve to sidetrack us from real improvement.

Each of you can play an important role in achieving this by being a constructive voice in encouraging the development of high state and local standards in mathematics

And you can work with middle and high schools and other partners to help ensure that students get a rigorous college-preparatory curriculum, particularly in mathematics, so they are prepared for college-level work and careers with a future.

This leads me back to the need to bring an end to the shortsighted, politicized, and harmful bickering over the teaching and learning of mathematics. I will tell you that if we continue down this road of infighting, we will only negate the gains we have already made, and the real losers will be the students of America.

We are suffering here from an "either-or" mentality. As any good K–12 teacher will tell you, to get a student enthused about learning, you need a mix of information and styles of providing that information. You need to provide traditional basics along with more challenging concepts, as well as the ability to problem solve and to apply concepts in real-world settings.

Different children learn in different ways and at different speeds. A good teacher will do whatever he or she can to reach that child and inspire him or her to learn.

That said, I believe that there is a "middle ground" between these two differing views of how to teach mathematics. In fact, if you take a close look at two opposing articles in the *American Mathematical Monthly* by Professors Wu and Kilpatrick and look beyond the rhetoric of this debate,

Secretary of Education Riley (left) with AMS President Arthur Jaffe.

I think you will see a good deal of common ground.

As Professor Wu asks, "Who does not want to improve education?" Indeed, all Americans should be able to agree on much about mathematics. We all want our students to master the traditional basics: to be able to add, subtract, multiply, and divide, and be accurate and comfortable with simple mental *and* pencil and paper computation.

We all want our students to have the opportunity to master challenging mathematics—which for K-12 students includes arithmetic and algebra, geometry, probability, statistics, data analysis, trigonometry, and calculus.

We also want our students to master the basics of a new information age—problem solving, communicating mathematical concepts, and applying mathematics in real-world settings—as part of this challenging mathematics.

There are, of course, examples of questionable practices and teaching methods on both sides of this debate. As Professor Kilpatrick pointed out, "Change in education is notoriously complex, difficult, and unpredictable. Reform movements in mathematics education turn out neither as advocates hope nor as detractors fear. But these movements can energize those teachers who want, as Ed Begle once put it, to teach better mathematics and to teach mathematics better."

That is why we need your help to educate Americans on how important mathematics is in building a strong future for every American. All of you understand this and take it for granted. I would suggest, however, that this group is not a reflection of average America.

Perhaps a better description would be how the humorist Garrison Keilor described the children in his fictional hometown, Lake Wobegon: "a place where all the kids are above average." Well, we need this above-average community to focus on getting this very important message out to a society that is less mathematically oriented.

It is time we focused on the students and the interest of our nation—on what really helps kids learn, not on what the process for learning is called. I hope each of you will take the responsibility to bring an end to these battles, to begin to break down stereotypes, and to make the importance of mathematics for our nation clear so that all teachers teach better mathematics and teach mathematics better.

This leads me to the final area I believe we need to focus on and in which all of you can play an especially important role—and that is making sure that there is a talented, dedicated, and prepared teacher in every classroom. Every teacher should not only know the importance of a subject like mathematics but should also have the training and the commitment to teach it well and to understand how to blend differing approaches.

Only in this way will we produce a generation that can learn the fundamentals and apply challenging mathematical concepts to the problems of the twenty-first century.

There are many wonderful teachers across the nation who give of themselves and who inspire students. Unfortunately, we are still falling short. We can do better, particularly in subjects like mathematics, which can require a special degree of skill and expertise.

Presently 28 percent of high school mathematics teachers do not have a major or minor in mathematics. The average K-8 teacher takes three or fewer mathematics or mathematics education courses in college.

Furthermore, fewer than one half of eighth-grade mathematics teachers have ever taken a course in the teaching of mathematics at this level. Equally distressing, the teacher qualifications are even lower in low-income and minority schools.

We must do better. Recent studies have shown that student achievement is most influenced by teacher expertise, accounting for as much as 40 percent of the measured variance in students' mathematics achievement. According to NAEP, at grade eight the teachers in the top-performing third of schools were almost 50 percent more likely to have majored in mathematics or mathematics education than the teachers in the bottom-performing third of schools.

It is time we took a good look at the way we train our teachers and the continuing support we give them. You have a direct impact on the future of the mathematics teachers this nation's schools turn out. According to the most recent CBMS [Conference Board of the Mathematical Sciences] survey figures available, at least 20 percent of mathematics majors completed high school teacher certification requirements. So the teachers of tomorrow are sitting in your classes today.

So I urge all of you to take a leading role in meeting this challenge, and I offer several suggestions to achieve this. First, I hope you will make it a priority to prepare K-12 teachers. Work with your colleges' schools of education to improve the mathematical preparation of our teachers by ensuring that courses focus on rigorous mathematical content that is tied to the content that K–12 teachers will teach.

Second, it is time for you to take a critical look at the curriculum and teaching methods used in undergraduate mathematics courses. It is only natural that a teacher will teach as he or she was taught. By improving this instruction we can simultaneously provide good examples and build for the future.

Third, we need to create more partnerships among your higher-education institutions, teachers, and the many museums, technology centers, businesses, and other community institutions that are sources of learning. In this way we can take advantage of the other learning resources that are out there and help students see new ways that mathematics and other learning is applicable to daily life.

I am pleased to note that some of this has already begun. The U.S. Department of Education is funding an effort by the MAA, the AMS, the National Council of Teachers of Mathematics, as well as other CBMS learned societies to develop over the next several years voluntary standards and a framework for the mathematical preparation of teachers of mathematics and for their induction into the profession. I hope you will work with them to expand this effort.

We need to have faith in our teachers, who, when given the proper resources and training, will teach to the highest standards. We need to have faith in our students, who, when taught well at challenging levels, will be able to learn to the highest standards. And we need to have faith in the American public that, given the facts about a subject as important as mathematics, they will in turn put in their creativity, discipline, energy, and hard work to build a stronger future for America's students.

Make no mistake about it. There is a disconnect about mathematics in this country. A recent Harris poll revealed that while more than 90 percent of parents *expect* their children to go to college and almost 90 percent of kids *want* to go to college, fully half of those kids want to drop mathematics as soon as they can. It is time to impress upon a nation eager for learning and achievement the importance of advanced study in this field.

As the statistics I have related to you today make clear, "Mathematics Equals Opportunity". There could be no more crucial message to send to the parents and students of America as we prepare for the coming century.

Lajos Pukánszky (1928–1996)

Jacques Dixmier, Michel Duflo, András Hajnal, Richard Kadison, Adam Korányi, Jonathan Rosenberg, and Michèle Vergne

Lajos Pukánszky was born in Budapest on November 24, 1928. He defended his Ph.D. thesis, which was written under the direction of Béla Sz. Nagy, in 1955 in Szeged, Hungary. He left Hungary in 1956. After taking several posts in the United States and France, he was a professor at the University of Pennsylvania from 1965 until his retirement. He died February 15, 1996, in Philadelphia. The mathematical community has lost one of its stars.

Niels Pedersen, for whom a memorial article appears in the January 1998 *Notices*, was Pukánszky's de facto student. As that article says, "[Pedersen's] interaction with Pukánszky was especially deep and fruitful. They became good friends and remained so throughout their lives."

Below are five commentaries on aspects of Pukánszky's mathematical life and mathematics.

—*the authors*

Jonathan Rosenberg

I was privileged to know Lajos Pukánszky since 1976. In many ways his personality was like his mathematics: based on a broad knowledge base, but single-minded, uncompromising, and very deep. Lajos was without a doubt the world's foremost expert on solvable Lie groups. But his magnum opus [8], which occupied an entire issue of the *Annales Scientifiques de l'École Normale Supérieure*, was probably never read by more than a dozen people. It stands as a lofty but isolated peak on the mathematical landscape—admired by many from afar, but scaled only by a few diehards. This was the brilliance, but also the tragedy, of Lajos Pukánszky—that his life's work was so perfect, yet so inaccessible and underappreciated by the mathematical public.

Lajos was a truly cultured person in a sense which we may not see again in future generations. He seemed to know all of European history, philosophy, and literature by heart. I think he identified himself with the protagonist of Thomas Mann's *Doctor Faustus*, a work which he discussed with me quite a number of times. But the best quick summary of his character may be found in the quotation which he attached to the beginning of his big *École Normale* paper. It is a quote within a quote within a quote: Schiller, quoted by Bohr, quoted by Heisenberg. Roughly translated, part of it says "...and in the abyss lies truth." Pukánszky's life work was the probing of this abyss.

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This segment of the article was read at a memorial service in Philadelphia in 1996.

András Hajnal and Adam Korányi

Lajos Pukánszky was a good friend of ours. There were long periods when we did not meet, but each time we resumed contact we continued our conversation as if we had stopped just the day before. Between 1953 and 1956 as beginning mathematicians we regularly had lunch together in the restaurant of the University of Szeged and went afterwards to have coffee in an espresso bar; G. Pollák and, during the last year, I. Kovács were also part of the group. Then as later Lajos was a good friend always ready to help, but this did not mean that anyone could persuade him to waste his time. He maintained the strictest standards both in his private life and in his scientific work. He demanded competence in everything. Woe to him who made

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This segment is a slightly abridged English translation of the original as it appeared in the Hungarian journal Matematikai Lapok.

a statement about Thomas Mann but turned out to be unfamiliar with Mann's correspondence with Karl Kerényi. He organized his life so as to be able to do mathematics at the highest possible level. Following a strict schedule, fighting chronic insomnia, he worked, so to speak, beyond his forces even though he was also able to relax and amuse himself among friends. But this he permitted himself only on designated rest days. When we teased him, saying that like Anatole France's Sylvestre Bonnard he was looking for "l'austère douceur du sacrifice",[1] he only smiled and continued with his work.

Coming back to Thomas Mann, who was a frequent subject of conversation in Szeged, we all saw the similarity between Lajos and the hero of Mann's novel *Doctor Faustus*. This not only concerned his personality, it also included the fact that Lajos too was interested, besides mathematics, in music and theology above all. Music was important to him all his life. And he studied theology very seriously: Catholic theology in his youth and Jewish when he was old, even though he was not religious, at least not in the period we knew him. Anyway, we never dared to ask him a direct question about this.

He left Hungary in the turmoil following the 1956 uprising, together with one of us. His purpose was to get access to the great mathematical centers of the world. It followed from his character that he cultivated those parts of mathematics that he judged to be of the most central importance, which were also those that required the greatest amount of knowledge. He worked alone, but beginning in 1953, he corresponded with Jacques Dixmier and regularly discussed his mathematical projects with him. The dedication of his article written for the retirement of Dixmier is the line of Horace, "O et praesidium et dulce decus meum."[2]

He did not like to travel, and above all he hated to be in the limelight. Pleading ill health, he did not go to the international conference organized by Niels Vigand Pedersen in Copenhagen for his sixtieth birthday. (But back in 1964 he did come from Los Angeles to visit the two of us in Berkeley, where we happened to be at the time.)

Beginning in 1994, the three of us again lived fairly near each other. Usually we met in New York, where Lajos insisted on a strict ritual: meeting at 2:00 p.m. in the Metropolitan Museum of Art in front of Michelangelo's portrait, later dinner in the Hungarian restaurant Mocca, from where he rushed away by taxi to get his train. He was his old self; even his memory was almost the same as before, although he was not able anymore to tell, as in Szeged, exactly what he had been doing on which day of which year.

[1] *"the austere sweetness of sacrifice".*

[2] *"O my safety and my sweet honor."*

Photograph courtesy of Béla Pukánszky.

Lajos Pukánszky

He had long been sick, but he did not complain much. He worked as before. Four chapters—that is, a very large part—of his projected new book were found fully completed after his death. He suffered from severe anemia, and his physicians were unable to find its cause or its cure. In the last two or three weeks of his life he was very weak; we found out about this only later. It seems he could not go on anymore, and we did not watch him carefully enough. Now there is only his memory for us to guard.

Michèle Vergne

I met Pukánszky for the first time in 1970. After 1980 I never saw him again, but I have kept an image of him in my memory. The news of his deliberate death affected me. I do not want to believe that I shall never again see his thin, worried silhouette in Paris.

I would like to relate some memories of the years 1970–76. In 1970 I was young, I felt like a nobody, and I was suffering from it. He appeared to me as a somebody. One of my first research articles consisted in giving a simpler proof of the "Pukánszky irreducibility criterion". This was work undertaken under the aegis of Dixmier, in an active group made up of Nicole Berline, Pierre Bernat, Michel Duflo, Monique Levy-Nahas, Mustapha Raïs, Rudolf Rentschler, Pierre Renouard, and others. Representation theory of solvable Lie groups was

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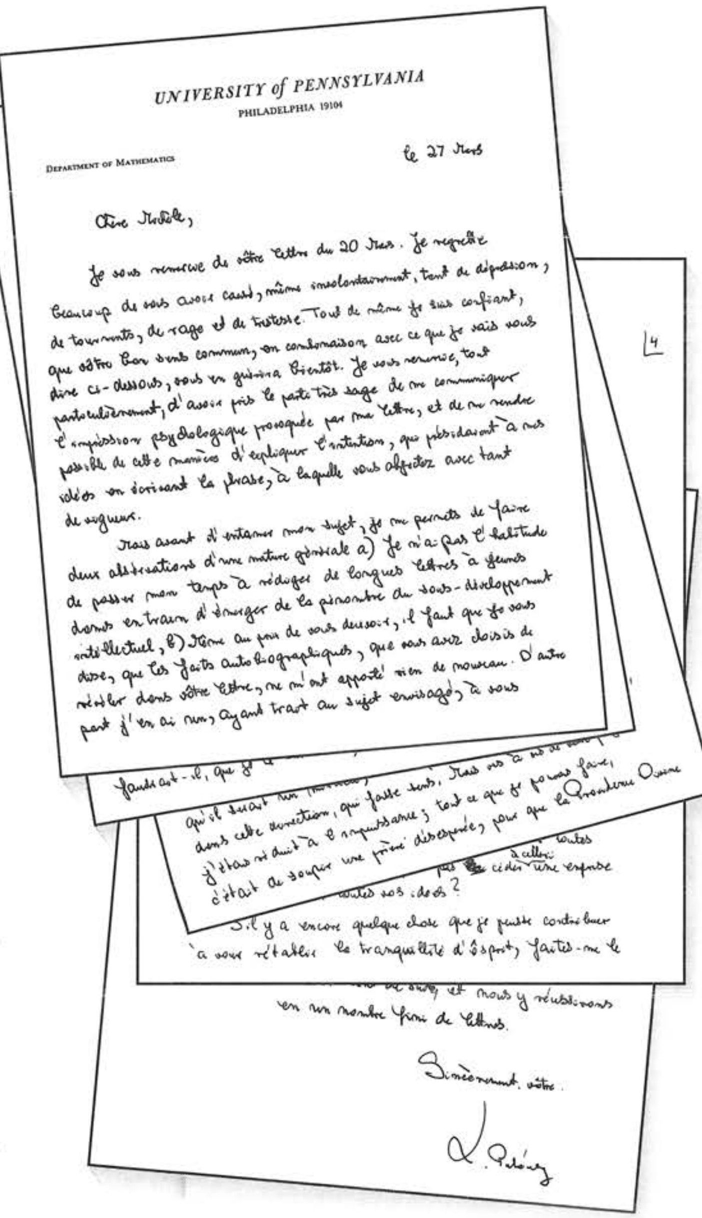
in full bloom at this time. Pukánszky, through his many articles on representations of nilpotent and solvable Lie groups, contributed to this flowering. I had studied his work on this subject. I had my small place in the middle of the "Dixmier family", but it seemed to me that I did not count for much. Then, how happy I was when Pukánszky would came to Paris! He surrounded me with a completely refined and exaggerated kindness, but so satisfying since the tributes were directed toward me.

Under the influence of the revolutionary atmosphere of May 1968, I was a "leftist". In principle I should have loathed Pukánszky, since he was the very representative of the decadent bourgeoisie targeted by the "permanent" antiestablishment activity of May 1968. Certain students had abandoned their studies to promote revolution by working in the factories. Claude Chevalley, my thesis advisor, had gone to Vincennes, an interdisciplinary noncompetitive university that accepted workers. The people alone were pure. These things were burning convictions for me. Despite everything I allowed myself to be invited by Lajos Pukánszky to excellent restaurants, I walked with him in Paris, I found everything amusing, and he would always tell me that I acted like a child. I found his company amusing, his conversation penetrating. He said to me, "You must be really feverish in order to find life so much fun." But he was feverish too. He was nervous, agitated, worried, and thin as a rail. He was an insomniac, spent whole nights without being able to sleep; his hotels were always too noisy. This difficulty in living made me feel for him. He spoke excellent French, which he embellished by quoting from Molière, Racine, La Bruyère, Anatole France. He was necessarily right whenever one disputed a definition or a grammatical point. He returned with the dictionary and a long discourse. This was sometimes amusing, sometimes irritating. He often repeated to me about mathematical work, "It is not necessary to hope in order to undertake, nor to succeed in order to persevere," and his persistence in inciting my perseverance put me in a really bad mood.

Starting in 1967, Lajos Pukánszky was interested in difficult problems about representations of solvable Lie groups. He had immediately understood that the orbit method proposed by Kirillov in 1962 could also be very fruitful in the study of representations of solvable Lie groups. He was particularly interested in groups that are not of type I, for which he produced factor representations resembling packets of coadjoint orbits.

In 1974 I was supposed to explain in the Séminaire Bourbaki the recent work of Auslander-Kostant and Pukánszky on the irreducible unitary representations of solvable Lie groups. This lecture and article were difficult to prepare, and I sent a preliminary version of the article to Pukánszky to ask his opinion. He wrote me a long letter on this subject in which he gave me advice on editing it, not always kind, but certainly completely fair. "I think that the host of details that you display here is going to bore rather than enlighten the novice." He added some corrections, many suggestions. I protested about certain parts of his letter; the phrase "you have come quite a long way since our last meeting" especially irritated me. Here is a portion of his response that shows what importance he attached to the study of groups from the point of view of C^*-algebras.

"I remember to this day very clearly the questions that you asked me in Williamstown, but I have


UNIVERSITY of PENNSYLVANIA
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DEPARTMENT OF MATHEMATICS

le 27 Mars

Chère Michèle,

Je vous remercie de votre lettre du 20 Mars. Je regrette beaucoup de vous avoir causé, même involontairement, tant de dépression, de tourments, de rage et de tristesse. Tout de même je suis confiant, que votre bon sens commun, en combinaison avec ce que je vais vous dire ci-dessous, vous en guérira bientôt. Je vous remercie, tout particulièrement, d'avoir pris le parti très sage de me communiquer l'impression psychologique provoquée par ma lettre, et de me rendre possible de cette manière d'expliquer l'intention, qui présidaient à mes idées en écrivant la phrase, à laquelle vous objectez avec tant de vigueur.

Mais avant d'entamer mon sujet, je me permets de faire deux observations d'une nature générale a) Je n'ai pas l'habitude de passer mon temps à rédiger de longues lettres à jeunes dames en train d'émerger de la pénombre du sous-développement intellectuel, b) Même au prix de vous decevoir, il faut que je vous dise, que les faits autobiographiques, que vous avez choisis de révéler dans votre lettre, ne m'ont apporté rien de nouveau. D'autre part j'en ai une, ayant trait au sujet envisagé, à vous

faudrait-il, que je ...

qu'il serait ... qui fasse sens. Mais ... tout ce que je pouvais faire, dans cette direction, ... l'impuissance; ... pour que la Providence ...

j'étais réduit à ... désespérée ... toutes

c'était de souper une ... à celles ... céder une expose ... toutes vos idées?

S'il y a encore quelque chose que je puisse contribuer à vous rétablir la tranquillité d'esprit, faites-me le ... et nous y réussirons en un nombre fini de lettres.

Sincèrement, votre.

L. Pukánszky

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Letter from Pukánszky to Michèle Vergne, part of which is quoted on the following page.

not thought about them until now. Consequently in connection with this article, I limit myself to making you know that I would have no respect for a mathematician who did not dare ask questions for fear of seeming naive. But a thing of which I am reminded is that you did not show a particularly favorable opinion about the usefulness of C^*-algebras, or any interest in factors that are not of type I, etc. I was a bit saddened by this, since I have been convinced, ever since my study of Godement's work soon after it appeared, that these things are absolutely indispensible for understanding representation theory for general Lie groups, in a way that becomes evident sooner or later to each person who is interested in this study. Furthermore, I was under the impression that you were only repeating current opinion, which is based on reasoning roughly as follows: I see X and Y who have become great men and do not know what a continuous factor is. So why is it necessary for me to know it?

"Since the conference in question, I have spoken about my recent work with several colleagues who are professionals in the theory of C^*-algebras, and despite some compliments that I have received, I have had to notice that their efforts to understand this work have been crowned by absolute failure.

"In view of that, my reaction to your letter of December 20, in which, you recall, you made an assessment of the results of my recent note (in which C^*-algebras play a decisive role), was a mixture of surprise and quite sharp disbelief. Finally, for lack of a better explanation, I came to believe that the views expressed there were sincere, but that they were probably due to the influence of somebody else's opinion (but whose?). Yet in this case the conclusion that a very profound change is operating in the set of your views of the importance of the above objects has become inescapable. Whence surely 'you have come quite a long way since our last meeting.' But at that time, there was nothing in the world that I desired less than that you would persist. In fact, I figured that it would take a miracle for you to be able to say something in this direction that would make sense. But, with respect to your project, I was completely powerless; all that I could do was sigh a desperate prayer that Divine Providence would prevent you from leaving the confines of type I phenomena.

"Finally when I received your most recent letter and your article, one glance was enough for me to see that the miracle had taken place: everything relative to the feared domain was in its place in perfect order, organized in a truly professional manner. At this point the only regrettable thing, as I have already explained to you, was that you have not harvested the fruit whose filled tree you planted before your audience in a marvelous way. To be sure, there were errors, but they could be fixed locally. ...If your current interest does not permit you to persist on this road, I am confident that despite your certainly quite advanced age you will be able to return to it perhaps as soon as next year."

I continued to correspond with him for a long time. He sent me very long letters in perfect French. His attitude, which was a mixture of exaggerated politeness and mocking skepticism, made me react quickly. I responded at length, explaining in great detail all my concerns, my ups, my downs. I needed him, his support, his recognition. He always gave me his attention without stinting. Beneath his irony he was always full of tact and kindness. He never spoke of himself; I think that he sensed himself too particular and did not want to impose on others his day-to-day problems. As for me, I was never preoccupied with his concerns and needs (and he never spoke of them). I have tried to say here how tactfully and how charmingly he knew how to maintain a deep and friendly relationship. Thanks to his letters, I keep an unfailing memory of him.

Richard Kadison

I first heard of Lajos through his early work on "rings of operators", or "von Neumann algebras" as they are now known. Is Singer and I had been trying an idea we had to produce two nonisomorphic factors of type III. It seemed like a good idea, but we got stopped by some technical order-of-choice difficulty. That was in 1956. We filed our work on this away—we had other things to attend to—with the thought of coming back to it in a while. Later in 1956 I received a reprint from Lajos—my first knowledge of him. He had had the same idea and pushed it through successfully. Where Is and I had displayed one of our factors in a general algebraic-analytic way, Lajos displayed it in a very specific analytic-ergodic-theoretic manner. He was able to navigate his way around our difficulty with clever and powerful analytic techniques. We took note of him.

A little later that year I was giving a talk to the AMS at a New York meeting, and I mentioned that work of Lajos. After the talk two chaps came up to me and asked if I knew Lajos personally, since I had mentioned his name. I did not, but nonetheless they asked me if I would help them get him a special visa. It seems that he had taken part in the

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This segment is adapted from remarks made at a memorial service at the University of Pennsylvania in 1996. The setting was the department's Common Room, where the faculty, staff, and a few of Pukánszky's friends were gathered; the paragraphs are best read with that setting in mind.

Hungarian uprising, crushed quickly by Soviet tanks. Lajos had fled to a refugee camp (in Yugoslavia, I think). Those chaps had been trying to get him a visa so that they could hire him at a recently created institute (RIAS, the Research Institute for Advanced Studies) in Baltimore. Of course I was willing to write a letter. It may have added an infinitesimal extra breath to their sails, and Lajos wound up at RIAS in 1957, where he worked as a research associate for three years.

Early in that period Lajos visited me at Columbia. We had a wonderful day together talking mathematics. In 1960 Lajos took an assistant professorship at the University of Maryland. Leon Cohen had become chair of the Maryland department. I remember that he was eager to keep Lajos there; he asked me to use whatever influence I might have to get Lajos to stay. I was fond of Leon, but of course I would not meddle in that sort of decision. The lure of the West Coast was too strong, and Lajos accepted a visiting assistant professorship at Stanford in 1961. In 1962 he was hired by UCLA to a regular assistant professorship. The following year they promoted him to tenure and an associate professorship. In 1964 our group in functional analysis was forming here at Penn. Lajos was recruited as a full professor and returned to the East Coast. How's that for a meteoric rise?

Lajos spent his first year on leave, accepting an invitation to Paris. He worshipped Dixmier, and Dixmier had high regard for Lajos's mathematics. I remember meeting Lajos in Paris that spring. We had dinner together at some place on Boulevard St. Germain. The meal was poor, but the company was splendid. Lajos had learned French that year and insisted on our speaking French together that evening. It was definitely a case of "the blind leading the blind"!

I will not go into all the details of how the speakers for the Nice Congress for our section were chosen. Dixmier ran it; it was the first time that our area was included in an explicit way. Dixmier, one of the fairest and most democratic people I know, canvassed a very large number of important functional analysts by mail, asking them to cast a vote. Pukánszky was the leading candidate for those speaking positions by a large margin.

Many of you will remember Lajos as quiet and reclusive. His friends knew that he had a lively, dry, and wry sense of humor. Sitting at lunch with a good-sized group (about twenty years ago), one of our very bright young research instructors was emphasizing the point that someone had won the Putnam Exam Prize. This instructor seemed to feel that that was a major mathematical credential. An active debate ensued. Lajos listened silently. After a number of minutes and much discussion, Lajos asked a question: "What does doing mathematical puzzles seated on top of a locomotive going 100 miles an hour have to do with being a mathematician?" That seemed to end the debate.

Lajos remained a professor here until his retirement a few years ago. He will be remembered with affection, reverence, and respect by those of us who knew him.

Jacques Dixmier and Michel Duflo

Pukánszky's impressive mathematical œuvre bears witness to a considerable cumulative effort. It is centered in the theory of unitary representations. Despite how focused this mathematics is, Pukánszky showed an immense mathematical knowledge; he used in his papers not only the entire arsenal of functional analysis and the theory of Lie groups but also some quite varied tools: connections, resolution of singularities, partial differential equations, division of distributions, homology, and others.

Pukánszky's early work was on von Neumann algebras and related subjects. The article [1] made an early name for him: in it one finds the construction, by quite an ingenious method, of two nonisomorphic factors of type III. Although this result was later greatly extended, it represented at the time a major advance. Pukánszky established also some properties of maximal abelian subalgebras of type III factors that were known previously only for factors of type II_1. This article had the honor of being reviewed by F. J. Murray in *Mathematical Reviews.*

Most of Pukánszky's subsequent work was devoted to unitary representations of Lie groups. He began by studying tensor products of representations in the context of the inhomogeneous Lorentz group and of $SL(2,\mathbb{R})$. Then he classified the irreducible unitary representations of the covering group of $SL(2,\mathbb{R})$, finding also an explicit Plancherel formula for this group [2].

Let G be a connected real Lie group. The classes of irreducible unitary representations of G form a set denoted $\widehat{G}$. The determination of $\widehat{G}$ for G noncompact semisimple was begun about 1947 and has been pursued to the present day. If one wants to study $\widehat{G}$ for arbitrary G, one of the first things to do, therefore, is to consider the case where G is solvable. In 1962 Kirillov's orbit method completely settled the case that G is nilpotent: $\widehat{G}$ is then identified with $\mathfrak{g}^*/G$, where $\mathfrak{g}$ is the Lie algebra of G and $\mathfrak{g}^*$ is the dual of $\mathfrak{g}$ with the coadjoint representation. In [3] Pukánszky makes a major addition to Kirillov's results: he shows that, for G nilpotent, in order to calculate the charac-

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ter of a representation associated to an orbit $\Omega \subset \mathfrak{g}^*$, one can use the measure on Ω induced by the symplectic structure, up to a constant factor that depends only on the dimension of Ω. He then finds that the Plancherel measure on $\widehat{G} = \mathfrak{g}^*/G$ is defined by a rational differential form. The book [4], based on a course given in Paris in 1964–65, expounds the entire Kirillov theory with some additions and with proofs that are simplified or new. This very clear book has attracted a number of young researchers to the theory of unitary representations.

Starting in 1967, in a series of papers that do honor to his tenacity, Pukánszky passed from the nilpotent case to the solvable case. This passage encounters a host of new difficulties.

Let G be a simply connected solvable Lie group, $\mathfrak{g}$ its Lie algebra. One says that G is *exponential* if the map exp is a bijection of $\mathfrak{g}$ onto G. For such a group Bernat had determined $\widehat{G}$ by extending Kirillov's method. In the construction of the irreducible representations of G, one must choose, for a linear form l on $\mathfrak{g}$, a subalgebra of $\mathfrak{g}$ *subordinate* to l. This choice presents no difficulty for G nilpotent. For G exponential, Bernat's method is complicated. Pukánszky gives in [5] a very clear method, introducing a geometric condition that has continued to play a large role in the subsequent development and was soon called the *Pukánszky condition.*

In [6] Pukánszky again considered the case where G is exponential. Let T be in $\widehat{G}$, corresponding to an orbit Ω. Among the many results of this article, let us note only the one that permits, when Ω is closed, the calculation of the character of T, in the following form. If $\phi \in C_c^\infty(G)$, T_ϕ is a Hilbert-Schmidt operator, and

$$\mathrm{Tr}(T_\phi^* T_\phi) = \int_\Omega \psi(l)\, d\nu(l),$$

where $d\nu$ is the canonical measure on Ω and where ψ is obtained in the following three steps:

1) one multiplies $\widetilde{\phi} * \phi$ by

$$\lambda(\exp l) = \Delta(\exp l)^{\frac{1}{2}} \prod_{\alpha \in \mathcal{F}} \frac{\exp\left(\frac{1}{2}\alpha(l)\right) - \exp\left(-\frac{1}{2}\alpha(l)\right)}{\alpha(l)},$$

where $\mathcal{F}$ is a certain set of roots of G and where Δ is the modular function of G;

2) one transports the resulting function to $\mathfrak{g}$ by means of the exponential map; and

3) one takes the Fourier transform to obtain a function on $\mathfrak{g}^*$.

However, for technical reasons, Pukánszky must suppose that $\mathfrak{g}$ is algebraic.

In [7] G is still connected, simply connected, and solvable. The Lie algebra $\mathfrak{g}$ is assumed algebraic, but G is not assumed exponential. (This situation is therefore not far from the case of solvable groups of type I, for which $\widehat{G}$ had been determined a little earlier by Auslander and Kostant.) Thanks to analysis even more difficult than in [6], Pukánszky shows that if $T \in \widehat{G}$ corresponds to a closed orbit, the character of T may be calculated almost as in the exponential case. As exp is no longer bijective, it is necessary to suppose that the function denoted ϕ above has its support in a certain open subset of G defined in terms of the roots of G and independent of the choice of T.

In [8] G denotes an arbitrary simply connected solvable group. Pukánszky associates to each orbit a family of semifinite factor representations parametrized by a torus. If all orbits are locally closed (as is the case if G is of type I), these representations are enough to carry out a central decomposition of the regular representation. But if certain orbits are not locally closed, a generalization of orbits is essential: Pukánszky introduces *quasi-orbits,* which are kinds of packets of orbits, on which G acts ergodically. As in the Auslander-Kostant theory, if Ω is a quasi-orbit, there exists a canonical principal fiber bundle $B(\Omega) \to \Omega$, whose structure group is a torus and which is a G-space. The closures of the G-orbits in $B(\Omega)$ are called *generalized orbits* in a later paper. It is to the generalized orbits that Pukánszky associates semifinite factor representations that he calls central and that permit the decomposition of the regular representation. One of the striking corollaries is that the regular representation is entirely of type I or entirely of type II; this dichotomy was absolutely unforeseen. The introduction of [8] contains conjectures, some of which anticipate deep results of Connes concerning the relationship between Lie group representations and injective factors.

Let G be a locally compact group. Let $R(G)$ be the von Neumann algebra on $L^2(G)$ generated by the left translations. It has been known for a long time (Godement and Segal) that, for G unimodular, $R(G)$ is semifinite and that a canonical trace can be constructed on $R(G)$. In the announcements of [8] Pukánszky says that if G is connected solvable (not necessarily unimodular), $R(G)$ is semifinite and that a "quasicanonical" trace can be constructed on $R(G)$. Dixmier proved in 1969 that $R(G)$ is semifinite for G any connected Lie group whatsoever. However, Dixmier's proof was incomplete, and in the difficult memoir [9] Pukánszky established the results needed to complete this proof.

Pukánszky completes the article [8] in [10]. Let G continue to be a simply connected solvable group. For every $T \in \widehat{G}$, let $\ker T$ be the kernel of T in the C^*-algebra of G. Let Prim G be the set of primitive ideals in $C^*(G)$. Let $\widehat{G}_{cent}$ be the set of quasi-equivalence classes of central representations of G. Then $T \mapsto \ker T$ is a bijection of $\widehat{G}_{cent}$

onto Prim G. In [11], to which we are going to return, it is proved that the central representations are exactly the traceable factor representations. The results of [8, 10, 11] furnish, from a certain point of view, a complete description of harmonic analysis on G.

The article [11] marks the start of a new cycle in Pukánszky's work, attacking now arbitrary connected Lie groups; such a program was probably his ambition from the beginning.

Thus, let G be a connected Lie group. Let $G^{\cap}$ be the set of quasi-equivalence classes of factor representations of G. The map $T \mapsto \ker T$ is a surjection δ of $G^{\cap}$ onto Prim G. Let $G^{\cap}_{tr}$ be the set of elements of $G^{\cap}$ that are traceable. Then δ induces a bijection of $G^{\cap}_{tr}$ onto Prim G. This result (which, according to Guichardet, is false for an arbitrary locally compact group), obtained after a rather formidable proof, is a major accomplishment in representation theory. (A part of the above work is summarized in [13] and [17].)

Let G be a separable locally compact group. One says that G is a CCR group if, for every $T \in \widehat{G}$ and every $\phi \in L^1(G)$, $T(\phi)$ is compact. In [12] Pukánszky gives a geometric characterization, in terms of orbits, of simply connected CCR groups. Such a group, assumed to have no semisimple direct factor, has a cocompact radical (but this condition is far from being sufficient), whence the title of the article. The result is a consequence of more general theorems. A factor representation T of G is said to be GCCR (G for "generalized") if every element of $T(C^*(G))$ is "compact" in the sense of the factor generated by $T(G)$. This said, under the assumption that G has no semisimple direct factor, the following conditions are equivalent:

(i) every point of Prim G is closed,

(ii) every traceable factor representation of G is GCCR,

(iii) every irreducible traceable representation of G is CCR,

(iv) the radical of G is cocompact and its roots are purely imaginary,

(v) the orbits of G satisfy a certain geometric condition (whose description is too long to be given explicitly here).

Pukánszky characterizes also, among all simply connected Lie groups with cocompact radical, those that are of type I.

The articles [14, 15, 16], and [18] are entirely geometric. Let G be a simply connected solvable Lie group, $\mathfrak{g}$ be its Lie algebra, and Ω be a coadjoint orbit. Pukánszky shows in [14] that the canonical mapping $\Lambda\pi_1(\Omega) \to H_*(\Omega, \mathbb{Z})$ is bijective, Λ denoting the exterior algebra. Let ω_Ω be the canonical symplectic form on the orbit Ω, g be in Ω, G_g be its stabilizer in G, G_{go} be its identity component, $\mathfrak{g}_g$ be its Lie algebra, and χ_g be the character of G_{go} with differential $-2i\pi g|\mathfrak{g}_g$. If $a, b \in G_g$, let α, β be the corresponding elements of $\pi_1(\Omega) \simeq G_g/G_{go}$. Then $\chi_g(aba^{-1}b^{-1}) = \exp 2i\pi(\alpha \wedge \beta, [\omega_\Omega])$, where $[\omega_\Omega]$ is the image of ω_Ω in $H^2(\Omega)$. This reproves the theorem of Kostant saying that χ_g extends to a character of G_g if and only if $[\omega_\Omega]$ is integral. The principal application is to the quasi-orbits studied in [8]. Let Ω' be such a quasi-orbit. Then one has an isomorphism $\Lambda\pi_1(\Omega') \to H_*(\Omega', \mathbb{Z})$. In general there does not exist a canonical 2-form on Ω', but Pukánszky constructs "admissible" elements ω of $Z^2(\Omega')$; here "admissible" means that ω, restricted to each coadjoint orbit Ω containing Ω', is equal to ω_Ω. Recall that in [8] Pukánszky introduced a principal fiber bundle $B(\Omega') \xrightarrow{\tau} \Omega'$ whose structure group is the dual $\widehat{\Pi}$ of a certain subgroup Π of $\pi_1(\Omega')$; $B(\Omega')$ is a G-space, and the generalized orbits are the closures of the G-orbits in $B(\Omega')$. Pukánszky constructs a remarkable section of τ, and one of the consequences is that if $[\omega]$ can be chosen integral, the restriction of τ to a generalized orbit is a bijection onto Ω'.

In [15] Pukánszky introduces Hamiltonian G-foliations. These are generalizations of Kostant's transitive Hamiltonian G-spaces. The generalized orbits are Hamiltonian G-foliations, and Pukánszky characterizes among the Hamiltonian G-foliations those that are isomorphic to generalized orbits. The moment map is defined in this context. However, as is shown by examples, many phenomena in the transitive case do not extend to the general case.

The article [16] has as its goal the generalization of certain results of N. V. Pedersen (Pukánszky's de facto student). Let G, g, Ω be as above. One supposes that ω_Ω is integral, which allows the construction of a fibration by complex lines L on Ω and of all the machinery of Kostant (prequantization, quantization). One supposes that $\mathfrak{g}$ admits a real G-invariant polarization. Then the quantization defines an isomorphism between $\mathcal{E}^1$ (a certain subalgebra of the Poisson algebra of Ω) and the Lie algebra of differential operators of order ≤ 1 on a certain space of sections of L. In Pukánszky's generalization, ω_Ω is no longer assumed integral, and thus it is necessary to replace Ω by a "standard sheet" of Ω. Then there exists a complex polarization of $\mathfrak{g}$ for which the announced result of Pedersen, suitably modified, remains true. Pukánszky deduces from this that if Ω is simply connected, there exist global Darboux coordinates on Ω (a result that Pedersen had established for G exponential). The article [18] gives a quite different proof for the existence of Darboux coordinates. It is based on a theorem valid when G is an arbitrary Lie group: in the presence of a certain ideal $\mathfrak{m}$ of $\mathfrak{g}$, Ω becomes a principal fiber bundle with structure group $\mathfrak{m}^\perp$, canonically isomorphic to a subbundle of the cotangent bundle $T^*\Omega$.

As a result of his remarkable mathematics, Pukánszky very soon attained an international reputation. His subsequent work lived up to the high early expectation. He gave an invited address at the International Congress of Mathematicians in Nice in 1970. In 1988 a conference entitled "The Orbit Method in Representation Theory" was held at the University of Copenhagen in honor of his sixtieth birthday. The proceedings of the conference were published by Birkhäuser as volume 82 of the Progress in Mathematics series.

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Movie Review

Good Will Hunting

Reviewed by Mark Saul

Good Will Hunting
Miramax Films
Starring Robin Williams, Matt Damon, Ben Affleck, Stellan Skarsgard, and Minnie Driver
Screenplay by Ben Affleck and Matt Damon
Directed by Gus Van Sant

The place of mathematics in general culture, and particularly in the arts, has varied only a little since Plato set the basic tone. He saw mathematics as pure rationality, but also as a glimpse of divine reality contained within even the lowest slave-boy. In more recent times this rationality came to be a metaphor for a lack of emotion (Whitman's Astronomer) or transcendent but inhuman beauty (Millay's Euclid). More recently, Stoppard's play *Arcadia* sets mathematics as rationality against romanticism but views both as extremes. Luckily, mathematics (but not the physical sciences) has been spared the symbolism of forbidden knowledge, fraught with ethical dilemmas (Faust, Frankenstein, Rappacini). In contrast, the film *Good Will Hunting* is more balanced, and its mathematicians are portrayed as more complex than those in the works referred to above.

Good Will Hunting is in fact not about mathematics. It is the touching story of a young man's struggle to transcend his Dickensian childhood, to discover his place in the world, and to achieve intimacy with others. The main character, Will (the title is a play on his name), is a tough and preternaturally gifted orphan from Boston's South Side who works as a janitor at MIT and cannot resist displaying anonymously his solutions to (supposedly) baffling mathematical problems. The identity of the solver is discovered just about the time that Will (Matt Damon) is arraigned for his part in a street brawl. His subsequent court-ordered supervision by a professor of mathematics and Fields Medalist (Professor Lambeau, played by Stellan Skarsgard) includes psychological counseling. This sets the plot in motion. Will's feelings about himself, about a woman he courts, about his gift and his background are explored and developed through his interaction with the psychologist (masterfully portrayed by Robin Williams) whose background turns out to be similar.

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So what role does mathematics play in all this? Alfred Hitchcock's metaphor of the "MacGuffin" comes to mind: an object or idea that drives the plot and with which everyone in the film, but not the audience, is preoccupied. In Hitchcock's films the MacGuffin might be a military secret, a hidden treasure, or someone's identity. This film's MacGuffins are Will's talent and the mathematical problems that he solves so easily. Will could have been gifted in biology, in physics, in languages and faced similar issues in his life. In fact, his intellect is drawn larger than life, so that he can talk about economics, learn organic chemistry, and even defend himself in court, citing precedents with facility. So why mathematics?

One reason is that mathematics is perceived as so obscure that few can do it. Indeed, this is among the few comments about mathematics that this film makes with which a mathematical audience will not agree. The first frames of the film, under the opening credits, are of a mathematical text out of focus and blurred, as if beheld by a general reader who cannot construe it. The mathematics referred to later on ranges from basic linear algebra, through simple graph theory, to Parseval's theorem (mispronounced in the film), Fourier analysis, and on to what seem to be some deeper graph theoretical results. Mathematics is referred to constantly, but in no scene is it presented coherently. Will's gift, it seems, is valuable partly because it is so rare.

Mathematics also highlights the class distinction between Will and the academics. Will is a tough street kid. His gift is admired but not envied by his friends. Had he been gifted in sports or rock music, the plot could not turn on the choice Will has to make between his background and his destiny. The culture of mathematics does not fit well with that of blue-collar South Boston.

And it is not particularly "our fault". Professor Lambeau takes great pains to keep Will out of jail, to find him a job which uses his talents, and to get him appropriate counseling. It is Will, out of loyalty to his background, who thwarts Lambeau's efforts, until a poorly motivated breakthrough in his therapy (the weakest detail of the film) allows him to begin a reconciliation between the two worlds he has come to know.

The people that create mathematics fare somewhat better in the film than the subject itself. Lambeau is a hard-working guy who drinks and talks tough with the Robin Williams character. He is much more patient with Will's foibles than one might expect, but not so sensitive to another graduate student, a background character who is shown up by Will's talents, is clearly miffed, but is still able to support and admire Will. A third mathematician, an established professor, is crestfallen and humiliated when Will points out an error in a proof and offers the correct alternative on the spot. Each character has a different adaptation to working with the intractable material of mathematics, and the viewer will find each in some measure familiar. The least familiar situation is Will's own. He is not portrayed as ever struggling with anything mathematical. Without the presence of such a struggle, the achievement of making a mathematical discovery easily loses its attraction, and so the film misses an essential emotional element of the experience of doing mathematics (I am indebted to Hyman Bass for this insight). Indeed, no one in the film is portrayed as taking particular pleasure in doing mathematics.

The film did have "coaches" for the mathematics. One was Daniel Kleitman, of MIT, who tells his own story in a sidebar. Listed in the credits as "math consultant" was Patrick O'Donnell, a physicist at the University of Toronto, who was originally hired as an extra. His authentic Irish brogue is heard in a bar scene late in the film, and he can be recognized from a photograph posted on his Web site. O'Donnell says that he built on references in the script to select mathematical content for filming. These references included eigenvectors, complex analysis, graph theory, and combinatorics, and the writers' choices were probably not guided by mathematical coherence. In a telephone interview O'Donnell revealed that he used a paper on graph theory (the reference from *Mathematical Reviews* appears at the end of this article). Those curious about this particular MacGuffin are welcome to look.

So the mathematical reader will enjoy stringing together the bits of proof and calculation that flash on the screen. Likewise, the Boston denizen will have fun trying to discern which actors grew up in Boston and which have been coached for their accent. MIT alumni and Cambridge hands will amuse themselves identifying the locations (in fact, most of the film was shot in Toronto, attracted there by tax breaks and the Canadian dollar). All these details have about the same importance to the total effect of the film.

Yet the film does contribute to the public image of mathematics. The Fields Medal gets some exposure, including an incident in a bar where it emerges that Unabomber Ted Kaczinsky is better known than any Fields Medalist. Some of the most memorable scenes in the film concern a series of job interviews that Lambeau sets up for Will. Predictably Will disdains these offers, but the sequence shows us a glimpse of the import that mathematical research has for the emerging world economy.

The film can also contribute to the self-knowledge of the mathematical community. One lesson we can learn is about social class. It is Will's background, and not just his abuse as a child, that prevents his talents from surfacing. We would do well to remember, in our efforts to include members of underrepresented groups in mathematics, that there can be as much resistance to our efforts from the students we work with as from the system we work in.

But social reality is not everything, and Will's personal struggle is at the center of the film. Perhaps the most important point in this for mathematicians is made by Lambeau's graduate student, the one who finds himself outshone by Will. When Will bridles at some of Lambeau's suggestions, the graduate student tells him, in a scene which brings life to this minor character, how lucky he is to have a teacher who cares about him.

And I think we should take this to heart. We don't nurture our young mathematicians nearly enough. Even those who have every advantage of family, education, and resources have an uphill battle establishing their careers. We would do well to examine our treatment as a community of these gifted young people. Mathematical talent is where you find it, but remains lodged in us useless unless there is a reason, a personal reward, for developing it. Some are lucky enough to acquire this reason on their own, but others need a helping hand. It is not enough for us to spend time hunting our good Wills. We must extend our own good will to them as well.

Reference

[1] Frank Harary and Geert Prins, *The number of homeomorphically irreducible trees, and other species*, Acta Math. **101** (1959), 141–162, MR 21 #653.

My Career in the Movies

One day this spring I got a phone call from someone asking if I would talk to two young men who were writing a screenplay for a movie. I made an appointment with them, and they appeared in my office. They told me the movie was about a young guy they had originally envisioned being a genius in physics, but after talking with Sheldon Glashow of Harvard they had decided his being a mathematician was more plausible. Glashow, who is married to my wife's sister, suggested they come talk with me. They wanted to hear mathematicians talk about mathematics, so that the lines about mathematics in the film would not be embarrassingly foolish. I felt a bit silly mumbling random mathematics to nonmathematicians, so I got ahold of Tom Bohman, a postdoc here, and we talked a bit about problems in combinatorics and graph theory, which are among our fields of interest. I even gave a short lecture (on Fred Galvin's proof that the stable marriage theorem implies the k-list colorability of a certain k by k graph). They also asked for an important unsolved problem that the hero could claim to have solved. We suggested $P = NP$ and had a discussion as to which way the hero might resolve this question. I recall that Ben Affleck suggested that after the hero announces his solution the MIT mathematician should say, "I better tell Mike Sipser about this." Unfortunately or fortunately the movie was vague about mathematics and did not resolve such serious questions even fictionally.

To be honest, I was a bit skeptical at this point as to whether a movie would actually emerge from all of this, but I was happy to help in any case.

They left after an hour or two, and we wished them good luck.

During the summer I received another call, this time from the man in charge of hiring extras for the movie. He offered me, as a sort of reward for my help, a part as an extra. My wife decided I should agree to do this. So one day in the late summer I went to Harvard Square and spent an evening being in two scenes. One was huge, with perhaps a hundred extras and involved the hero and heroine walking through Brattle Square where there were magicians, jugglers, etc., and crowds of extras watching all this amusement. This shooting lasted a long time but never appeared in the movie. In any case, I was way out in left field and never would have been seen.

Afterward a few of us were retained to walk up and down outside the Tasty, a now defunct sandwich shop in Harvard Square, while the hero and heroine smooch a bit at the counter with the window as a backdrop. Strangely enough, in the take that appears in the movie I walk by the window and then do it again in the opposite direction. I guess I was lost. Two more strange things: the scene in the Tasty with me visible outside is in one of the cuts used to advertise the movie; also—and this is a first—the review of the movie in the *Boston Globe* was full of praise for it and even praised the extras.

As another thank you I was invited to the Cambridge premiere of the movie and to the party afterward, where I got to shake hands with the two authors and Minnie Driver. They apologized for any botching of the math, and I congratulated them on the movie, which seemed to me to be prize winning, though I rarely go to the movies.

The movie is really about a troubled, intelligent young man, and the mathematics is only a gimmick to get him a sponsor who will make him see a psychiatrist. The mathematician seemed a bit of a wimp to me, but he could have been much worse, and he does indeed take an interest in the hero and is responsible for anything good that happens to him.

Well, my short movie career has brought me a credit for advising on a screenplay that has won a Golden Globe Award and a bit part that actually appeared visibly on national television. I can now retire from it with satisfaction.

—Daniel J. Kleitman,
Massachusetts Institute of Technology

Kasparov Versus Deep Blue: Computer Chess Comes of Age

Reviewed by Hans Berliner

Kasparov Versus Deep Blue: Computer Chess Comes of Age
Monty Newborn
Springer-Verlag
322 pages
Hardcover $29.95

This book was published after the 1996 match between Kasparov and Deep Blue, but before the 1997 match in which Kasparov was defeated. Given the hype and speculation following that event, I find it difficult to believe that anything I say in this review will persuade anyone to either buy this book or pass on it. However, here goes.

Monty Newborn is a phenomenal raconteur. His stories are truly wonderful, and his introductory tale of a conversation among a group of birds watching early attempts at human flight is probably worth one third the price of admission. However, Newborn is not a strong chess player, and he repeatedly does not face up to this. He makes assertions about chess playing and chess strength that are patently ridiculous to anyone who understands chess and computer chess. Why he did not find someone who is a good player to help him write this book is a total mystery to me.

Newborn gives a lot of the history of computer chess. In this he also shows his lack of skill as a chess player, deeming things that were technologically interesting but unsuccessful to be worth more attention than those things that were highly successful. Also, there is the impression that this book was rushed into publication, possibly on the anticipation that Deep Blue might defeat Kasparov in 1996. There is a picture on page 166 in which Peter Jensen, a part-time helper on Deep Thought, is misidentified as "Andreas Nowatzyk", someone whom Newborn obviously did not know or take the time to find out about.

Also, while the material presented by Newborn is sound as far as it goes, it is very slanted toward technical mishaps and other irrelevant trivia when he could have presented games that show the gradual growth of playing strength. It is significant that a coterie of computer chess achievers have not understood much about chess itself. It is highly commendable that these individuals have achieved all that they have, based principally on generation innovations tested against older versions.

However, when such individuals write about their work, it becomes quite clear that they really do not understand what they have or have not achieved. It is as if someone swam the English Channel and his report is that he just kept putting one arm in front of the other until he touched shore. True, yes, but not very informative. Related to this schism between the technologists and the chess players is the fact that the 1996 Deep Blue was dominated by the technologists, and once Kasparov understood its weaknesses, he had no trouble bringing it to its knees. However, in 1997 chess understanding was invoked in a number of small innovations, and this created an entity that played so well that Kasparov became flustered as his tricks were turned aside, and he eventually went off the "deep" end. The real story of *Computer Chess Comes of Age* should be written about what the Deep Blue team did between the matches of 1996 and 1997. I hope this book will be written some day. In the meantime, I will give Newborn's book a 7 on a scale of 1 to 10 and hope that someone who knows more about chess will revise it.

Hans Berliner is Principal Research Scientist, School of Computer Science, Carnegie Mellon University.

1998 Steele Prizes

The 1998 Leroy P. Steele Prizes were awarded at the 104th Annual Meeting of the AMS in January in Baltimore. These prizes were established in 1970 in honor of George David Birkhoff, William Fogg Osgood, and William Caspar Graustein and are endowed under the terms of a bequest from Leroy P. Steele.

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

The recipients of the 1998 Steele Prizes are Joseph H. Silverman for Mathematical Exposition, Doron Zeilberger and Herbert S. Wilf for a Seminal Contribution to Research, and Nathan Jacobson for Lifetime Achievement.

The Steele Prizes are awarded by the AMS Council acting through a selection committee whose members at the time of these selections were: Richard A. Askey, Ciprian Foias, H. Blaine Lawson Jr., Andrew J. Majda, Louis Nirenberg, Jonathan M. Rosenberg, and John T. Tate.

The text that follows contains for each award the committee's citation, a brief biographical sketch, and the recipient's response upon receiving the award.

Steele Prize for Mathematical Exposition: Joseph H. Silverman

Citation

The Leroy P. Steele Prize for Mathematical Exposition is awarded to Joseph H. Silverman of Brown University for his books *The Arithmetic of Elliptic Curves*, Graduate Texts in Mathematics, vol. 106, Springer-Verlag, New York-Berlin, 1986, ISBN 0-387-96203-4; and *Advanced Topics in the Arithmetic of Elliptic Curves*, Graduate Texts in Mathematics, vol. 151, Springer-Verlag, New York, 1994, ISBN: 0-387-94328-5. The review of the first of these volumes in *Math. Reviews* by Robert S. Rumely, MR 87g:11070, begins as follows:

> This well-written book covers the basic facts about the geometry and arithmetic of elliptic curves, and is sure to become the standard reference in the subject. It meets the needs of at least three groups of people: students interested in doing research in Diophantine geometry, mathematicians needing a reference for standard facts about elliptic curves, and computer scientists interested in algorithms and needing an introduction to elliptic curves. For a long time one of the standard references for elliptic curves has been the survey article of J. W. S. Cassels [J. London Math. Soc. **41** (1966), 193–291; MR 33 #7299; errata; MR 34 #2523]. In its choice of topics this book may be viewed as an amplification of Cassels' article, with technical details filled in, much more motivation, and an excellent set of exercises.

Cassels himself reviewed the book in the *AMS Bulletin* [*Bull. Amer. Math. Soc.* (N.S.) **17** (1987), 148–149]. The review is short, but to the point. It concludes: "In the reviewer's opinion [Silverman]'s book fills the gap admirably. An old hand is hardly the best judge of a book of this nature, but reports of graduate students are equally favorable."

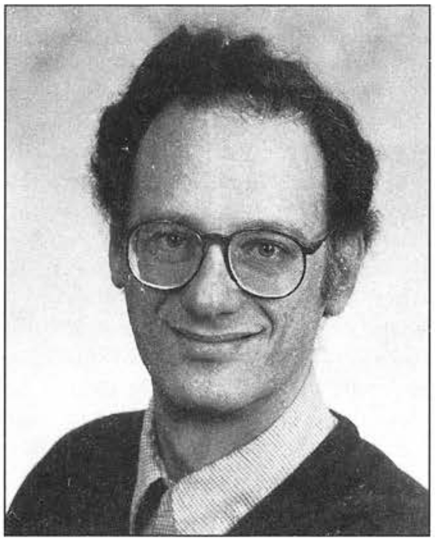
The review of Silverman's second volume in *Math. Reviews* by Henri Darmon, MR 96b:11074, is even more enthusiastic. It says:

> Since its publication almost 10 years ago, Silverman's book *The Arithmetic of Elliptic Curves* has become a standard reference, initiating thousands of graduate students (the reviewer among them) to this exciting branch of arithmetic geometry. The eagerly awaited sequel, *Advanced Topics in the Arithmetic of Elliptic Curves*, lives up to the high expectations generated by the first volume....After reading *Advanced Topics* with much pleasure, we can only hope for a third volume....

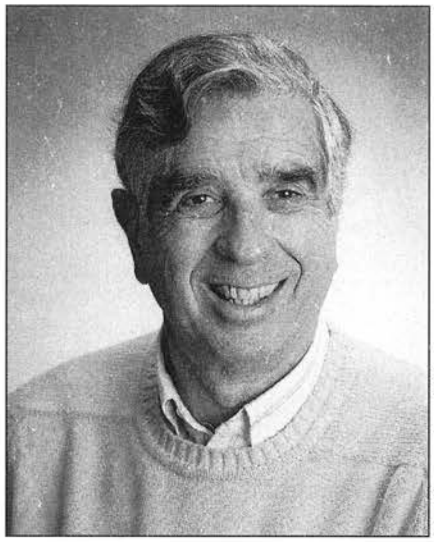
In short, Silverman's volumes have become standard references on one of the most exciting areas of algebraic geometry and number theory.

Biographical Sketch

Joseph H. Silverman was born on March 27, 1955, in New York. He received his Sc.B. from Brown University (1977) and his M.A. (1979) and Ph.D.

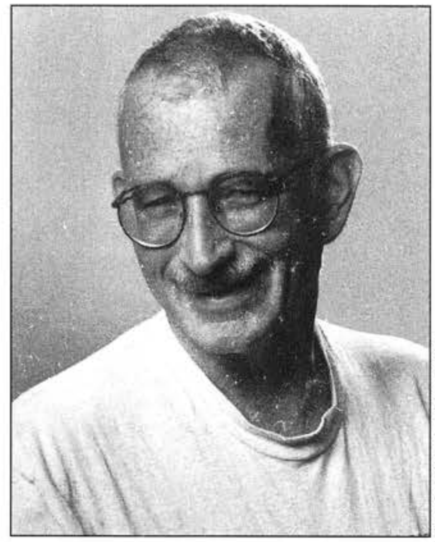


Joseph H. Silverman



Sabra Photography and Video.

Herbert S. Wilf



Temple University News Bureau

Doron Zeilberger

(1982) from Harvard University. He began his career as a Moore Instructor at MIT (1982–86), followed by associate professorships at Boston University (1986–88) and Brown University (1988–91). Since 1991 he has been a professor of mathematics at Brown University.

Professor Silverman has been an NSF Post-Doctoral Fellow (1983–86) and an Alfred P. Sloan Foundation Fellow (1987–91) and is a recipient of an MAA Lester Ford Award (1994). In addition to the two books cited in his Steele Prize, Professor Silverman has written *Rational Points on Elliptic Curves* (jointly with John Tate, 1992) and *A Friendly Introduction to Number Theory* (1996), as well as numerous research articles. He has also coorganized two conferences, "Arithmetic Geometry" (Storrs, 1984) and "Fermat's Last Theorem" (Boston, 1995) and coedited the proceedings. His research interests include number theory, arithmetic geometry, elliptic curves, and arithmetic aspects of dynamical systems.

Response

I am deeply honored to receive a Steele Prize for my two books on elliptic curves. When I wrote the first volume shortly after receiving my Ph.D., my aim was to write the book that I wished had been available when I was a graduate student. It has given me great pleasure to see it fulfilling that purpose for other students over the past decade. In the original outline for that first (and, I assumed, solitary) book, there were twenty topics to be covered. Ten topics and 400 pages later, the publisher and I agreed that the book was finished, but as a sop to the reader and to my conscience, I included a short appendix briefly describing the ten omitted topics. This foolish act on my part was considered by many people to be a tacit promise that someday there would be a second volume. Eventually the second volume was written, and not surprisingly, its 500 pages only sufficed to cover half of the remaining material!

No writer operates in a vacuum. I would like to thank the many people from whom I learned about the beautiful theory of elliptic curves, including John Tate, Barry Mazur, Serge Lang, the members of the Harvard Elliptic Curves Seminar (1977–82), and many other writers, colleagues, students, and friends far too numerous to catalog. My books could never have been written without their encouragement and inspiration.

Steele Prize for a Seminal Contribution to Research: Herbert S. Wilf and Doron Zeilberger

Citation

The Leroy P. Steele Prize for Seminal Contribution to Research is awarded to Herbert S. Wilf, Thomas A. Scott Professor of Mathematics, of the University of Pennsylvania, and Doron Zeilberger of Temple University for their paper *Rational functions certify combinatorial identities*, J. Amer. Math. Soc. **3** (1990), 147–158.

New mathematical ideas can have an impact on experts in a field, on people outside the field, and on how the field develops after the idea has been introduced. The remarkably simple idea of the work of Wilf and Zeilberger has already changed a part of mathematics for the experts, for the high-level users outside the area, and for the area itself. George Andrews, one of the world's leading experts on q-series (which arise, for example, in statistical mechanics), wrote the following about the method of Wilf and Zeilberger: "In my proof of Capparelli's conjecture, I was completely guided by the Wilf-Zeilberger method, even if I didn't use Doron's program explicitly. I couldn't have produced my proof without knowing the principle behind 'WZ'. It is a really powerful result and does indeed merit the Steele Prize."

Donald Knuth, winner of the Steele Prize in 1986 for his books on *The Art of Computer Programming,* has written the following in his foreword to the book *A=B* by Marko Petkovšek, Wilf, and Zeilberger:

> Science is what we understand well enough to explain to a computer. Art is everything else we do. During the past several years an important part of mathematics has been transformed from an Art to a Science. No longer do we need to get a brilliant insight in order to evaluate sums of binomial coefficients, and many similar formulas that arise frequently in practice; we can now follow a mechanical procedure and discover the answers quite systematically.
>
> I fell in love with these procedures as soon as I learned them, because they worked for me immediately. Not only did they dispose of sums that I had wrestled with long and hard in the past, they also knocked off two new problems that I was working on at the time I first tried them. The success rate was astonishing.
>
> Notice that the algorithm doesn't just verify a conjectured identity *A=B.* It also answers the question "What is A?", when we haven't been able to formulate a decent conjecture.

Computer packages have been written to make it possible for others to use the Wilf-Zeilberger idea. Doron Zeilberger has written one. This is the "package" George Andrews mentioned in his quote above. Tom Koornwinder in Amsterdam has a variant, as does Wolfram Koepp in Berlin and Peter Paule in Linz. Marko Petkovšek has extended this work from terminating series to nonterminating series, and work has recently been done on multisums using similar but not identical methods. As offshoots of the Wilf-Zeilberger method become built into computer algebra systems, many people will be using it without being aware it is what makes their calculations possible.

Biographical Sketch: Herbert S. Wilf

Herbert Wilf has written several books, including *Combinatorial Algorithms* with Albert Nijenhuis; *Algorithms and Complexity*; *Generating Functionology*; and, most recently, *A=B* with Marko Petkovšek and Doron Zeilberger. He has been the editor-in-chief of the *American Mathematical Monthly*, 1987–91; was co-founder with Donald Knuth of the *Journal of Algorithms*; and was co-founder with Neil Calkin and is co-editor-in-chief of the *Electronic Journal of Combinatorics*, a peer-reviewed free electronic research journal on the WWW, which is now publishing its sixth volume and is in its fourth year of publication. He received in 1996 the Haimo Award of the Mathematical Association of America for Distinguished Teaching of College or University Mathematics, and he is especially proud to have supervised the dissertations of more than twenty Ph.D. students. The University of Pennsylvania recently named him Thomas A. Scott Professor of Mathematics.

He was born in 1931 in Philadelphia, did undergraduate work at MIT, and got his Ph.D. from Columbia University in 1958. His first faculty position was at the University of Illinois, and he came to the University of Pennsylvania in 1962, where he has been ever since. He has been a Visiting Professor at Imperial College of the University of London, Stanford University, and Rockefeller University, where he was a Guggenheim Fellow.

Response: Herbert S. Wilf

I am deeply honored to receive the Leroy P. Steele Prize. I might say that doing this research was its own reward—but it's very nice to have this one too! My thanks to the Selection Committee and to the AMS.

Each semester, after my final grades have been turned in and all is quiet, it is my habit to leave the light off in my office, leave the door closed, and sit by the window catching up on reading the stack of preprints and reprints that have arrived during the semester. That year, one of the preprints was by Zeilberger, and it was a 21st-century proof of one of the major hypergeometric identities, found by computer, or more precisely, found by Zeilberger using his computer. I looked at it for a while, and it slowly dawned on me that his recurrence relation would assume a self-dual form if we renormalize the summation by dividing first by the right-hand side. After that normalization, the basic "WZ" equation $F(n+1,k)-F(n,k)=G(n,k+1)-G(n,k)$ was in the room with me, and its self-dual symmetrical form was very compelling. I remember feeling that I was about to connect to a parallel universe that had always existed but which had until then remained well hidden and that I was about to find out what sorts of creatures lived there. I also learned that such results emerge only after the efforts of many people have been exerted, in this case, of Sister Mary Celine Fasenmyer, Bill Gosper, Doron Zeilberger, and others. Doing joint work with Doron is like working with a huge fountain of hormones — you might get stimulated to do your best or you might drown. In this case I seem to have lucked out. It was a great adventure.

Biographical Sketch: Doron Zeilberger

Doron Zeilberger was born on July 2, 1950, in Haifa, Israel, to Ruth (Alexander) and Yehudah Zeilberger. He received his Ph.D. in 1976 from the Weizmann Institute of Science (as a student of

Harry Dym (a student of Henry McKean (a student of William Feller (a student of Richard Courant (a student of David Hilbert))))).

In 1979 he married Jane D. LeGrange (Ph.D., physics, Illinois, 1980, currently at Lucent Technology Bell Labs). Their children are Celia (b. 1983), Tamar (b. 1986), and Hadas (b. 1990).

In January 1996 he delivered the second Gillis Memorial Lecture at the Weizmann Institute.

Including this Steele Prize, his earnings to date from mathematical prizes are 2600 U.S. dollars ((1/2)(4000)+ 500 [MAA's 1990 L. R. Ford Award] + (1/2)50 [from Dick Askey and George Andrews for a proof of the q-Dyson conjecture, joint with Dave Bressoud] + (1/2)50 [from Dick Askey for a proof of the G2 case of Macdonald's conjecture, shared with Laurent Habsieger] +50 [from Dick Askey for a proof of the G2-dual case of Macdonald's conj.]), 10 bottles of wine [from Xavier Viennot for a certain tree-bijection], and one book [from Mark Pinsky, for a "calculus problem"].

Response: Doron Zeilberger

[Generic thanks and expressions of astonishment.]

At 11:05 p.m., December 24 (sic!), 1988, Herb Wilf called me up, and with Wilfian enthusiasm told me how the beautiful one-line proofs of certain classical identities, generated by my beloved computer, Shalosh B. Ekhad, could be made even prettier and how to obtain as a bonus a "dual identity" that is often much more interesting than the one originally proved. Thus was born WZ theory.

WZ theory has taught me that computers, by themselves, are not yet capable of creating the most beautiful math. Conversely, humans do much better math in collaboration with computers. More generally, combining different and sometimes opposite approaches and viewpoints will lead to revolutions. So the moral is: Don't look down on any activity as inferior, because two ugly parents can have beautiful children, and a narrow-minded or elitist attitude will lead nowhere.

We live in the great age of the democratization of knowledge and even of that elitist ivory tower called mathematics. Whoever would have believed thirty years ago that a 1988 Steele Prize would go to Rota for his work in "combinatorics" (a former slum), and whoever would have believed ten years ago that a 1998 Steele Prize would go to W and Z for their work on "binomial coefficients identities" (hitherto a slum squared).

The computer revolution, and especially the World Wide Web, is quickly making mathematics accessible and enjoyable to many more people. Especially commendable are the wonderful Web site of Eric Weisstein's "Eric Treasure Troves", Steve Finch's pages on mathematical constants, the Sloane-Plouffe On-Line Encyclopedia of Integer Sequences, Simon Plouffe's "Inverse Symbolic Calculator", and St. Andrews University's MacTutur site on the history of mathematics.

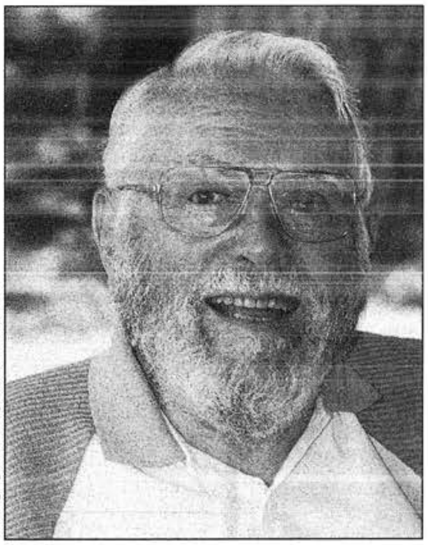
It is very important to make information, in particular mathematical information, freely accessible. The pioneering, and extremely successful, *Electronic Journal of Combinatorics*, created by Herb Wilf in 1994, should be emulated. It is very regrettable that the American Mathematical Society has subscription-only electronic journals and that the electronic versions of its paper journals are only available to paper subscribers. It is a disgrace that MathSciNet is only viewable for paying customers, thereby making its contents unsearchable by public search-engines.

On the positive side, the AMS has been very efficient in taking advantage of the electronic revolution, and the free ERA-AMS, under the leadership of Svetlana Katok, is a real gem!

I am really happy, not only for myself and Herb, but also because of the recognition that the field of hypergeometric series (alias binomial-coefficients identities) is hereby granted. There are so many giants on whose shoulders we are standing. Guru Dick Askey, q-Guru George Andrews, and Guru Don Knuth who preached the gospel from the continuous and discrete sides. Sister Celine Fasenmyer, a non-standard, yet very tall, giant. Hacker Bill Gosper who deserves this prize even more, and many others.

I should also mention our collaborators in this area: Gert Almkvist and Marko Petkovšek, and the beautiful work of Tewodros Amdeberhan, Frederic Chyzak, J. Hornegger, Bruno Gauthier, Ira Gessel, Wolfram Koepf, Christian Krattenthaler, John Majewicz, Istvan Nemes, John Noonan, Sheldon Parnes, Peter Paule, Bruno Salvy, Marcus Schorn, Volker Strehl, Nobuki Takayama, P. Verbaeten, Kurt Wegschaider, and Lily Yen.

Finally, I must mention my main influencers, in roughly chronological order: my terrific seventh-grade math teacher, Devorah Segev, and my great eighth-grade history teacher (and principal), Matityahu Pines. My cousin Mati Weiss, who showed me Joe Gillis's *Gilyonot leMatematika*. Joe Gillis, who, in my early teens, first made me into a mathematician through his *Gilyonot leMatematika*. My advisor, Harry Dym, who initiated me into research. My god-advisor, Dick Duffin, who discretized me. Leon Ehrenpreis, who dualized me. Joe Gillis (again!), who deranged me. Gian-Carlo Rota, who umbralized me. Dick Askey, who hypergeometrized me. George Andrews, who q-ified me. Herb Wilf (the same Herb!), who combinatorized me. Dominique Foata, who bijectified me. Jet Wimp, who asymptotized me. Xavier Viennot, who Schutzenbergerized me. Marco Schutzenberger, who formalized me. Bruno Buchberger, who basically standarized [grobnerized] me. Gert Almkvist, who integralized me, and Pierre Cartier, who Bourbakised me. Let them all be blessed!



Photograph courtesy of Michael Rosen.

Nathan Jacobson

Steele Prize for Lifetime Achievement: Nathan Jacobson

Citation

The Leroy P. Steele Prize for Lifetime Achievement is awarded to Nathan Jacobson, Henry Ford II Professor of Mathematics, Emeritus, of Yale University for his many contributions to research, teaching, exposition, and the mathematical profession. In research he is known primarily for his contributions to ring theory and to the theory of Lie algebras and Jordan algebras. Among the concepts or theorems that bear his name are the Jacobson radical (of a ring), the Jacobson topology (on primitive ideals), and the Jacobson-Morosov Theorem (in Lie theory). In exposition Jacobson is known for quite a number of important books, especially *Lectures in Abstract Algebra* (3 volumes, Van Nostrand, 1951, 1953, and 1964; reprinted by Springer, 1975), later superseded by *Basic Algebra I and II* (Freeman, 1974 and 1980, 1975 and 1989); *Structure of Rings* (AMS Colloquium Publications, vols. 37 and 39, 1956 and 1968); and *Lie Algebras* (Wiley-Interscience, 1962; reprinted by Dover, 1979).

Jacobson served as president of the AMS in 1971–72 and as vice-president of the International Mathematical Union in 1972–74. He received an honorary D.Sc. degree from the University of Chicago in 1972. The list of authors of *Algebraists' Homage*, volume 13 of the AMS Contemporary Mathematics series dedicated to Jacobson on the occasion of his retirement in 1981, includes dozens of the world's greatest algebraists. Few mathematicians have been as productive over such a long career or have had as much influence on the mathematical profession as Jacobson.

Biographical Sketch

Born in Warsaw, Poland, in 1910, Nathan Jacobson immigrated to the United States with his family at the age of seven and grew up in Mississippi and Alabama. He graduated from the University of Alabama in 1930 and embarked upon his graduate studies in mathematics at Princeton University, where he received his Ph.D. in 1934. Professor Jacobson taught at Bryn Mawr College, the University of North Carolina, and the Johns Hopkins University for several years before being appointed professor at Yale University in 1947. In 1963 he was named the Henry Ford II Professor of Mathematics at Yale, a position he held until his retirement in 1981. As a visiting professor he lectured at universities all over the world, including France, Israel, India, China, Japan, and the former Soviet Union.

The author of seventeen books, as well as numerous papers, he is renowned for his contributions to the theory of associative rings, Lie algebras, Jordan algebras, and topological algebra. Presently retired and living in New Haven, Connecticut, Professor Jacobson retains a keen interest in the world of mathematics.

Response

I am greatly honored and deeply moved to have been chosen for the Leroy P. Steele Prize for Lifetime Achievement in Mathematics. It is especially gratifying for me to be honored in this way by the American Mathematical Society.

A lifetime achievement award is particularly meaningful for someone like me who has had, both professionally and personally, such a rich, rewarding, and, yes, long life. My mathematical career and the contributions you have cited in research, writing, and teaching have spanned a period of over sixty years. During that time it has been my pleasure to come in contact with many eminent mathematicians both here in the United States and throughout the world. As their work has stimulated and inspired me, so it is my hope that my own efforts, especially those in ring theory and the theory of Lie and Jordan algebras, will stimulate and inspire the research, writing, and teaching of those who come after.

There are many individuals whom it would be appropriate to thank, too many to name without the risk of omitting some. Nevertheless, I wish to acknowledge a special debt to my thesis advisor and mentor, J. H. M. Wedderburn. I also wish to express my gratitude to my fifty former thesis students who chose me as their mentor. Yale University should be singled out for giving me nearly half a century of support and a fertile academic environment in which to work. Finally, I want to thank my deceased wife, Florie, for her devotion and sparkling companionship over the course of a long and happy marriage. I could never have achieved as much as I did without her.

Once again, I extend my sincere gratitude to the American Mathematical Society, in particular to the members of the Steele Prize Committee, for this prestigious award. I will cherish this honor for the rest of my days. Thank you.

1998 Birkhoff Prize

The 1998 George David Birkhoff Prize was awarded at the 104th Annual Meeting of the AMS in Baltimore in January. Awarded every five years to an individual selected by a joint committee of the AMS and the Society for Industrial and Applied Mathematics (SIAM), the prize recognizes outstanding contributions to applied mathematics in the highest and broadest sense. The Birkhoff Prize Fund was originally created in 1967 by the family of George David Birkhoff. The award of $4,000 is currently augmented by monies from the AMS Leroy P. Steele Fund.

The recipient of the 1998 Birkhoff Prize is Paul H. Rabinowitz. The prize is awarded by the Councils of the AMS and SIAM on recommendation of the AMS-SIAM selection committee whose members at the time of these selections were: Ivo M. Babuška, Jürgen Moser, and Srinivasa Varadhan.

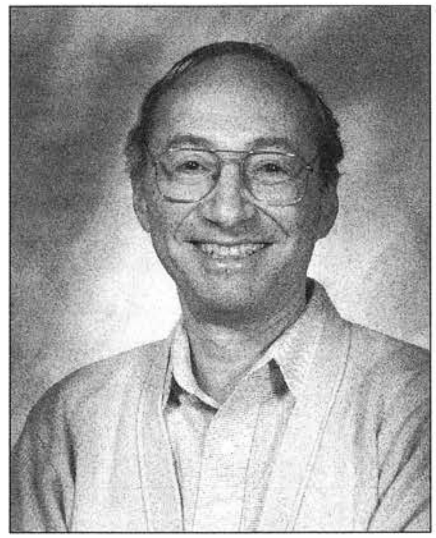
The text that follows contains the committee's citation, a brief biographical sketch, and the response of Professor Rabinowitz upon receiving the prize.

Citation

Perhaps more than anyone else, Paul Rabinowitz has deeply influenced the field of nonlinear analysis. His methods for the analysis of nonlinear systems has changed the way we think of them.

His global bifurcation theorem is astonishing for its many applications. He discovered that under certain circumstances a local linearized analysis forces the existence of a global bifurcation. This is a very powerful result that is quoted very often.

In 1977 Paul Rabinowitz was the first person to prove the existence of periodic solutions of Hamiltonian systems on a star-shape energy surface. The existence of periodic orbits, a problem close to the interests of G. D. Birkhoff, is of course of fundamental importance to mechanics. This was the beginning of a remarkable development that is still going on. Rabinowitz introduced indefinite variational principles, which was a major achievement.



Paul H. Rabinowitz

The traditional methods are limited to extrema or at best to problems involving functionals that are bounded on one side and satisfy the Palais-Smale compactness condition. Paul Rabinowitz broke new ground to invent general mini-max methods for problems not necessarily satisfying the Palais-Smale condition and that are indefinite. He was able to treat Hamiltonian systems, semilinear elliptic equations, and nonlinear wave equations. The famous mountain pass theorem, proved jointly with Antonio Ambrosetti, is one of the deep and beautiful results in the area. Rabinowitz has also introduced the use of sophisticated topological tools to obtain multiple solutions to nonlinear problems.

Rabinowitz is a powerful mathematician who combines abstract mathematics with concrete applications to problems arising in various fields.

Biographical Sketch

Paul H. Rabinowitz was born in Newark, New Jersey, on November 15, 1939. He carried out both his undergraduate and graduate studies at New York University, receiving a B.A. in 1961 and a Ph.D. in 1966. He joined the faculty of Stanford University in January of 1966, serving first as instructor and then as assistant professor. In 1969 he became an associate professor at the University of Wisconsin-Madison and was promoted to professor in 1971. He was named the E. B. Van Vleck Professor of Mathematics in 1986. He has been a visiting professor at the Universities of Aarhus, Pisa, and Paris (1972–73) and at the ETH in Zurich (1982 and 1994).

Professor Rabinowitz has served on several AMS committees and is on the editorial board of several journals. He was a member of the Board of Trustees of the Mathematical Sciences Research Institute (1987–93).

Professor Rabinowitz was a Guggenheim Fellow in 1978–79. In 1984 he delivered the Colloquium Lectures and also was the principal speaker in a Regional Conference sponsored by the CBMS (Conference Board of the Mathematical Sciences). He was elected to the American Academy of Arts and Sciences in 1987 and received an honorary degree from the University of Paris in 1992.

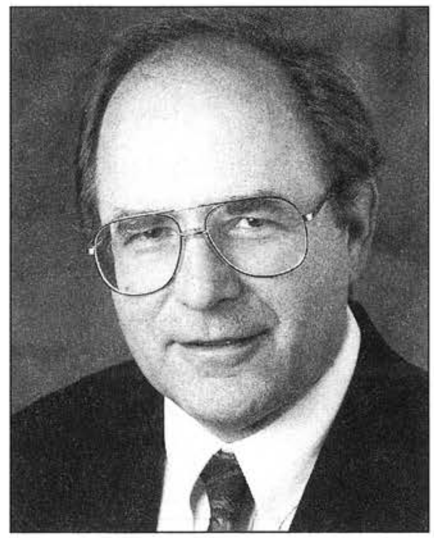
Professor Rabinowitz's research interests include the calculus of variations, partial differential equations, and dynamical systems.

Response

It is an honor and a pleasure to be awarded the Birkhoff Prize by the AMS and SIAM for my work in nonlinear analysis. I greatly appreciate the generous citation of my achievements. I have always found the interface between analysis and applications to be a fruitful area. In addition, the interaction between problems and methods has always been central to my work: the solutions of concrete problems lead to general methods which in turn lead to progress on broader classes of problems.

I am grateful to my teachers at the Courant Institute, my colleagues in Madison, my collaborators, and my friends, from all of whom I have learned so much.

1998 Award for Distinguished Public Service



Kenneth C. Millett

The 1998 Award for Distinguished Public Service was presented during the 104th Annual Meeting of the AMS in Baltimore. Proper recognition for mathematicians who contribute valuable service to the profession is a matter of great importance to the Society. The continued growth and health of the discipline depends in large part on those individuals who contribute their time to public service activities in support of mathematics. To provide encouragement and recognition for such service, the AMS Council, responding to a recommendation from the Committee on Science Policy, established the Award for Distinguished Public Service. The $4,000 award is presented every two years to a research mathematician who has made a distinguished contribution to the mathematics profession through public service during the previous five years. Previous recipients of the award are Kenneth M. Hoffman (1990), Harvey B. Keynes (1992), I. M. Singer (1993), and D. J. Lewis (1995).

The 1998 Award for Distinguished Public Service was presented to KENNETH C. MILLETT. The award is made by the Council acting through a selection committee whose members at the time of this selection were: Ronald L. Graham, Harvey B. Keynes, Peter D. Lax, Everett Pitcher, and I. M. Singer.

The text below contains the committee's citation, a biographical sketch, and Professor Millett's response upon receiving the award.

Citation

Professor Kenneth C. Millett of the University of California at Santa Barbara has been selected by the Council of the American Mathematical Society for the Award for Distinguished Public Service for 1998. His notable accomplishments include his work devoted to underrepresented minority students in mathematical science. This appears in particular in his founding of the UCSB Achievement Program, in his direction of the mathematics component of the Summer Academic Research Internship, and in his direction of the residential Summer Institute in Mathematics and Science for students entering UCSB.

Biographical Sketch

Kenneth C. Millett is currently professor of mathematics at the University of California, Santa Barbara. He was the founding president and executive director of the California Coalition for Mathematics and Science. He is the regional director of the California Alliance for Minority Participation. Millett received his B.S. from the Massachusetts Institute of Technology in 1963 and received his M.S. and Ph.D. degrees from the University of Wisconsin at Madison in 1964 and 1967, respectively. Following lecturer appointments at UCLA and MIT, he joined the faculty of the University of California in 1969. Since then he has been a visiting professor at the Institut des Hautes Études Scientifiques, Princeton University, Occidental College, UCLA, MSRI, several French research institutes and universities, most recently the Université de Provence in Marseille, and at the LOMI, Saint Petersburg, Russia.

He is married to Janis Cox Millett, an educational consultant. He is the father of Rebecca Millett, of New York City, and David Millett, a student at the University of California at Santa Cruz. He was born on November 16, 1941, in Hustisford, Wisconsin, and grew up in Oconomowoc, Wisconsin, with his sisters, Diane, Rita, and Roxanne. His parents, Clarence and Isola Millett, live in Oconomowoc on Lac La Belle.

His research interests include the geometric topology of manifolds and knot theory. In 1985 he participated in the discovery of new families of invariants associated to classical knots. His current research projects are focused on the study of these algebraic invariants; the extension to knotted graphs; the study and development of algorithms to detect knotting, random knotting and linking of curves in space; and the topology and geometry of spaces of polygonal knots. In addition, he is interested in applications to theoretical physics, to topological fluid dynamics, to the molecular biology of enzyme action on DNA, to the dynamics of polymers, and to the topological structure of molecules. In 1988 he received the Carl B. Allendoerfer Award, and in 1991 he received the Chauvenet Prize for an article on knot theory written with W. B. R. Lickorish. He has published over forty scientific papers and edited four research volumes. He has also written articles on mathematics education and educational reform as well as developing materials to increase public understanding and support for the renewal and reform of mathematics teaching and learning.

Millett has been active in efforts to reform mathematics education in California through work with the AMS, Mathematical Association of America, the California Mathematics Project, the California Mathematics Council, the Mathematicians and Educational Reform Network, and the California Coalition for Mathematics and Science. From 1985 through 1997 he was a member of the statewide Advisory Committee of the California Mathematics Project, which he chaired as well as chairing its Executive Committee. Millett is the University of California's representative to the Academic Council of the College Board and was elected to its Western Regional Council, which he now chairs. He was also elected Member-at-large of the Section Committee of the Mathematics Section of the American Association for the Advancement of Science.

At UCSB he is the founder of the UCSB Achievement Program, dedicated to assisting the highest level of achievement of underrepresented minority students in mathematics and science. He has directed highly successful mathematics components of the Summer Academic Research Internships, in which more than a dozen minority students have worked on research projects under his direction. He directs the three-week residential Summer Institute in Mathematics and Science for some thirty underrepresented students in mathematics and science entering UCSB in the fall. In 1991 he was a co-founder of the South Coast Partnership for the Teaching and Learning of Mathematics. The Partnership consists of individuals working to increase the mathematical achievement of underrepresented minority students in the South Coast area through a summer internship program and academic year programs. This program places twenty fellows in summer school classes and awards scholarships to underrepresented students entering mathematics and science credential programs.

Response

I am deeply moved to have received the 1998 Award for Distinguished Public Service. The work it recognizes is deeply personal, even closer to my heart than mathematics. May I explain? Within the University of California, I serve as the Regional Director of the NSF-funded California Alliance for Minority Participation (CAMP), a project that funds much of this work. I am also supported by a couple of my colleagues in mathematics as well as my dean, my chancellor, and senior statewide leadership of the University of California. And I am blessed with a family that loves me without reservation, a family whose fidelity sustains me, and a family whose capacity to love extends deeply into the lives of all who know them. For as long as I can remember, our family has shared whatever it has with others—people of all ethnicities, languages, traditions, and styles of life. For me this has meant sharing the love, the understanding, and the adventure of mathematics and science.

The support of all these has been essential to my continuing in this work. So I am surprised to be recognized for doing what I love: working with dedicated, creative, intelligent young people who have the strongest desire to learn and to succeed. I learn with them and I learn from them. I get up each morning facing new challenges, experiencing quite a few successes, and encountering a defeat or two along the way. (But my dad says, "If you don't fail every once in a while, you're just not trying hard enough!")

To be recognized for this by my colleagues, research mathematicians, and members of the American Mathematical Society—what an amazing idea. Fellow AMS members, I wish to urge you to join me in this effort to invite, support, and sustain all persons, independent of race, ethnicity, culture, gender, ability or disability in their pursuit of mathematics. While there are some who don't share this dream, may I assure you, there are many others like you and me. Our profession's future requires that we succeed. We can do it! My heartfelt thanks. God bless you all.

1998 Citations for Public Service

Two 1998 Citations for Public Service were presented during the 104th Annual Meeting of the AMS in Baltimore. Proper recognition for mathematicians who contribute valuable service to the profession is a matter of great importance to the Society. The continued growth and health of the discipline depends in large part on those individuals who contribute their time to public service activities in support of mathematics. To provide encouragement and recognition for such service, the AMS Council, responding to a recommendation from the Committee on Science Policy, established the Citation for Public Service. One to three \$500 awards are presented to individuals who have made notable contributions to the mathematics profession through public service.

The 1998 Citations for Public Service were presented to Liang-Shin Hahn and Arnold E. Ross. The citations are made by the Council on recommendation of a selection committee whose members at the time of these selections were: Ronald Graham, Harvey Keynes, Peter Lax, Everett Pitcher, and I. M. Singer.

The text that follows contains, for each recipient, the committee's citation, a brief biographical sketch, and the recipient's response.

Citation: Liang-shin Hahn

Professor Liang-shin Hahn is selected for a citation for public service for carrying forward and developing the New Mexico High School Mathematics Contest and for exposition and popularization of mathematics attractive to and suitable for potential candidates for the contest and others with similar intellectual interests.

Biographical Sketch: Liang-shin Hahn

Liang-shin Hahn was born in Tainan, Taiwan. He received his B.S. from National Taiwan University and his Ph.D. from Stanford University. After a brief period of teaching at Johns Hopkins University, he moved to the University of New Mexico, where he has been ever since. He has held visiting positions at the University of Washington (Seattle), National Taiwan University (Taipei), the University of Tokyo, the International Christian University (Tokyo), and Sophia University (Tokyo).

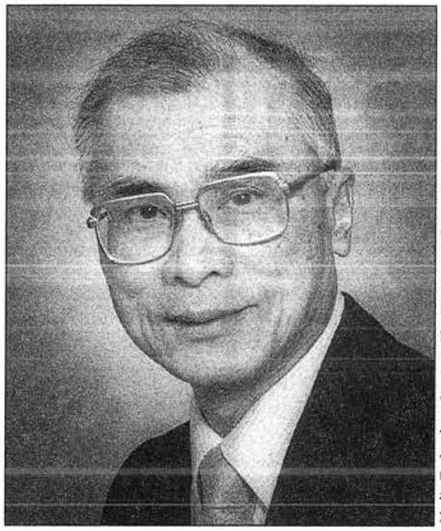
His contest problems are collected in one volume, *Teaching Mathematics through Contest Problems.* It has been submitted to the Mathematical Association of America for publication. He also is the author of the book *Complex Numbers and Geometry*, published by the Mathematical Association of America in 1994, and the co-author of *Classical Complex Analysis* (with Professor Bernard Epstein), published by Jones and Bartlett Publishers in 1995.

He enjoys playing Ping-Pong, cultivating roses, listening to classical music, and solving as well as creating mathematical puzzles.

Response: Liang-shin Hahn

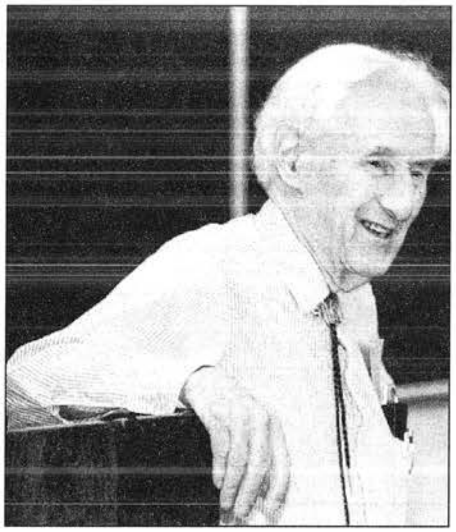
I never ever dreamed that I would get an award by simply doing what I considered a fun thing.

As an unabashed admirer of the late Professor George Pólya, I am fond of telling students half jokingly, "The trick in teaching mathematics is that I do the easy part and you do the hard part." My motto in teaching is: "Don't try to teach the most general theorems. Teach the basic ideas, then use questions to guide the students to explore and



Media Technology Services, The University of New Mexico.

Liang-shin Hahn



Arnold E. Ross

discover for themselves." As a corollary, I am allergic to fat textbooks.

This teaching philosophy is reflected in the New Mexico Mathematics Contest, which I compose. The New Mexico Mathematics Contest consists of two rounds. For example, consider the following: Through a point in a triangle, draw lines parallel to the three sides. That divides the triangle into three small triangles and three parallelograms. In the first round, I would give the areas of the three small triangles and ask the contestants to find the area of the original triangle. Then in the second round, I would give the areas of the three parallelograms and ask the contestants to find the area of the original triangle. In this way I try to encourage contestants to explore the problems in the first round for possible variations and extensions. In the process I hope they will learn not only mathematics but also some approach to mathematics.

Thank you very much for the great honor.

Citation: Arnold E. Ross

Professor Arnold E. Ross is selected for a citation for public service for inspiring generations of young people through the summer mathematics programs he created and has continued to run for nearly forty years.

Biographical Sketch: Arnold E. Ross

Arnold Ross was born in Chicago on August 24, 1906. He spent his boyhood in the USSR during the difficult years. He was able to return to Chicago in 1924. He earned his B.S., M.S., and Ph.D. at the University of Chicago. He was fortunate to study with Professor E. H. Moore before Professor Moore's retirement. His Ph.D. thesis was written under Professor L. E. Dickson. The two postdoctorate years were spent at the California Institute of Technology under E. T. Bell.

During the great depression Arnold Ross taught in a junior college put together by a group of unemployed postdocs representing English, foreign languages, sciences, and economics. His first university position was at St. Louis University. When the war ended, he moved to Notre Dame. Then in 1963 he came to the Ohio State University, where he still teaches as professor emeritus in the "Young Scholars Program".

This last program is a summer program which was started in 1957 in the post-Sputnik era at the time of heightened concern with the need for the search and development of young mathematical talent. The program survived many trials and tribulations largely through encouragement and help by many able colleagues who share educational concerns represented by the program.

More details may be found about topics passed over lightly above in the essay "Windmills or Stepping Stones" in the AMS collection entitled *A Century of Mathematical Meetings* [1].

Response: Arnold E. Ross

Editor's Note: Arnold Ross prepared the following written response upon receiving the award. The text of his oral response presented during the prize ceremony also appears below.

Written Response

I do thank our colleagues of the AMS Selection Committee for the warm moral support to all of us in the program represented by the award conferred on it.

Concern with the upbringing of the new generation of scientists, although not universal, has been represented by many generations of creative members of the world scientific community. In the U.S. this tradition was kept alive by the remarkable influence of E. H. Moore at Chicago.

I have always considered the above concerns to be a vital obligation in the life of a professional. In the Sputnik era such concerns moved dramatically into the central position in our public life. The unexpected appearance of Sputnik sent up by the Soviet Union [4] questioned our claims to technical superiority, and in the days of the cold war we felt threatened. Our popular press laid the blame upon our school teachers.

Soon after, considerable material resources were available for programs designed to upgrade the scientific and mathematical background of the secondary school teachers [1, p. 233]. This was followed by material support of summer programs for able precollege youngsters.

At Notre Dame we were among the first to introduce programs for teachers and a program for able youngsters [1, p. 234]. Our program for the youngsters, which was originally closely associated with our program for teachers, was beginning to acquire a life of its own in 1960. We were confronted with the dilemma as to what purpose should be served by a program for a collection of young individuals who have in common only eagerness, curiosity, an unbounded (and hitherto undirected) supply of vitality, and possibly an ultimate destiny in science.

We settled on the objective of providing a vivid apprenticeship to a life of exploration. This has remained our guiding motivation to the present [2, pp. 44–45].

Has our choice been relevant to the needs of our nation over the years since 1960? Is it relevant today?

The world economy, moved by the forces of the free market and shaped by science fiction technology, does not forgive weakness. The realities of weakness, however, are not presented as clearly and dramatically today as in the past, when weakness could lead to a disastrous defeat in an unequal confrontation. Appreciation of what is needed to survive and prosper in a knowledge-intensive environment grows slowly. Freedom of movement of human talent and of production prowess worldwide mitigates local economic difficulties. This is only temporary—the payment is only deferred.

Education is one of the key ingredients of a healthy economy. Median performance by our young people in mathematics, in science, and in the use of language has been moving steadily downward in quality during the last few decades. Deep anxiety over what this will mean for the well-being of our nation reached upward as far as the White House. Still there is no promise of improvement.

Our problems in education are enormous and many-faceted. The component which is involved in the bringing up of practitioners in the knowledge-intensive occupations is more focused and is, I feel, the responsibility of our professions. The penalty of neglect has been heavy and promises to be even graver in the near future. The hazards of today have different faces and different names than they had in the Sputnik era, but they are equally threatening to our well-being.

Concern with the task of discovery and development of our nation's talented in all walks of life should still be one of our major preoccupations. This feeling provides for us the motive power for the effort needed to keep our program alive and on an acceptable level of excellence.

Mathematics, science, and technology look very different today than they looked forty years ago. Our program must reflect these changes.

Each group of summer participants has a distinct personality all its own. We must respond without losing sight of our major aims.

In selecting our summer participants we try to ascertain that our applicant is ready to benefit by coming to us. Collaboration of master teachers is extraordinarily valuable in accomplishing this. We usually bring together for the summer a group of youngsters with reasonably happy mathematical experience and healthy curiosity not yet dampened.

We make a strong effort to achieve deep student involvement. A rapid transition from a role of very passive spectator to the role of active participant is very demanding for all of the participants, dramatically so for those in the group who are least experienced.

Young participants acquire the deeply moving experience in the use of language as they share results of their observations and of their exploration with others. In this process is born a community of young scholars (very young indeed) where a vivid exchange of ideas between newcomers and program veterans (some acting as counselors) enriches the quality of everyday life.

Happy slogans are always helpful. To indicate involvement, we used to speak of "hands on". With the advent of computer software this is no longer appropriate. Our friends in the life sciences proposed "minds on". Since this expresses our sentiments as well, we have adopted it. After we make our charges realize that "thinking deeply of simple things" is a quality of a fine, inquisitive mind, reexamining the familiar becomes for them a fulfilling experience.

In the crucible of the first summer, individual talents assert themselves. Fortunately, basic mathematical ideas have deep appeal and wide pertinence. Thus intensive participant involvement still allows us to keep many doors open. Nonetheless, deep mathematical and scientific talent also has an opportunity to flower.

Our newcomers do what we call number theory. Number theory proper reflects much of what has been happening in mathematics. On the other hand, many important mathematical ideas, such as those in abstract algebra, for example, are traced back to number theory. Number theory proper and its rich environment are a fertile ground for exploration and are a valuable source for nontrivial but accessible problems. Also, one can increase the density of encounter with new ideas without increasing unduly the computational complexity. Every so often a beginner can get a glimpse of usefulness of geometric or analytic ideas.

Those who return to us for the second summer study combinatorics very intensively. In the last forty years combinatorics has moved into one of the central positions in mathematics. Combinatorics has many interesting and accessible ideas and provides many challenges for the exercise of ingenuity. It has many varied uses in mathematics, in science, and in technology.

Subjects studied by our advanced participants who return to us for an additional summer reflect their interests as well as their experience. Also, as often as possible we try to provide for them an opportunity to learn some interesting mathematics which becomes important in science. This became true for knot theory soon after 1986 and for the representation theory of finite groups in the work of stereochemists about thirty years ago. Moving away from the already established interest helps to broaden the outlook of a budding young mathematician. Failure to be concerned with this facet of education has been deplored by many influential people who oversee the careers of young scientists and mathematicians.

I am happy to say that experimentation is still alive. David Kelly at Hampshire College is much gentler than we are—he reaches out to a different audience. Glenn Stevens and David Fried at Boston University augmented their program (PROMYS) by a symbiotic program for master teachers. The remarkable program of Manuel Berriozabal has reached deeply into the community of San Antonio, which is predominantly Hispanic. Max Warshauer at San Marcos, Texas, lays emphasis on working with underrepresented groups—students and teachers alike. The program, which began under the sponsorship of Admiral Rickover, works through faculty mentors. Paul Sally searches keenly for talent among minorities. His exploration begins through programs in the Chicago city schools at the sixth-grade level and above till college and involves teachers as well. Tom Banchoff assisted in our program while a student at Notre Dame. His deep interest in his students is still very much in evidence. George Berzsenyi of Rose-Hulman Institute of Technology revived for the U.S. the inspired Hungarian tradition. ARML, a society of master teachers, sponsors discussion centers throughout the nation. Julian Stanley's concern with Mathematically Precocious Youth since 1971 has enriched the lives of many youngsters [3]. His imaginative exploration has been instrumental in inspiring widespread interest in the needs of able youngsters.

I am deeply grateful to Professors Daniel Shapiro, Gerald Edgar, Dijen Ray-Chaudhuri, Bogdan Baishanski, Ranko Bojanic, and to Dr. Gloria Woods for their warm support and help in keeping our program alive through many trials and tribulations.

Oral Response

I wish to thank the award selection committee for this award. It serves as a warm moral support for all of us who work in the program.

My deep gratitude goes to my wife, Madeleine, for her faith in our aims and for her unstinted support and help.

In my written response I have tried to describe what we do. As I speak I would like to lay the accent on motivation.

I was told that when Woodrow Wilson served as the president of Princeton, he proposed some radical changes at the university. The board of trustees would not let him do that. A quotation which I discovered not so long ago may give us an inkling of what he had in mind. Let me share it with you. Here is Woodrow Wilson in 1889.

> America is sauntering through her resources and through the mazes of her politics with an easy nonchalance; but presently there will come a time when she will be surprised to find herself grown old—a country crowded, strained, perplexed—when she will be obliged to pull herself together, husband her resources, concentrate her strength, steady her methods, sober her views, restrict her vagaries, *trust her best not her average members.* That will be the time of change.

This is a very attractive vision—a vision well worth working for. I hope the future will be kind to me and my colleagues and that we will be able to carry on.

References

1. Arnold Ross, *Windmills or stepping stones?*, A Century of Mathematical Meetings, Amer. Math. Soc., Providence, RI, 1966, p. 221.
2. ____, *Creativity: Nature or nurture?*, CBMS Issues in Mathematics Education, vol. 2, Amer. Math. Soc., Providence, RI, 1991.
3. *Quo Vadis America*, Intellectual Talent, The Johns Hopkins Univ. Press, Baltimore, MD, 1996, Chapter 13.
4. *Fostering scientific talent*, Science and Technology Policies, Ballinger Publishing Co., 1973, Chapter V.

Mathematics People

Khesin Receives Aisenstadt Prize

BORIS KHESIN of the University of Toronto has received the 1997 André Aisenstadt Prize. The $3,000 prize, presented by the Centre de Recherches Mathématiques (CRM) in Montreal, recognizes talented young Canadian researchers in pure and applied mathematics. Upon receiving the prize at the CRM on January 30, 1998, Khesin presented a lecture entitled "Complexification dictionary and holomorphic linking number". Khesin, who received his Ph.D. in 1989 from Moscow State University, works in the areas of Poisson geometry, integrable systems, and topological hydrodynamics.

Previous recipients of the Aisenstadt Prize are Niky Kamran (1991), Ian Putnam (1992), Michael Ward and Nigel Higson (1994), Adrian Lewis (1995), and Henri Darmon and Lisa Jeffrey (1996).

—*Allyn Jackson*

CAREER Awards Made

The National Science Foundation (NSF) has honored 359 individuals with Faculty Early Career Development (CAREER) Grants. The NSF established the grants to help promising scientists, mathematicians, and engineers develop simultaneously their contributions to research and education early in their careers. The grants are for 4–5 years and range from $200,000 to $500,000 each.

What follows is a listing of the CAREER grants in the mathematical sciences. The name of each awardee is followed by his or her institutional affiliation and the title of his or her grant project.

THOMAS ANATHARAMAN, New York University: Statistical search techniques for human genome and computer chess; KRISTIN BENNETT, Rensselaer Polytechnic Institute: Optimization methods for higher-order learning machines; HELEN DOERR, Syracuse University: Student modelers—a study of technology-enhanced modeling activities; MING GU, University of California, Los Angeles: Algorithms for eigenvalue and singular value problems; DANIEL LIEMAN, University of Missouri, Columbia: Evaluation of L-series and explorations in mathematics; RICHARD MCLAUGHLIN, University of Utah: Mathematical fluid dynamics and education; RODNEY MCNAIR, Vanderbilt University: Socio-cultural development of mathematics discourse as a framework for the design of mathematics instruction; KATHERINE OKIKIOLU, University of California, San Diego: Determinants of elliptic and Toeplitz operators with applications to geometry; DANIEL SPIELMAN, Massachusetts Institute of Technology: Computationally efficient error-correcting codes and their applications; W. NICK STREET, Oklahoma State University: Mathematical optimization for inductive machine learning; and ESTEBAN TABAK, New York University: Nonlinear mechanics for energy transfer in the atmosphere and the ocean.

—*from NSF Announcement*

Repovš Receives Republic of Slovenia Award

DUŠAN REPOVŠ has received the 1997 Award of the Republic of Slovenia for scientific work, that country's highest such honor. He holds a chair in geometry and topology in the Faculty of Education at the University of Ljubljana and is the head of the topology group at the Institute for Mathematics, Physics, and Mechanics. For his contribution to the promotion of Slovenian science he was also awarded the title of Ambassador for Science of the Republic of Slovenia in 1995.

—*Miran Čuk, Dean of the Faculty of Education*

Royal Medal Awarded

JOHN MAYNARD SMITH, FRS, has received the 1997 Royal Medal of the Royal Society, London. The award is made in recognition of his theoretical contributions to evolutionary biology, combining mathematics and biology to develop a sound understanding in such fields as population dynamics, paleobiology, ethology, behavioral ecology, bacteriology, and genetics.

—*from* London Mathematical Society Newsletter

Fulbright Awards Announced

The J. William Fulbright Foundation and the United States Information Agency have announced the names of nearly 1,400 academics, professionals, and independent scholars who have received Fulbright awards to lecture or conduct research.

The following lists the U.S. scholars in the mathematical sciences who are receiving Fulbright awards, together with their home affiliations and the country in which they will use the award. DAVID E. BLAIR, Michigan State University: Belgium; KAREN M. BRUCKS, University of Wisconsin at Milwaukee: Hungary; NAHIDA H. GORDON, Case Western Reserve University: West Bank; ANDREW E. LONG, Loyola University of Chicago: Benin; ARUNAVA MUKHERJEA, University of South Florida: India; MARCEL F. NEUTS, University of Arizona: Spain; TERRY L. OBERT, Mississippi State University: Bulgaria; and ANDREW J. SIMOSON, King College: Tanzania.

The following lists the names and affiliations of scholars in the mathematical sciences who are receiving Fulbright awards for stays in the U.S., followed by the U.S. affiliation where they will use the award. VLADIMIR BALAN, Polytechnic University of Bucharest, Romania: University of Kansas; JAN BEIRLANT, Catholic University of Leuven, Belgium: University of Washington; FOUED BEN ABDELAZIZ, University of Tunis III, Tunisia: Rutgers University at New Brunswick; MARIO BOLEDA, National University of Salta, Argentina: Bureau of the Census and Library of Congress; ABDESSLAM BOUTAYEB, University of Mohammed I, Morocco: Colorado School of Mines; JAN CHOLEWA, Silesian University, Poland: Georgia Institute of Technology; MONICA DUMITRESCU, University of Bucharest, Romania: Arizona State University; JOHN H. EINMAHL, Eindhoven University of Technology, The Netherlands: Florida State University; ALBERTO GANDOLFI, University of Rome Tor Vergata, Italy: New York University; PETER JOHN GIBLIN, University of Liverpool, Britain: Brown University; ALGIMANTAS JUOZAPAVICIUS, Vilnius University, Lithuania: University of Delaware; ROSA ELVIRA LILLO RODRIGUEZ, Complutense University of Madrid, Spain: University of California, Berkeley; ALF RUSTAD, Norwegian University of Science and Technology: Northern Illinois University; and GIUSEPPE VALLA, University of Genoa, Italy: Rutgers University at New Brunswick.

—*from the* Chronicle of Higher Education

Deaths

THEODORE J. BENAC, professor of mathematics, U.S. Naval Academy, died on November 9, 1997. Born in January 1912, he was a member of the Society for 56 years.

JOEL L. BRENNER, of Palo Alto, CA, died on November 14, 1997. Born on August 8, 1912, he was a member of the Society for 61 years.

FOSTER BROOKS, professor emeritus, Kent State University, died on January 3, 1998. Born on September 4, 1908, he was a member of the Society for 63 years.

R. CREIGHTON BUCK, professor emeritus, University of Wisconsin, died on February 1, 1998. Born in August 1920, he was a member of the Society for 55 years.

SAMUEL EILENBERG, of Columbia University, died on January 30, 1998. Born on September 30, 1913, he was a member of the Society for 58 years.

RONALD W. GOLLAND, senior mathematician, Nalco Chemical Co., Naperville, IL, died on December 8, 1997. Born on July 17, 1939, he was a member of the Society for 7 years.

ARISTIDE HALANAY, of the University of Bucharest, died on December 6, 1997. Born on June 7, 1924, he was a member of the Society for 18 years.

WILLIAM A. HARRIS JR., of the University of Southern California and AMS Associate Secretary for the Western Section, died on January 8, 1998. Born on December 18, 1930, he was a member of the Society for 43 years.

J. G. HORNE, professor emeritus, University of Georgia, Athens, died on July 25, 1997. Born on April 6, 1926, he was a member of the Society for 46 years.

JAMES R. F. KENT, professor emeritus of mathematics, SUNY Binghamton, died on December 3, 1997. Born on February 29, 1912, he was a member of the Society for 26 years.

HARRY KIEVAL, professor emeritus, Humboldt State University, died on September 9, 1997. Born on November 17, 1913, he was a member of the Society for 56 years.

LAURA MAYER, of Loyola University of Chicago, died on March 23, 1997. Born on September 16, 1957, she was a member of the Society for 17 years.

DAVID CLARENCE MORROW, of Evansville, Indiana, died on December 27, 1997. Born on January 12, 1900, he was a member of the Society for 70 years.

THIRZA A. MOSSMAN, of Manhattan, KS, died on October 10, 1997. Born on March 8, 1895, she was a member of the Society for 74 years.

GUNDO NARIBOLI, of Iowa State University, died in January 1998. Born on September 2, 1925, he was a member of the Society for 22 years.

JOHN P. NORDLUND, of Brooklyn, New York, died on November 4, 1997. Born on January 28, 1930, he was a member of the Society for 8 years.

SIR ALEXANDER OPPENHEIM, of Henley-on-Thames, England, died on December 13, 1997. Born on February 4, 1903, he was a member of the Society for 69 years.

WILLIAM T. PUCKETT, professor emeritus and former registrar of the University of California, Los Angeles, died on January 6, 1998. Born on November 21, 1905, he was a member of the Society for 61 years.

MINA S. REES, professor emeritus, Graduate School and University Center, CUNY, died on October 25, 1997. Born on August 2, 1902, she was a member of the Society for 69 years.

RICHARD RESCO, associate professor of mathematics, University of Oklahoma, died on September 29, 1997. Born on November 7, 1949, he was a member of the Society for 20 years.

K. C. SCHRAUT, of the University of Dayton, OH, died on October 29, 1997. Born on May 19, 1913, he was a member of the Society for 57 years.

JAMES R. SMART, professor emeritus, San Jose State University, died on September 15, 1997. Born on December 17, 1930, he was a member of the Society for 10 years.

Mathematics Opportunities

News from the IMA

The Institute for Mathematics and its Applications (IMA) is holding a 10-day workshop on Mathematical Modeling in Industry for graduate students and qualified advanced undergraduates. The workshop, which will be held July 22–31, 1998, is meant to provide students with first-hand experience in industrial research.

Students will work in teams of up to six students under the guidance of a tutor from industry. Each team will be assigned project on the first day. The tutor will help guide the students in the modeling process, analysis, and computations through discussion sessions. Each team is expected to make a public oral presentation and submit a written report at the end of the 10-day period.

Some of the projects are polishing of semiconductor wafers, energy trading, computer security, crystalization process, and GPS systems. Companies represented include IBM, Motorola, 3M, Lockheed Martin, and Secure Computing.

Further information and application material can be found at the Web site `http://www.ima.umn.edu/`. The application deadline is **April 15, 1998**, but early submission is encouraged. Please contact the IMA for specific questions at `imastaff@ima.umn.edu`. The postal address is Institute for Mathematics and its Applications, University of Minnesota, 514 Vincent Hall, 206 Church Street, S.E., Minneapolis, MN 55455. The telephone number is 612-624-6066, and the fax number is 612-626-7370.

—*IMA Announcement*

Research Fellowship Opportunities in Asia

What follows is information about fellowship opportunities in Asia offered by the National Science Foundation (NSF).

Summer Programs in Japan and Korea: The NSF, in conjunction with the National Institutes of Health and the Agricultural Research Service, administers the Summer Programs in Japan and Korea, which consists of three separate programs designed to provide participants with first-hand experience in Japanese or Korean research environments, an introduction to the science and science policy infrastructure of the respective countries, and language training. The primary goals of the programs are to introduce students to Japanese or Korean science and engineering in the context of a research laboratory and to initiate personal relationships that will better enable them to collaborate with Japanese or Korean counterparts in the future. All qualified graduate students in science and engineering, including the biomedical, agricultural, and social sciences, may apply. The deadline for application is **December 1**.

Research Fellowships in Japan: The NSF nominates researchers for five fellowship programs administered by the Japan Society for the Promotion of Science (JSPS) and the Science and Technology Agency (STA) of Japan. The range of programs allows visits of nearly any length to Japanese universities, interuniversity research institutes, and over 120 Japanese national laboratories, public corporations, and nonprofit research organizations. The following fellowships are available: (1) JSPS Postdoctoral Fellowships support 12–24-month research stays for researchers who have received the Ph.D. degree within the last six years, (2) JSPS Short-Term Postdoctoral Fellowships support 3–11-month research stays for researchers who have received the Ph.D. degree within the last ten years, (3) JSPS Short-Term Invitation Fellowships support research visits to Japan of 7–60 days for researchers with Ph.D. degrees, (4) STA Postdoctoral Fellowships support 6–24-month research stays for researchers who have received the Ph.D. degree within the last six years, (5) STA Short-Term Fellowships support research visits to Japan of 1–3 months for researchers with Ph.D. degrees.

For information, requirements, and application materials please access the NSF/Tokyo home page, `http://www.twics.com/~nsftokyo/home.html`. Specific questions can be directed to `JKPinfo@nsf.gov`. The mailing address is National Science Foundation, U.S. Embassy, Tokyo, Unit 45004, Box 236, APO AP 96337-0001.

—*from NSF Announcement*

1999–2000 Fulbright Awards for U.S. Faculty and Professionals

The Fulbright Senior Scholar Program offers opportunities for lecturing or advanced research in over 125 countries to college and university faculty and professionals outside academe. U.S. citizenship and the Ph.D. or comparable professional experience are required. For lecturing awards, university or college teaching is expected. Foreign language skills are needed for some countries, but most lecturing assignments are in English.

The deadlines are: **August 1, 1998,** for lecturing and research grants in the academic year 1999–2000; **May 1, 1998,** for distinguished Fulbright chairs in Western Europe and Canada; and **November 1, 1998,** for international education and academic administrator seminars.

For further information contact USIA Fulbright Senior Scholar Program, Council for International Exchange of Scholars, 3007 Tilden Street, NW, Suite 5L, Box GNEWS, Washington, DC 20008-3009; telephone 202-686-7877; World Wide Web `http://www.cies.org/`. Requests for application materials only may be sent by e-mail to `apprequest@cies.iie.org`.

—CIES Announcement

NSF Initiative in Knowledge and Distributed Intelligence

The National Science Foundation (NSF) has announced a new initiative entitled Knowledge and Distributed Intelligence (KDI). Projects funded under KDI will draw on expertise from all areas supported by the NSF, including mathematics. "This solicitation provides many opportunities for mathematicians in such areas as data security and integrity, data mining, problems involving multiple scales, modeling and simulation, cognitive studies, pattern recognition, etc.," noted Donald J. Lewis, director of the NSF's Division of Mathematical Sciences (DMS).

Lewis chaired the committee of NSF staff that conceived the KDI initiative. The KDI budget is expected to be about \$62 million for fiscal year 1998, and grants are expected to range from about \$100,000 up to \$1,000,000 per year.

KDI is intended to build on what has been achieved in computation and communications to make new advances in science and engineering. KDI proposals must be for research that is inherently multidisciplinary or that, while lying within a single discipline, has clear impact on at least one other discipline.

In the current fiscal year, KDI will have three foci.

- Knowledge Networking will focus on attaining new levels of knowledge integration, information flow, and interactivity among people, organizations, and communities.
- Learning and Intelligent Systems will emphasize research that advances basic understanding of learning and intelligence in natural and artificial systems and supports the development of tools and environments to test and apply this understanding in real situations.
- New Computational Challenges will emphasize new computational approaches to frontier science and engineering problems as well as problems involving data-intensive computations and simulations. In the first year NCC especially encourages projects that deal with interactions between phenomena involving multiple scales or structures and problems involving dynamic interplay between computations and data.

The Learning and Intelligent Systems component began last year, and 28 grants totaling \$22.5 million were awarded in October 1997. The grants included support for work that involved such mathematically based areas as statistics, control theory, and imaging.

It should be emphasized that KDI is an interdisciplinary initiative. But within that context there are great opportunities for the mathematical sciences. Common tools in areas touched by KDI use data-based optimization to achieve a task, but these tools do not always address the main issue of understanding the nature of the patterns encountered, the ability to describe them mathematically, or their structure. Biological, neural, and machine learning bring into focus the basic question of alternative processing or computational paths, translating natural processing into mathematical models of computations. In computation, the need for a mathematical algorithmic language to describe complex natural phenomena requires a detailed focus on geometry and approximation in high dimensions, as well as structures enabling systematic descriptions of scale transitions.

Because of the importance of mathematics to all facets of KDI, the DMS is strongly encouraging mathematicians to participate in the initiative. In fact, Lewis says that at least 50% of the proposals could well involve mathematicians. Each KDI focus area depends heavily on the mathematical sciences, presenting substantial opportunities in statistics, data mining, modeling, analysis, computation, and visualization of data, objects, or processes. Data security and integrity and communications management offer further opportunities for algebra and number theory.

There are two deadlines pertaining to KDI: **April 1, 1998,** for letters of intent to submit proposals, and **May 8, 1998,** for full proposals. The next deadline for KDI will be February 1, 1999. Letters of intent should be submitted by e-mail to `kdiletin@nsf.gov`. Proposals must be submitted through the NSF's electronic FastLane system.

For further information and continuing developments, consult the Web site `http://www.nsf.gov/kdi/`. General questions about KDI may be sent to the e-mail address `kdi@nsf.gov`. Specific topical questions in one of the three KDI focus areas may be sent to `kn@nsf.gov` (for Knowledge Networking), `lis@nsf.gov` (for Learning and Intelligent Systems), and to `ncc@nsf.gov` (for New Computational Challenges).

—Allyn Jackson

For Your Information

JPBM Task Force on Educational Activities of Faculty

The Joint Policy Board for Mathematics (JPBM) has created a task force whose mission is to provide the postsecondary mathematical community with resources for enhancing the educational activities of faculty. Its goal is to help institutions and departments reflect on their educational missions, determine the range of educational activities that should "count" in the promotion and tenure process given their missions, and document educational activities in reliable and meaningful ways. We want to help faculty do the job well and be rewarded appropriately for their efforts.

The task force, which is funded by the Exxon Education Foundation, will produce two books. One will describe the state of the art, providing a statistical survey of current practices at different kinds of institutions. It will say what we know about reliable methods for enhancing, documenting, and rewarding faculty's educational contributions (e.g., through student evaluations, peer review, and documentation of instructional efforts via course and teaching portfolios).

The second will provide descriptions of models that work. It will offer case studies showing how institutions as different as community colleges, small colleges, and public and private universities help faculty, graduate students, and administrators develop institutional cultures and procedures that enhance and reward educational efforts. There will be no prescriptions, but rich examples to learn from.

The task force is looking for information and ideas.

- What issues should we address? Are there things you want to know about or you think the field should know about?
- What resources, ideas, or programs should we be aware of?
- What departments would be good candidates for site visits?

Please contact the task force chair, Alan Schoenfeld, with this or any other information and suggestions. Write to Alan H. Schoenfeld, Chair, JPBM Task Force on Educational Activities, School of Education, EMST, University of California, Berkeley, CA 94720-1670. Or send e-mail to alans@socrates.berkeley.edu. Information will be welcome at any time but will be most useful if received by April 30, 1998.

—*Alan H. Schoenfeld*

Call for Manuscripts on Mathematics Teaching

The February 2000 issue of *Teaching Children Mathematics*, an official journal of the National Council of Teachers of Mathematics (NCTM), will focus on children as mathematicians to highlight the engagement of children as discoverers and inventors, as well as users, of mathematics to understand the world. The editorial panel wishes to highlight pre-kindergarten through sixth-grade examples of young mathematicians at work, classrooms that exhibit a community of inquiry, tasks that require powerful thinkers, and methods to assess children's thinking. Teachers and mathematicians are encouraged to collaborate on and coauthor manuscripts. Topics of particular interest include engaging all children as mathematicians, learning environments for mathematical work, children's mathematical discoveries, and assessing the thinking and dispositions of young mathematicians.

The complete call for manuscripts and guidelines for submitting manuscripts is published in the April 1998 issue of *Teaching Children Mathematics* and is also available from the NCTM Web site at http://www.nctm.org/. For more information contact Daniel Breidenbach, telephone 703-620-9840, e-mail: dbreidenbach@nctm.org.

—*Daniel Breidenbach*

VideoMath Festival at ICM-98

In an effort to reach out to the general public, the organizers of the International Congress of Mathematicians 1998 are going to offer, in addition to the scientific program, several cultural activities related to mathematics designed to appeal to a broad audience beyond the ICM attendees. One of these events is the VideoMath Festival.

Short high-quality videos on mathematical topics will be combined into one or two films of about two hours' length and will be shown in the movie theater of the Urania, a center for popular science presentations in Berlin.

The collection of videos to be presented will be selected by a program committee. A prize of 5,000 DM will be awarded to recognize the most outstanding contribution.

Further information is available at the VideoMath Web site, `http://www-sfb288.math.tu-berlin.de/VideoMath/`. Submissions should be sent to ICM-98—VideoMath Festival, c/o Ms. Saida Grase, Konrad-Zuse-Zentrum (ZIB), Takustr. 7, D-14195 Berlin, Germany; e-mail: `video-math@zib.de`. The deadline for receipt of submissions is **April 3, 1998**. Submissions that arrive after this deadline will not be considered. Please consider that customs delays of up to two weeks can occur.

The ICM will be held in Berlin, Germany, August 18–27, 1998. Further information is available at the Web site `http://elib.zib.de/ICM98/`.

—from ICM-98 Announcement

ICMI Study on University Teaching and Learning

The International Commission on Mathematics Instruction (ICMI), which operates under the auspices of the International Mathematical Union, has initiated a study, "On the Teaching and Learning of Mathematics at University Level." The ICMI has recently released a Discussion Document (ICMI Bulletin 43) relating to the study. As part of the study there is to be a conference in December 1998, and the Discussion Document invites submissions from people who might be interested in attending that conference.

As a result of the changing world scene, ICMI feels that there is a need to examine both the content and future of the teaching and learning of mathematics at university level. The primary aim of this study is therefore to pave the way for improvements in this area for all students.

In order to achieve this aim the study will attempt to

- identify, review, encourage, and disseminate research in educational matters at the tertiary level;
- identify and describe major approaches to tertiary mathematics teaching within different cultures and traditions;
- identify obstacles which might prevent the learning of mathematics;
- discuss equity and other issues relating to mathematics education at university level;
- discuss the goals of teaching mathematics to a range of students with different backgrounds and needs and discuss who should be responsible for that teaching;
- find ways to meet changing needs without compromising the integrity of the subject;
- identify, publicize, and expose to scrutiny new teaching methods and the positive use of technology;
- discuss the transition and the relations between secondary school and university;
- consider ways to improve the preparation of teachers of mathematics at university level.

The work of this study will take place in two parts. The first consists of a conference which is to be held in Singapore from December 8 to 12, 1998. English will be the language of the conference. The conference will be a working one where every participant will be expected to be active. Current planning is for a limited attendance of about seventy-five persons.

Given the style of the conference, we anticipate a variety of types of contributions that will be presented in plenary sessions, working groups, panels, and short presentations. Presentations may include position papers, discussion papers, surveys of relevant areas, reports of projects, or research papers of an educational nature.

We invite you to make a submission for consideration by the International Program Committee no later than **May 1, 1998**. Submissions should be up to three pages in length and may be e-mailed, faxed, or sent as hard copy. They should be related to the problems and issues identified in this document but need not be limited to these alone. You might also draw to the attention of the committee the names of other people whom you feel ought to be invited, stating the type of contribution they might make. We would appreciate knowing the nature and results of related studies in this area.

Participation in the conference is by invitation only. Invitations to those whose submissions have been accepted will be made in July 1998. At the same time invitees will be asked to produce a longer version of their submission for publication in the preconference proceedings. The study organizers are seeking funds to provide partial support to enable participants from nonaffluent countries to attend the conference, but it is unlikely that full support will be available for any one individual.The second part of the study is a publication that will appear in the ICMI Study Series. This publication will be based both on the contributions requested above and the outcomes of the conference working group and panel deliberations. The exact format of the publication has not yet been decided, but it is expected to be an edited, coherent book that it is hoped will be a standard reference in this field for some time.

The Discussion Document and information relating to the conference can be found on the ICMI Web site, `www.nie.ac.sg:800/~wwwmath/`, and at `http://emmy.otago.ac.nz:800/Maths.html`.

All contributions, suggestions, and enquiries concerning the study should be sent to Derek Holton, Chair, IPC, ICMI Study, Department of Mathematics and Statistics, University of Otago, P.O. Box 56, Dunedin, New Zealand; e-mail: `dholton@maths.otago.ac.nz`; fax: (+64-3)-479-8427.

—Derek Holton

Reference

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

Upcoming Deadlines

April 15, August 15, 1998: Deadlines for applications for NRC Associateship Programs. Information available at the Web site `http://rap.nas.edu/`.

May 1, 1998 (distinguished Fulbright chairs in Western Europe and Canada), **August 1, 1998** (lecturing and research grants for 1999–2000), **November 1, 1998** (international education and academic administrator seminars): Deadlines for applications for 1999–2000 Fulbright Awards for U.S. faculty and professionals. World Wide Web: `http://www.cies.org/`; application requests only to e-mail: `apprequest@cies.iie.org`.

December 1, 1998: Deadline for applications for fellowship opportunities in Asia offered by the NSF. World Wide Web: `http://www.twics.com/~nsftokyo/home.html` or by e-mail: `JKPinfo@nsf.gov`.

Board on Mathematical Sciences, National Research Council

U.S. National Committee for Mathematics

Michael Artin (chair), Massachusetts Institute of Technology

Rodrigo Banuelos, Purdue University

Lynne Billard, University of Georgia

Michael Crandall, University of California, Santa Barbara

Ingrid Daubechies, Princeton University

Donald G. Saari, Northwestern University

Yum Tong Siu, Harvard University

James C. Turner, Arizona State University

Ruth J. Williams, University of California, San Diego

The 1998 General Assembly of the International Mathematical Union will meet just prior to the International Congress of Mathematicians in Berlin in August 1998. The U.S. delegation to the General Assembly is:

Ronald Graham (chair), AT&T Laboratories

M. Salah Baouendi, University of California, San Diego

Lynne Billard, University of Georgia

Robert D. MacPherson, Institute for Advanced Study

Margaret H. Wright, Bell Laboratories/Lucent Technologies

Yum Tong Siu (alternate delegate), Harvard University

The U.S. National Committee for Mathematics is overseen by the Office of International Affairs, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2243.

Where to Find It

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

Add this Cover Sheet to all of your Academic Job Applications

How to use this form

1. Using the facing page or a photocopy, (or a $\TeX$ version which can be downloaded from the e-math "Employment Information" menu, `http://www.ams.org/profession/employ.html`), fill in the answers which apply to *all* of your academic applications. Make photocopies.

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

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

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

JCEO Recommendations for Professional Standards in Hiring Practices

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

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

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

Academic Employment in Mathematics

AMS STANDARD COVER SHEET

Last Name ____________________

First Name ____________________

Middle Names ____________________

Address *through June 1998* ____________________

Home Phone ____________________

e-mail Address ____________________

Current Institutional Affiliation ____________________

Work Phone ____________________

Highest Degree and Source ____________________

Year of Ph.D. (optional) ____________________

Ph.D. Advisor ____________________

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

This form is provided courtesy of the American Mathematical Society.

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

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

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

Primary Interest ____________________

Secondary Interests *optional* ____________________

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

____

____

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

University or Company ____________________

Position Title ____________________ Dates ____________________

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

____

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

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

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

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

☐ ____________________

☐ ____________________

☐ ____________________

☐ ____________________

1991 Mathematics Subject Classification

00 General
01 History and biography
03 Logic and foundations
04 Set theory
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General mathematical systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra, matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory, homological algebra
19 K-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
39 Finite differences and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations, optimal control
51 Geometry
52 Convex and discrete geometry
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
68 Computer science
70 Mechanics of particles and systems
73 Mechanics of solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
86 Geophysics
90 Economics, operations research, programming, games
92 Biology and other natural sciences, behavioral sciences
93 Systems theory, control
94 Information and communication, circuits

Mathematics Calendar

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

April 1998

*2–5 **Connections in Modern Mathematics and Physics**, State University of New York, Stony Brook, New York.

Aim: This special year of the Geometry Festival will be concerned with the theory of connections and its role in recent developments in mathematics and physics.

Topics: Developments in gauge theory such as Seiberg-Witten theory and Floer cohomology; secondary invariants in topology, including the perturbative invariants for 3-manifolds and links arising from the Chern-Simons functional; secondary invariants in geometry—index theory, including higher eta-invariants, adiabatic limits, holomorphic torsion, etc.; secondary invariants in algebra and number theory, including the refined Riemann-Roch theorem in Arakelov theory; metrics with special holonomy; string theory and mirror symmetry; and pseudoholomorphic curves.

Main Speakers: S. Axelrod, J.-M. Bismut, S. Bloch, R. Bryant, J. Cheeger, S. S. Chern, J. Froehlich, M. Gromov, M. Kontsevich, B. Lawson, R. MacPherson, J. Milnor, I. M. Singer, D. Sullivan, C. Taubes, G. Tian, C.-N. Yang, S.-T. Yau.

Local Organizers: J. Cheeger, cheeger@math.cims.nyu.edu; and B. Lawson, blaine@math.sunysb.edu.

Information: Registration forms, information concerning accommodations, local maps, etc. can be accessed at the Web site: http://www.math.sunysb.edu/g-fest. Further information can be obtained from L. Meci at 516-632-8260, e-mail: lucille@math.sunysb.edu or A. DelloRusso at 516-632-8290, e-mail: amy@math.sunysb.edu.

*4 **The Ontario Analytic Geometry Seminar**, The Fields Institute, Toronto, Ontario, Canada.

Speakers: J. Bland (Univ. of Toronto), R. Kobayashi (Nagoya Univ.), T. Napier (Lehigh Univ.), S. Takayama (Osaka Univ.), H. Tsuji (Tokyo Institute of Technology).

Information: http://www.math.uwo.ca/~larusson/.

*16–17 **Models and Numerical Methods in Transport Theory and in Mathematical Physics: An international conference dedicated to V. Boffi on his 70th birthday**, Rome, Italy.

Dedication: This is an international conference dedicated to V. Boffi on his 70th birthday.

Program: The conference is aimed at bringing together scientists with interest in all fields of mathematical physics and applied mathematics which are related to transport theory. It is structured in a number of invited lectures, each one given by an eminent specialist in the field, about the state of the art and the most recent available results, in order to promote exchange of ideas and methods, as well as dissemination of advanced scientific knowledge, in the interested research community. Both mathematical modeling and numerical techniques will be emphasized. The main lectures will be published in a special issues of the journal "Transport Theory and Statistical Physics".

Organizing Committee: G. Frosali (Firenze), G. Spiga (Parma), R. Spigler (Roma).

Scientific Committee: M. Anile (Catania), A. Belleni-Morante (Firenze), P. Benvenuti (Roma), V. Capasso (Milano), M. Fabrizio (Bologna), G. Frosali (Firenze), R. Monaco (Torino), R. Piva (Roma), L. Salvadori (Trento), G. Spiga (Parma), R. Spigler (Roma), G. Toscani (Pavia).

Invited Speakers: N. Bellomo, C. Cercignani, L. De Socio, J. Dorning, A. Fasano, B. D. Ganapol, C. Marchioro, E. Massa, J. Mika, H. Neunzert, T. Nonnenmacher, P. Podio-Guidugli, J. Pomraning, S. Rionero, R. Scozzafava.

Information: G. Frosali, fax +39-55-471787; e-mail: frosali@dma.unifi.it and via WWW at http://www.dma.unifi.it/~congressi/.

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

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

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

In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **six months** prior to the scheduled date of the meeting.

The complete listing of the Mathematics Calendar will be published only in the September issue of the *Notices*. The March, June, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through e-MATH on the World Wide Web. To access e-MATH, use the URL: http://e-math.ams.org/ (or http://www.ams.org/). (For those with VT100-type terminals or for those without WWW browsing software, connect to e-MATH via Telnet (telnet e-math.ams.org; login and password e-math) and use the Lynx option from the main menu.)

* 18 **Northeastern Conference on Topological Methods in Computer Science**, Roger Williams University, Bristol, Rhode Island.
Information: Web site: `http://www.usm.maine.edu/~flagg/mc/`.

* 25 **47th Algebra Day**, Carleton University, Ottawa, Ontario, Canada.
Speakers: Invited one-hour speakers: W. N. Herfort (Tech. Univ. of Vienna), O. Kharlampovich (McGill Univ.), M. Kleiner (Univ. of Syracuse).
Sponsor: Ottawa-Carleton Institute of Mathematics and Statistics.
Information: L. Ribes, tel: 613-520-2600 (ext. 2164), e-mail: `lribes@math.carleton.ca`.

* 25 **Twelfth New England Statistics Symposium**, Department of Mathematics, MIT, Cambridge, Massachusetts.
Principal Lecturers: J. Stock, Kennedy School of Government, (Harvard Univ.) and L.-J. Wei (Harvard School of Public Health).
Information: R. Dudley, MIT; tel: 617-253-7567; fax: 617-253-4358; e-mail: `rmd@math.mit.edu`.

May 1998

* 1-2 **The Duke Mathematics Journal and International Mathematics Research Notices Conference**, Duke University, Durham, North Carolina.
Organizers: R. Hain and J. Wahl.
Speakers: J.-M. Bismut, S. Bloch, R. Borcherds, B. Gross, H. Hofer, D. Jerison, P. Sarnak.
Information: More information may be obtained from `http://www.math.duke.edu/conference/` or by sending e-mail to A. Langen, `langen@math.duke.edu`.

* 1-3 **Pure, Applied, and Industrial Mathematics: Strength through Connections**, University of Minnesota, Minneapolis, Minnesota.
Organizers: R. Gulliver, N. Jain, W. Miller.
Information: Institute for Mathematics and its Applications, University of Minnesota, 206 Church St., SE, Minneapolis, MN 55455.

* 7-9 **Dynamical Systems in Oceanography: Chaotic Advection in Ocean Mesoscale Structures**, University of Minnesota, Minneapolis, Minnesota.
Organizer: C. Jones.
Information: Institute for Mathematics and its Applications, University of Minnesota, 206 Church St., SE, Minneapolis, MN 55455.

* 18-19 **DIMACS Reconnecting Two-Year College Faculty to the Mathematical Sciences Enterprise**, DIMACS Center, Rutgers University, Piscataway, New Jersey.
Aim: DIMACS is presenting a series of 2 two-day workshops geared towards introducing two-year college faculty to discrete mathematics and to some current research topics relevant to the classroom. These workshops will reconnect faculty to the mathematical sciences enterprise by involving them in a leading research center which is a consortium of Rutgers University, Princeton University, AT&T Labs, Bell Labs, and Bellcore.
Organizers: J. Lane (Union County College), F. S. Roberts (Rutgers Univ.), and J. Rosenstein (Rutgers Univ.).
Information: Contact E. Foley, DIMACS/CoRE Bldg., Room 430, Rutgers, The State University of New Jersey, 96 Frelinghuysen Road, Piscataway, NJ 08854-8018; e-mail: `epfoley@dimacs.rutgers.edu`; tel: 732-445-4631; WWW: `http://dimacs.rutgers.edu/reconnect/`.

* 21-24 **Conference on Representations of Affine and Quantum Affine Algebras**, North Carolina State University, Raleigh, North Carolina.
Program: (1) Affine and quantum affine algebras and generalizations, (2) Vertex operator algebras, (3) Applications to combinatorics and statistical mechanics.
Organizers: N. Jing and K. C. Misra, Dept. of Mathematics, North Carolina State Univ., Raleigh, NC 27695-8205; `jing@math.ncsu.edu`; `misra@math.ncsu.edu`.
Information: Further information about speakers, accommodations, and registration forms is available on the Web at `http://www4.ncsu.edu/~jing/conf.html` or by mail from the organizers.
Deadlines: March 15, 1998.

* 22-24 **The XXIVth Ohio State-Denison Mathematics Conference**, Denison University, Granville, Ohio.
Funding: Funded by the Ohio State University Mathematics Research Institute, the Ohio State University (Lima), and hosted by Denison University.
Topics: Parallel sessions in combinatorics, group theory, and ring theory.
Papers and Abstracts: Titles and a one-page abstract should be e-mailed to the organizers in the appropriate area by March 16: Combinatorics: T. A. Dowling, `tdowling@math.ohio-state.edu`; Group theory: S. Sehgal, `sehgal@math.ohio-state.edu`; Ring theory: T. Rizvi, `rizvi@math.ohio-state.edu`; or S. K. Jain, `jain@oucsace.cs.ohiou.edu`.
Information: Further information and on-line registration may be found on the conference Web page: `http://www.math.ohio-state.edu/~denison/` or from the organizer (preferably by e-mail): T. A. Dowling, Dept. of Mathematics, Ohio State Univ., 231 West 18th Avenue, Columbus, OH 43210-1174; e-mail: `tdowling@math.ohio-state.edu`; tel: 614-292-5013; fax: 614-292-1479.

June 1998

* 8-12 **IMA Workshop: Continuum Mechanics and Nonlinear Partial Differential Equations**, University of Minnesota, Minneapolis, Minnesota.
Aim: This workshop will honor J. Ball on the occasion of his fiftieth birthday.
Organizers: R. James (Univ. of Minnesota), S. Mueller (Max-Planck Inst., Leipzig), and V. Sverak (Univ. of Minnesota).
Information: Institute for Mathematics and its Applications, University of Minnesota, 206 Church St., SE, Minneapolis, MN 55455.

* 21-26 **5th International Conference on Teaching Statistics (ICOTS-5)**, Singapore, Malaysia.
Information: B. Phillips, School of Mathematical Sciences, Swinburne University of Technology, P.O. Box 218, Hawthorn, Victoria 3122, Australia; e-mail: `bphillips@swin.edu.au`.

* 22-25 **IMACS International Symposium on Soft Computing in Engineering Applications (SOFTCOM'98)**, Athens, Greece.
Scope: SOFTCOM'98 aims to provide a unique forum to researchers and practioners in the field of soft computing and its engineering applications for exchanging ideas, techniques, experiences, and latest results.
Sponsors: IMACS—The International Association for Mathematics and Computers in Simulation, and IFAC—The International Federation of Automatic Control.
Language: English, both for presentation and manuscripts.
Book of Abstracts: A booklet involving the abstracts of the papers accepted for presentation will be available at the symposium desk.
Information: S. Tzafestas, SOFTCOM'98, Intelligent Robotics & Automation Laboratory (IRAL), Institute of Communication and Computer Systems, National Technical University of Athens, Zographou, Athens 15773, Greece; tel: +30-1-7722489, +30-1-7721527; fax: +30-1-7722490; e-mail: `dkostis@robotics.ece.ntua.gr`; or contact the IMACS Secretariat, IMACS, Dept. of Computer Science, Rutgers University, New Brunswick, NJ 08903.

* 22-July 10 **Foundations and Developments of Mathematical Economics**, Accademia Aeronautica, Pozzuoli-Napoli, Italy.
Scope: This international workshop is devoted to young researchers as well as to experienced scientists. The aim is to lead young researchers with a mathematical or economic background to the frontier of research in key sectors of mathematical economics and to provide experienced scientists with new hints for their research.
Topics: Decision theory, game theory, general equilibrium (finite dimension), finance, infinite-dimensional economies, incomplete markets.
Speakers: C. D. Aliprantis (Indiana Univ.-Purdue Univ.), J. P. Aubin (Univ. Paris Dauphine), P. Gottardi (Univ. di Venezia), M. Li Calzi (Univ. di Venezia), M. Marinacci (Univ. of Toronto), J. Morgan (Univ. di Napoli Federico II), A. Villamil (Univ. of Illinois, Urbana-Champaign), A. Volcic (Univ. di Trieste), N. C. Yannelis (Univ. of Illinois, Urbana-Champaign).

Scientific Committee: C. D. Aliprantis (Indiana Univ.-Purdue Univ.), V. Aversa (Univ. di Napoli Federico II), A. Basile (Univ. di Napoli Federico II), M. Li Calzi (Univ. di Venezia).

Information: A. Basile at basile@dmsna.dms.unina.it, fax: +3981-675009.

* 25-26 **8th Stockholm Optimization Days**, KTH (Royal Institute of Technology), Stockholm, Sweden.

Topics: There will be sessions on various aspects of optimization, including nonsmooth optimization, linear and nonlinear programming.

Invited Speakers: Invited and contributed presentations of tentatively 30 minutes each will be given at the conference. Invited speakers include: F. Barahona (IBM T. J. Watson Research Center), J. T. Betts (Boeing Inf. & Sup. Services), R. Fletcher (Univ. of Dundee), P. E. Gill (Univ. of California, San Diego), D. W. Hearn (Univ. of Florida), K. C. Kiwiel (Systems Research Institute), W. Murray (Stanford Univ.), M. L. Overton (New York Univ.), F. J. Prieto (Univ. Carlos III de Madrid), M. V. Ramana (Univ. of Florida), M. A. Saunders (Stanford Univ.), T. Terlaky (Delft Univ. of Technology), M. J. Todd (Cornell Univ.), L. Vandenberghe (Univ. of California, Los Angeles), S. W. Wallace (Norwegian Univ. of Science and Technology), D. P. Williamson (IBM T. J. Watson Research Center), and J. Zowe. In addition to the invited presentation, we also welcome a limited number of contributed presentations.

Abstracts: Abstracts (maximum 200 words) should be sent by May 1 (preferably by e-mail) to: optdays@math.kth.se or by mail to Optimization Days, Division of Optimization and Systems Theory, KTH, SE-100 44 Stockholm, Sweden; fax: +46-8-22-53-20.

Information: http://www.optsyst.math.kth.se/~optdays/.

* 28-July 1 **A Conference in Probability in Honor of Harry Kesten**, Cornell University, Ithaca, New York.

Organizers: M. Bramson (Univ. of Minnesota) and R. Durrett (Cornell Univ.).

Invited Speakers: The conference will feature one-hour talks by 14 prominent probabilists: D. Aldous, J. Chayes, P. Diaconis, G. Grimmett, G. Lawler, J.-F. Le Gall, C. Neuhauser, C. Newman, E. Perkins, R. Schonmann, G. Slade, M. Talagrand, S. R. S. Varadhan, and R. Williams.

Support: The meeting is supported by grants from the National Science Foundation and the National Security Agency. Part of the funding will provide travel grants for 14 young investigators. To be specific, the conference will pay for lodging costs and half the airfare for 14 young investigators (defined as not having achieved the rank of full professor), and we encourage you to seek matching funds from your university. If you want to apply for one of these grants, send e-mail to rtd1@cornell.edu or a letter to R. Durrett, Dept. of Math., Cornell Univ., Ithaca, NY, with the following information: name, e-mail and postal addresses, when and where you got your Ph.D., your employment since that time, list of publications, and the names of one or two persons we can contact for more information about you. Applications must be submitted by April 1, 1998. Decisions will be made within 2-3 weeks after that date.

Information: Watch the WWW at http://math.cornell.edu/~durrett/ or write to one of the organizers.

* 29-July 2 **The First International Conference on Functional Differential Equations (FDE1)**, The Research Institute, The College of Judea and Samaria, Ariel, Israel.

Topics: Functional differential equations, ordinary differential equations, functional and difference equations, stochastic differential equations, related topics in functional analysis and operator theory.

Organizing Committee: L. Berezanskii, A. Domoshnitsky, Y. Goltser, G. Kresin, E. Litsyn (chair), and E. Merzbach.

Information: E. Litsyn (chair), The Research Institute, The College of Judea and Samaria, Kedumim-Ariel 44837, Israel; elenal@black.wisdom.weizmann.ac.il; E. Braverman (secretary), Computer Science Dept., Technion-Israel Institute of Technology, Haifa 32000, Israel; e-mail: maelena@tx.technion.ac.il; tel: 972-4-8294341; fax: 972-4-8294353.

July 1998

* 5-17 **DIMACS Reconnect Conference: Reconnecting Teaching Faculty to the Mathematical Sciences Enterprise**, DIMACS Center, Rutgers University, Piscataway, New Jersey.

Aim: This conference is geared towards exposing faculty teaching undergraduates to two current research topics relevant to the classroom, involving them in writing materials useful in the classroom. The conference is also aimed at reconnecting faculty to the mathematical sciences enterprise by involving them in a leading research center which is a consortium of Princeton University, Rutgers University, AT&T, Bellcore, and Bell Labs/Lucent Technologies.

Organizers: R. Leibowitz (Wheaton College) and F. S. Roberts (Rutgers Univ.).

Invited Speakers: J. Berry (Elon College), N. Dean (Bell Labs/Lucent Technologies), M. Farach (Rutgers Univ.), R. Ravi (Carnegie Mellon Univ.).

Information: E. Foley, DIMACS/CoRE Bldg., Rutgers, The State University of New Jersey, 96 Frelinghuysen Road, Piscataway, NJ 08854-8018; e-mail: epfoley@dimacs.rutgers.edu; tel: 732-445-4631; WWW: http://dimacs.rutgers.edu/reconnect/.

* 6-9 **Second International Conference Finite-Difference Methods: Theory and Applications**, Minsk, Belarus.

Organizers: Institute of Mathematical Modelling, Russian Academy of Sciences; Institute of Mathematics, National Academy of Sciences of Belarus; Belarussian State University; University of Rousse (Bulgaria).

Scope: The scope of the conference is concerned with developing practical usage of difference methods for numerical solution of modern problems in science and engineering.

Topics: Validation of finite-difference methods for solving problems of mathematical physics, iterative methods and parallel algorithms for solving grid equations, finite-difference method for nonlinear problems; projective-difference methods, inverse problems and problems of control, finite difference methods in continuum mechanics, application of difference methods to engineering problems.

Program Committee: V. Abrashin (Belarus), G. Akrivis (Greece), V. Bobkov (Belarus), P. Hemker (Netherlands), B. Jovanovich (Yugoslavia), A. Konovalov (Russia), R. Lazarov (USA), V. Makarov (Ukraine), G. Meladze (Georgia), A. Samarskii (Russia, Chair), M. Sapagovas (Lithuania), V. Thomee (Sweden), P. Vabishchevich (Russia, vice-chair), L. Vulkov (Bulgaria), S. Zhong-ci (China).

Organizing Committee: M. Chuiko, A. Egorov, I. Gaishun (chair), V. Korzjuk (vice-chair), S. Lemeshevsky, P. Matus (vice-chair), I. Mikhiliouk, V. Rychagov, V. Scheglik, A. Senko, V.Tzurko.

Information: Institute of Mathematics NASB, 11, Surganov Str., 220072, Minsk, Belarus; e-mail: cfdm98@im.bas-net.by; fax: 017-239-31-92; http://im.bas-net.by/cfdm98/.

* 6-18 **IMA Summer Program: Coding and Cryptography**, University of Minnesota, Minneapolis, Minnesota.

Organizers: I. Blake, R. Calderbank, A. Odlyzko, V. Pless.

Information: Institute for Mathematics and its Applications, University of Minnesota, 206 Church St., SE, Minneapolis, MN 55455.

* 8-11 **IFAC-LSS '98, Symposium on Large Scale Systems: Theory and Applications**, Patras, Greece. (Oct. 1997, p. 1158)

Sponsors: IMCS, IFORS, IFAC, IFIP.

Information: P. P. Groumpos, Electrical and Computer Engineering Department, Laboratory for Automation and Robotics, Rion Patras 26500, Greece; tel: +39-997295; fax: +30-997309; e-mail: groumpos@ee.upatras.gr.

Proceedings Editor: N. T. Koussoulas, Electrical and Computer Engineering Department, Laboratory for Automation & Robotics, Rion Patras 26500, Greece; tel: +30-997296; fax: +30-997309; e-mail: ntk@ee.upatras.gr; or contact the IMACS Secretariat, IMACS, Dept. of Computer Science, Rutgers Univ., New Brunswick, NJ 08903.

* 13-16 **3rd (Biennial International) Engineering Mathematics and Applications Conference (EMAC'98)**, Adelaide, Australia.

Information: J. Mazundor, EMAC'98 chair, Department of Applied Mathematics, The University of Adelaide, Adelaide, SA 50501, Australia; e-mail: jmazunda@maths.adelaide.edu.au; Web site: http://www.maths.adelaide.edu.au/Applied/EMAC98/.

* 13–31 **The Beijing Workshop on Universal Algebra, Logic and Computer Science**, Institute of Software, Beijing, China.

Objectives: This three-week workshop will be a combination of minicourses and individual lectures designed to bring scholars from all over the world together to discuss exciting developments in universal algebra, logic, and computer science.

Topics: The selection of minicourses is still under development, but at present includes: McKenzie's solution to Tarski's finite basis problem, and its consequences, presented by G. McNulty (Univ. of South Carolina); Algorithmic problems in varieties of algebras, presented by M. Sapir (Vanderbilt Univ.); An introduction to denotational semantics of programming languages, presented by C. Tsinakis (Vanderbilt Univ.); Progress on symbolic computation, complexity, and 0-1 laws in universal algebra, by S. Burris (Univ. of Waterloo); Equational theories, word problems and finite basis theorems, presented by D. Delic (Univ. of Waterloo). All participants will have the opportunity to present their research work in individual 30-minute lectures.

Organizers: S. Burris (Univ. of Waterloo), J. Wang (Logic Division, Institute of Software, Chinese Academy).

Sponsor: The Institute of Software of the Chinese Academy.

Registration: Deadline: June 15, 1998.

Information: S. Burris, Department of Pure Mathematics, University of Waterloo,Waterloo Ontario, Canada N2L 3G1, snburris@thoralf2.uwaterloo.ca. For current information regarding this workshop and two other algebra conferences to be held in summer 1998, in Nanijing and Lanzhou, China, see the Web homepage for these events at http://thoralf2.uwaterloo.ca/htdocs/china98.html.

* 23–31 **International Centre for Mathematical Sciences: Computation and Geometric Aspects of Modern Algebra**, Heriot-Watt University, Edinburgh, Scotland.

Program: An ICMS workshop with concentration on (1) Word Problems in Algebra (23–25 July); invited speakers include: J. H. Davenport (Bath), G. Havas (Queensland), D. F. Holt (Warwick), K. Madlener (Kaiserslautern), U. H. M. Martin (St. Andrews), C. F. Miller (Melbourne), W. Nickel (St. Andrews), S. E. Rees (Newcastle). (2) Geometric Group Theory (27–31 July); invited speakers include: N. Brady (Cornell), T. Brady (Dublin City Univ.), D. B. A. Epstein (Warwick), R. I. Grigorchuk (Steklov Institute), W. D. Neumann (Melbourne), A. Yu. Ol′shanskii (Moscow State Univ.), M. Sageev (Rutgers), M. V. Sapir (Vanderbilt), Z. Sela (Hebrew Univ.), V. Suchshanskii (Kiev).

Support: The workshop is partially supported by the UK Engineering and Physical Sciences Research Council. Support may be available for participants from UK institutions.

Registration: Deadline: May 1, 1998. Registration fee £60 sterling (£75 for late registrations), including copy of conference proceedings. Deadline for contributed talks: June 1, 1998.

Information: For further details and a registration form contact: N. Gilbert; N.D.Gilbert@hw.ac.uk; tel: +44-0-131-451-3718; CGAMA 98, Dept. of Mathematics, Heriot-Watt Univ., Riccarton, Edinburgh, EH14 4AS, Scotland; or visit the Web site: http://www.ma.hw.ac.uk/~nick/cgama.html.

* 27–31 **Calculus Enhanced with Computer-Algebra and Graphing Using the TI-92**, Department of Mathematical Sciences, United States Military Academy, West Point, New York.

Program: University, college, and high school calculus instructors are invited to attend a calculus short course sponsored by the United States Military Academy Department of Mathematical Sciences and the Ohio State University, partially funded by Texas Instruments. Each participant will have a loan of a TI-92 for the week. Computer-based laboratory instruments will also be available for data collection. Real-world applications and other calculus reform pedagogy will be featured. Continental breakfast, lunch, snacks, and instructional materials will be provided. One afternoon or evening meal will include a boat ride on the Hudson River. Texas Instruments will have reduced prices on the TI-83 and TI-82 ($55), TI-85 ($60), CBL ($110), and TI-92 ($120). Payment may be included with registration fee. Purchases are limited to one calculator and one other item. Graph Link ($30) software is also available. (Prices are subject to change.)

Presenters: M. A. Connors (United States Military Academy). F. Demana (The Ohio State University) will be a guest lecturer one day.

Registration Fee: There are a limited number of spaces available. Applicants will be accepted on a first come-first served basis upon receipt of the $150 registration fee. Please make checks payable to: Department of Mathematical Sciences.

Hotel Rooms: Air-conditioned hotel rooms are available at conference rates of $53 single or $83 double occupancy. Please indicate (Booking #2948) when making reservations at the Hotel Thayer, 914-446-4731.

Information: K. G. Snook, Department of Mathematical Science, United States Military Academy, West Point, NY 10996; tel: 914-938-4544; e-mail: ak7056@exmail.usma.edu.

August 1998

* 2–14 **Difference Sets, Sequences and Their Correlation Properties. A NATO Advanced Study Institute**, Bad Windsheim, Germany.

Participants: The number of participants is limited. Researchers and students interested in the workshop should contact the organizers as soon as possible.

Organizers: T. Helleseth, D. Jungnickel, P. V. Kumar, and A. Pott.

Information: Contact A. Pott, University of Augsburg, Department of Mathematics, 86135 Augsburg, Germany, pott@math.uni-augsburg.de, http://www.math.uni-augsburg.de/opt/ASI.htm.

* 28–September 3 **Function Spaces V**, Poznan, Poland.

Scope: The conference is a satellite conference of ICM98 Berlin.

Organizing Committee: Z. Ciesielski, H. Hudzik, J. Musielak, M. Nowak, and L. Skrzypczak.

Topics: Operators and interpolation in function spaces, geometry and topology in function spaces, approximation.

Information: Function Spaces V, Faculty of Mathematics and Computer Science, A. Mickiewicz University, Matejki 48-49, P1-60-769 Poznan, Poland; e-mail: funsp5@math.amu.edu.pl.

* 31–September 5 **An International Conference on Representation Theory of Algebras**, University of Bielefeld, Bielefeld, Germany.

Scientific Committee: D. Happel (Chemnitz), H. Lenzing (Paderborn), C. M. Ringel (Bielefeld), and K. W. Roggenkamp (Stuttgart).

Program: There will be 18 one-hour lectures on important recent developments in the subject and on decisive relations to other parts of mathematics.

Invited Speakers: H. J. Baues (Bonn, Germany), R. Bautista (UNAM, Mexico), J. Carlson (Athens, USA), W. Crawley-Boevey (Leeds, England), G. James (London, England), M. Kapranov (Boston), O. Mathieu (Strasbourg, France), S. Ovsienko (Kiev, Ukraine), I. Reiten (Trondheim, Norway), A. Skowroński (Toruń, Poland), K. Uno (Osaka, Japan), M. Van den Bergh (Hasselt, Belgium), J. Xiao (Beijing, China). The remaining one-hour lectures and additional twenty-minute lectures (in parallel sessions) will be arranged on the basis of abstracts provided by participants.

Abstracts: The deadline for the submission of an abstract is June 30, 1998. Such an abstract should be no longer than one page and should clearly state the result to be presented. The abstracts obtained in time will be distributed to all participants.

Information: Further information concerning the meeting (including a registration form) is available on the internet: http://www.mathematik.uni-bielefeld.de/~sek/98rep.html, or you may contact H. Scharsche, Fakultät für Mathematik, Universität, P.O. Box 100 131, D-33501 Bielefeld, Germany; fax: (+49) 521 106-

4743; e-mail: scharsch@mathematik.uni-bielefeld.de.

*31–September 18 **Workshop on Dynamical Systems**, Trieste, Italy.
Directors: J. Palis (IMPA, Brazil), Y. Sinai (Princeton Univ.; Landau Institute, Russia), J.-C. Yoccoz (Collège de France, Paris).
Aim: The aim of this meeting is to expose the participants to a variety of current research problems in dynamical systems. The activity will be divided into seminars and minicourses. The main topics to be covered will be: chaotic systems, strange attractors, invariant measures, bifurcations: homoclinic and singular cycles, variational methods in Hamiltonian and Lagrangian systems, elliptic and nonuniformly hyperbolic behavior, one-dimensional real and complex dynamics.
Invited Speakers: W. de Melo, H. Eliasson, Yu. Ilyashenko, M. Lyubich, R. MacKay, J. Mather, C. McMullen, J. Milnor, S. Newhouse, F. Takens.
Information: Deadline for requesting participation: February 28, 1998; e-mail: smr1069@ictp.trieste.it.

September 1998

*7–11 **A Euroconference on Infinite Length Modules**, University of Bielefeld, Bielefeld, Germany.
Scientific Committee: K. Brown (Edinburgh), P. M. Cohn (London), I. Reiten (Trondheim), and C. M. Ringel (Bielefeld).
Program: The aim of the conference is to provide a survey of methods and results concerning modules of infinite length (in comparison to the well-known properties of finite length modules). A detailed program will be available by the end of February 1998.
Financial Support: The Euroconference is financially supported by the TMR-program of the European Union. Special funds are available for allowing young researchers from member states of the European Union to participate.
Information: Further information concerning the Euroconference (including a registration form) is available on the internet: http://www.mathematik.uni-bielefeld.de/~sek/E-C-BIE.html, or you may contact H. Scharsche, Fakultät für Mathematik, Universität, P.O. Box 100 131, D-33501 Bielefeld, Germany; fax: +49-521-106-4743, e-mail: scharsch@mathematik.uni-bielefeld.de.

*26–28 **Interdisciplinary Conference on Waves and Continuation Methods in Biology**, University of Pittsburgh, Pennsylvania.
Program: There will be a series of general lectures addressed to both mathematicians and biologists and also separate sessions where more specialized discussions will be held.
Organizers: G. B. Ermentrout, S. Hastings, J. B. McLeod, D. Simons, and D. Terman.
Confirmed Speakers: B. Ermentrout, M. Feller, P. Fife, D. Golomb, C. K. R. T. Jones, J. Keener, D. Kleinfeld, J. Mallet-Paret, K. Mischaikov, D. Pinto, J. Rinzel, D. Terman, R. Traub, J. Tyson, X. F. Wang, X. J. Wang.
Information: http://www.math.pitt.edu/~sph/conference.html, or sph+@pitt.edu.

October 1998

*12–30 **Third School on Nonlinear Functional Analysis and Applications to Differential Equations**, Trieste, Italy.
Directors: A. Ambrosetti (Scuola Normale Superiore), K.-C. Chang (Peking Univ.), and I. Ekeland (Univ. de Paris IX).
Aim: This third school will be more advanced than the 1996 and 1997 schools, devoted mainly to research problems. It will be divided into two parts. In the first two weeks there will be advanced lectures on the following topics: Harmonic and Wave Maps; Critical Point Theory: Min-max principles, Morse theory and problems in absence of Palais-Smale condition; Elliptic Problems: Singularly perturbed semilinear equations; Hamiltonian Systems: Periodic solutions and connecting orbits; Nonlinear Schrödinger Equations; Applications to Mathematical Physics. The last week will be devoted to seminars on current research problems by several experts.
Information: Deadline for requesting participation: March 31, 1998; e-mail: smr1071@ictp.trieste.it.

*18–20 **Fourth IMACS International Symposium on Iterative Methods in Scientific Computation**, Austin, Texas.
Special Event: Banquet celebrating 75th birthday of D. M. Young Jr.
Theme: The conference is dedicated to providing an overview of the state of the art in scientific computing when using iterative methods for solving large sparse linear systems. The focus is on contributions of the past, present, and future.
Information: U.S. contact: D. Kincaid, RLM 13.150-C1300, Center for Numerical Analysis, University of Texas at Austin, Austin, TX 78713-8510; tel: 512-471-1242; fax: 512-471-9038; e-mail: kincaid@cs.utexas.edu. European contact: R. Beauwens, Universite Libre de Bruxelles, Campus du Solbosch, Avenue F.D. Roosevelt, 50, 1056 Bruxelles, Belgium; tel: +32-2-6502085; fax: +32-2-6504513; e-mail: rbeauwen@ulb.ac.be.

*26–28 **2nd International Circuits, Systems and Computers'98 (CSC'98)**, Military Institutions of University Education (MIUE), Hellenic Naval Academy, Terma Hatzikyriakou, 18539, Piraeus, Greece.
Aim: The objective of CSC is to promote the study of circuits (networks, electronics, neural networks, etc.), systems (control systems, systems theory, robotics, artificial intelligence, telecommunications systems, signal processing systems, multidimensional systems, fuzzy systems, multimedia, transportation, environmental engineering systems, nonlinear systems, discrete event dynamic systems, etc.), and computers (all the areas in software and hardware engineering). The objective is also to bring together experts from academia, industry, and the armed forces to present the state of the art in the technical areas involved.
Information: N. E. Mastorakis, Military Institutions of University Education (MIUE), Hellenic Naval Academy, Chair of Computer Science, Terma Hatzikyriakou, 18539, Piraeus, Greece; e-mail: mastor@softlab.ntua.gr; Web page: http://www.soflab.ece.ntua.gr/~mastor/; tel-fax: +301-777-5660; or contact the IMACS Secretariat, IMACS, Dept. of Computer Science, Rutgers University, New Brunswick, NJ 08903.

November 1998

*21–22 **DIMACS Reconnecting Two-Year College Faculty to the Mathematical Sciences Enterprise**, DIMACS Center, Rutgers University, Piscataway, New Jersey.
Aim: DIMACS is presenting a series of 2 two-day workshops geared towards introducing two-year college faculty to discrete mathematics and to some current research topics relevant to the classroom. These workshops will reconnect faculty to the mathematical sciences enterprise by involving them in a leading research center which is a consortium of Rutgers University, Princeton University, AT&T Labs, Bell Labs, and Bellcore.
Organizers: J. Lane (Union County College), F. S. Roberts (Rutgers Univ.), and J. Rosenstein (Rutgers Univ.).
Information: E. Foley, DIMACS/CoRE Bldg., Room 430, Rutgers, The State University of New Jersey, 96 Frelinghuysen Road, Piscataway, NJ 08854-8018; e-mail: epfoley@dimacs.rutgers.edu; tel: 732-445-4631; WWW: http://dimacs.rutgers.edu/reconnect/.

December 1998

*16–22 **Symmetry and Perturbation Theory II**, Rome, Italy.
Participants: D. Bambusi (Milano), P. Bonckaert (Limburgs), V. Belavkin* (Nottingham), G. Cicogna (Pisa), P. Clarkson (Canterbury), A. Degasperis (Roma), G. Dell'Antonio* (Roma), F. Fasso' (Padova), G. Gaeta (Roma), C. Hayat (Toulouse), L. A. Ibort* (Madrid), G. Marmo (Napoli), J. Montaldi (Nice), P. Morando (Torino), A. Neishtadt (Moscow), N. Nekhoroshev (Moscow), M. A. Rodríguez (Madrid), M. Roberts* (Warwick), S. Ruffo (Firenze), P. Santini (Catania), G. Sartori (Padova), A. Skeldon (London), M. Tarallo (Milano), F. Verhulst (Utrecht), W. Zakrzewski (Durham).
Information: The workshop will take place in the Universita' di Roma I, participants will be lodged in a city hotel for which a reduced rate will be available. It is expected that no financial support will be available to participants, except maybe for those from Eastern Europe. A small registration fee,

giving right to a copy of the proceedings, will be payable. Those interested in participation should contact the main organizer by e-mail.

This follows the workshop with the same title organized in Torino (December 96); the abstracts for this first conference are available at http://info.lboro.ac.uk/departments/ma/staff/gg/workshop.

Further information and updated list of participants through the organizers or the home page at http://www.lboro.ac.uk/departments/ma/staff/gg/SPT98.html; later this will also be available through the servers http://w3.roma1.it/ and http://www.mat.unimi.it/. Information is also available by e-mail through the main organizer at: g.gaeta@lboro.ac.uk or giuseppe.gaeta@roma1.infn.it (please use "subject: SPT98").

January 1999

* 8–9 **Nonlinear Differential Equations: A Meeting Honoring Professor Alan Lazer on the Occasion of his 60th Birthday**, The University of Miami, Coral Gables, Florida.
Plenary Speakers: C. Cosner (Univ. of Miami), J. McKenna (Univ. of Connecticut), P. Rabinowitz (Univ. of Wisconsin-Madison), and K. Schmitt (Univ. of Utah).
Call for Papers: The conference will feature special sessions on four topics (solvability of nonlinear boundary value problems, critical point theory, dynamical systems, and population dynamics). There will also be sessions for 20-minute contributed talks. Titles and abstracts for contributed talks should be received by the organizing committee no later than September 15, 1998. Abstracts should be typed in LaTeX or TeX format and sent to alcon.cs.miami.edu.
Organizing Committee: S. Cantrell, chair (Univ. of Miami), A. Castro (Univ. of North Texas), and C. Cosner (Univ. of Miami).
Information: Contact the organizers at alcon.cs.miami.edu or visit the conference Web site at http://www.cs.miami.edu/~alcon/.

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

April 1999

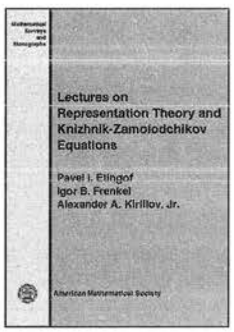
* 12–15 **Nonlinear Evolution Equations and Wave Phenomena: Computation and Theory**, Athens, Georgia.
Focus: The conference will focus on mostly computational, but also theoretical, aspects of nonlinear wave phenomena. It will be interdisciplinary in nature, bringing together topics in computational mathematics, applied mathematics, and applications in physics.
Proposals: Proposals to organize sessions and suggestions for keynote speakers are solicited at this time. Proposed contributed papers may also be submitted. In all cases include an abstract no more than 2 pages in length. It is currently planned to have proceedings of the conference produced in camera-ready form, and selected papers will be refereed and published in a special issue in one of the IMACS journals (North Holland/Elsevier).
Information: T. Taha, Dept. of Computer Science, University of Georgia, Athens, GA 30602; e-mail: thiab@pollux.cs.uga.edu; or contact the IMACS Secretariat, IMACS, Dept. of Computer Science, Rutgers University, New Brunswick, NJ 08903.

September 1999

* 14–16 **ElectrIMACS—Conference on Electrical Machines, Converters and Systems**, Lisbon, Portugal.
Information: A. Dente, Instituto Superior Tecnico, Departamento de Engenharia Electrotecnica e de Computadores, Seccao de Maquinas Electricas e Electronica de Potencia, Av. Rovisco Pais, 1096 Lisboa Codex, Portugal; tel: 351-1-8417435; fax: 351-1-8417167; e-mail: edentepc@alfa.ist.utl.pt. R. LeDoeuff, Secretariat Electrimacs, GE 44 - LARGE, Boulevard de l'Universite - BP 406, 44602 Saint-Nazaire Cedex, France; tel: 33-2-40-17-26-02; fax: 33-2-40-17-26-18; or contact the IMACS Secretariat, IMACS, Dept. of Computer Science, Rutgers University, New Brunswick, NJ 08903.

New Publications Offered by the AMS

Algebra and Algebraic Geometry



Lectures on Representation Theory and Knizhnik-Zamolodchikov Equations

Pavel I. Etingof, *Harvard University, Cambridge, MA*, **Igor B. Frenkel**, *Yale University, New Haven, CT*, and **Alexander A. Kirillov, Jr.**, *Massachusetts Institute of Technology, Cambridge*

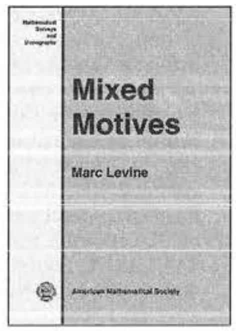
This book is devoted to mathematical structures arising in conformal field theory and the q-deformations. The authors give a self-contained exposition of the theory of Knizhnik-Zamolodchikov equations and related topics. No previous knowledge of physics is required. The text is suitable for a one-semester graduate course.

This text will also be of interest to those working in mathematical physics.

Contents: Introduction; Representations of finite-dimensional and affine Lie algebras; Knizhnik-Zamolodchikov equations; Solutions of the Knizhnik-Zamolodchikov equations; Free field realization; Quantum groups; Local systems and configuration spaces; Monodromies of the Knizhnik-Zamolodchikov equations; Quantum affine algebras; Quantum Knizhnik-Zamolodchikov equations; Solutions of the quantum Knizhnik-Zamolodchikov equations for $\mathfrak{sl}_2$; Connection matrices for the quantum Knizhnik-Zamolodchikov equations and elliptic functions; Current developments and future perspectives; References; Index.

Mathematical Surveys and Monographs

May 1998, approximately 208 pages, Hardcover, ISBN 0-8218-0496-0, 1991 *Mathematics Subject Classification*: 81R40, 81R50; 17B67, 17B69, **All AMS members $39**, List $49, Order code SURV-ETINGOFN



Mixed Motives

Marc Levine, *Northeastern University, Boston, MA*

This book combines foundational construction in the theory of motives and results relating motivic cohomology to more explicit constructions. Prerequisite for understanding the work is a basic background in algebraic geometry.

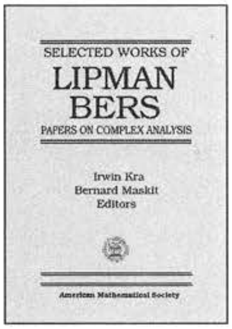
The author constructs and describes a triangulated category of mixed motives over an arbitrary base scheme. Most of the classical constructions of cohomology are described in the motivic setting, including Chern classes from higher K-theory, push-forward for proper maps, Riemann-Roch, duality, as well as an associated motivic homology, Borel-Moore homology and cohomology with compact supports.

Contents: *Motives:* Introduction: Part I; The motivic category; Motivic cohomology and higher Chow groups; K-theory and motives; Homology, cohomology and duality; Realization of the motivic category; Motivic constructions and comparisons; Equi-dimensional cycles; K-theory; *Categorical algebra:* Introduction: Part II; Symmetric monoidal structures; DG categories and triangulated categories; Simplicial and cosimplicial constructions; Canonical models for cohomology; Bibliography; Subject index; Index of notation.

Mathematical Surveys and Monographs

May 1998, approximately 520 pages, Hardcover, ISBN 0-8218-0785-4, 1991 *Mathematics Subject Classification*: 19E15, 14C25; 14C15, 14C17, 14C40, 19D45, 19E08, 19E20, **Individual member $75**, List $125, Institutional member $100, Order code SURV-LEVINEN

Analysis



Selected Works of Lipman Bers

Papers on Complex Analysis

Irwin Kra and **Bernard Maskit**, *State University of New York at Stony Brook, NY*, Editors

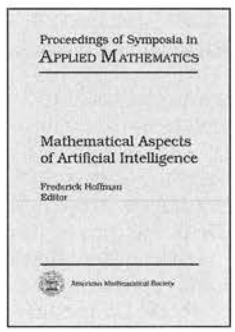
One of the founders of a major modern branch of complex analysis, Lipman Bers made fundamental contributions to the modern theory of Kleinian groups and moduli of Riemann surfaces. This volume is a collection of Bers' papers in complex analysis. Included are seminal papers in the field and articles by the editors and other colleagues discussing Bers' achievements and influence on the mathematical developments of the second half of the 20th century. Lists of his students, his publications, and reprints of hard-to-find papers are included.

Contents: On bounded analytic functions of two complex variables in certain domains with distinguished boundary surface; On rings of analytic functions; Singularities of minimal surfaces; Isolated singularities of minimal surfaces; Abelian minimal surfaces; Boundary value problems for minimal surfaces with singularities at infinity; Univalent solutions of linear elliptic systems; On a representation theorem for linear elliptic systems with discontinuous coefficients and its applications; On linear and non-linear elliptic boundary values in the plane; Local behavior of solutions of general linear elliptic equations; An outline of the theory of pseudoanalytic functions; Formal powers and power series; On a theorem of Mori and the definition of quasiconformality; Simultaneous uniformization; Spaces of Riemann surfaces as bounded domains; Riemann's mapping theorem for variable metrics; Uniformization and moduli; Completeness theorems for Poincaré series in one variable; Quasiconformal mappings and Teichmüller's theorem; Spaces of Riemann surfaces; Holomorphic differentials as functions of moduli; Uniformization by Beltrami equations; The equivalence of two definitions of quasiconformal mappings; Holomorphic convexity of Teichmüller spaces; An approximation theorem; Automorphic forms and Poincaré series for infinitely generated Fuchsian groups; Automorphic forms and general Teichmüller spaces; A nonstandard integral equation with applications to quasiconformal mappings; On Ahlfors' finiteness theorem; Inequalities for finitely generated Kleinian groups; Universal Teichmüller space; On boundaries of Teichmüller spaces and on Kleinian groups. I; L_1-approximation of analytic functions; Spaces of Kleinian groups; Extremal quasiconformal mappings; Isomorphisms between Teichmüller spaces; Eichler integrals with singularities; Uniformization, moduli, and Kleinian groups; A remark on Mumford's compactness theorem; Fiber spaces over Teichmüller spaces; Poincaré series for Kleinian groups; Spaces of degenerating Riemann surfaces; On spaces of Riemann surfaces with nodes; Automorphic forms for Schottky groups; Deformations and moduli of Riemann surfaces with nodes and signatures; On Hilbert's 22nd problem; Nielsen extensions of Riemann surfaces; The action of the universal modular group on certain boundary points; Quasiconformal mappings, with applications to differential equations, function theory, and topology; An extremal problem for quasiconformal mappings and a theorem by Thurston; An application of quasiconformal mappings to topology; A new proof of a fundamental inequality for quasiconformal mappings; The action of the modular group on the complex boundary; Finite-dimensional Teichmüller spaces and generalizations; On trace formula; On iterates of hyperbolic transformations of Teichmüller space; On a theorem of Abikoff; An inequality for Riemann surfaces; Holomorphic families of isomorphisms of Möbius groups; Fricke spaces; Holomorphic families of injections; On Teichmüller's proof of Teichmüller's theorem; On Sullivan's proof of the finiteness theorem and the eventual periodicity theorem; The migration of European mathematicians to America.

Collected Works

August 1998, Hardcover, 1991 *Mathematics Subject Classification*: 30-XX, 32-XX
Part 1: Approximately 570 pages, ISBN 0-8218-0996-2, **Individual member $75**, List $125, Institutional member $100, Order code CWORKS-BERS-1N
Part 2: Approximately 564 pages, ISBN 0-8218-0997-0, **Individual member $75**, List $125, Institutional member $100, Order code CWORKS-BERS-2N
Set: Approximately 1134 pages, ISBN 0-8218-0858-3, **Individual member $135**, List $225, Institutional member $180, Order code CWORKS-BERSN

Applications



Mathematical Aspects of Artificial Intelligence

Frederick Hoffman, *Florida Atlantic University, Boca Raton*, Editor

There exists a history of great expectations and large investments involving artificial intelligence (AI). There are also notable shortfalls and memorable disappointments. One major controversy regarding AI is just how mathematical a field it is or should be.

This text includes contributions that examine the connections between AI and mathematics, demonstrating the potential for mathematical applications and exposing some of the more mathematical areas within AI. The goal is to stimulate interest in people who can contribute to the field or use its results.

Included is work by M. Newborn on the famous Deep Blue chess match. He discusses highly mathematical techniques involving graph theory, combinatorics and probability and statistics. G. Shafer offers his development of probability through probability trees with some of the results appearing here for the first time. M. Golumbic treats temporal reasoning with ties to the famous Frame Problem. His contribution involves logic, combinatorics and graph theory and leads to two chapters with logical themes. H. Kirchner explains how ordering techniques in automated reasoning systems make deduction more efficient. Constraint logic programming is discussed by C. Lassez, who shows its intimate ties to linear programming with crucial theorems going back to Fourier. V. Nalwa's work provides a brief tour of computer vision, tying it to mathematics—from combinatorics, probability and geometry to partial differential equations.

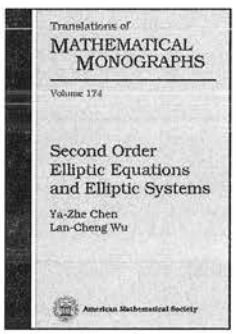
All authors are gifted expositors and are current contributors to the field. The wide scope of the volume includes research problems, research tools and good motivational material for teaching.

Contents (Tentative): **F. Hoffman**, Introduction and history; **M. C. Golumbic**, Reasoning about time; **H. Kirchner**, Orderings in automated theorem proving; **C. Lassez**, Programming with constraints: Some aspects of the mathematical foundations; **V. S. Nalwa**, The basis of computer vision; **M. Newborn**, Outsearching Kasparov; **G. Shafer**, Mathematical foundations for probability and causality; Index.

Proceedings of Symposia in Applied Mathematics

May 1998, approximately 288 pages, Hardcover, ISBN 0-8218-0611-4, 1991 *Mathematics Subject Classification*: 68; 03, 05, 51, 60, 90, **All AMS members $39**, List $49, Order code PSAPM-HOFFMANN

Differential Equations



Second Order Elliptic Equations and Elliptic Systems

Ya-Zhe Chen and **Lan-Cheng Wu**, *Peking University, People's Republic of China*

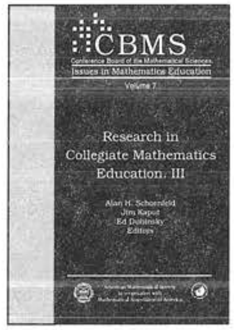
There are two parts to the book. In the first part, complete introduction of various kinds of a priori estimate methods for the Dirichlet problem of second order elliptic partial differential equations is presented. In the second part, the existence and regularity theories of the Dirichlet problem for linear and nonlinear second order elliptic partial differential systems are introduced. The book features appropriate materials and is an excellent textbook for graduate students. The volume is also useful as a reference source for undergraduate mathematics majors, graduate students, professors, and scientists.

Contents: *Second Order Elliptic Equations:* L^2 theory; Schauder theory; L^p theory; De Giorgi-Nash-Moser estimates; Quasilinear equations of divergence form; Krylov-Safonov estimates; Fully nonlinear elliptic equations; *Second Order Elliptic Systems:* L^2 theory for linear elliptic systems of divergence form; Schauder theory for linear elliptic systems of divergence form; L^p theory for linear elliptic systems of divergence form; Existence of weak solutions of nonlinear elliptic systems; Regularity for weak solutions of nonlinear elliptic systems; Sobolev spaces; Sard's theorem; Proof of the John-Nirenberg theorem; Proof of the Stampacchia interpolation theorem; Proof of the reverse Hölder inequality; Bibliographic notes; Bibliography; Index.

Translations of Mathematical Monographs, Volume 174

May 1998, 246 pages, Hardcover, ISBN 0-8218-0970-9, LC 97-46794, 1991 *Mathematics Subject Classification*: 35-01, 35-02; 35B45, 35B65, 35J15, 35J60, 35K10, **Individual member $59**, List $99, Institutional member $79, Order code MMONO/174N

General and Interdisciplinary



Research in Collegiate Mathematics Education. III

Alan H. Schoenfeld, *University of California, Berkeley*, **Jim Kaput**, *University of Massachusetts, Dartmouth*, **Ed Dubinsky**, *Georgia State University, Atlanta*, Editors

Volume 3 of *Research in Collegiate Mathematics Education* (RCME) presents state-of-the-art research on understanding, teaching and learning mathematics at the post-secondary level. This volume contains information on methodology and research concentrating on these areas of student learning:

- **Problem solving.** Included here are three different articles analyzing aspects of Schoenfeld's undergraduate problem-solving instruction. The articles provide new detail and insight on a well-known and widely discussed course taught by Schoenfeld for many years.
- **Understanding concepts.**These articles feature a variety of methods used to examine students' understanding of the concept of a function, selected concepts from calculus and conceptual understanding. The conclusions presented offer unique and interesting perspectives on how students learn concepts.
- **Understanding proofs.** This section provides insight on student understanding from a distinctly psychological framework. Researchers examine how existing practices can foster certain weaknesses. They offer ways to recognize and interpret students' proof behaviors and suggest alternative practices and curricula to build more powerful schemes. The section concludes with a focused look at using diagrams in the course of proving a statement

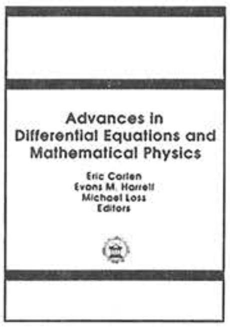
This series is published in cooperation with the Mathematical Association of America.

Contents: **A. Arcavi**, **L. Meira**, **J. P. Smith III**, and **C. B. Kessel**, Teaching mathematical problem solving: An analysis of an emergent classroom community; **M. Santos-Trigo**, On the implementation of mathematical problem solving instruction: Qualities of some learning activities; **A. H. Schoenfeld**, Reflections on a course in mathematical problem solving; **M. P. Carlson**, A cross-sectional investigation of the development of the function concept; **D. E. Meel**, Honor students' calculus understandings: Comparing calculus&mathematica and traditional calculus students; **A. Baranchik** and **B. Cherkas**, Supplementary methods for assessing student performance on a standardized test in elementary algebra; **G. Harel** and **L. Sowder**, Students' proof schemes: Results from exploratory studies; **D. Gibson**, Students' use of diagrams to develop proofs in an introductory analysis course; **A. Selden** and **J. Selden**, Questions regarding the teaching and learning of undergraduate mathematics (and research thereon); **E. Dubinsky**, **J. Kaput**, and **A. Schoenfeld**, Research in collegiate mathematics education.

CBMS Issues in Mathematics Education, Volume 7

February 1998, 316 pages, Softcover, ISBN 0-8218-0882-6, 1991 *Mathematics Subject Classification*: 00-XX, 92-XX, **All Individuals $24**, List $40, Order code CBMATH/7N

Mathematical Physics



Advances in Differential Equations and Mathematical Physics

Eric Carlen, Evans M. Harrell, and **Michael Loss,** *Georgia Institute of Technology, Atlanta,* Editors

This volume consists of selected contributions from the "1997 Georgia Institute of Technology-UAB International Conference on Differential Equations and Mathematical Physics". The book offers a combination of certain emerging topics and important research advances in this active area. The topics range widely and include magnetic Schrödinger operators, the Boltzmann equations, nonlinear variational problems and noncommutative probability theory. Some articles were included for their aesthetic value and others to present an overview. All articles were reviewed for scientific content and readability. The text is suitable for graduate and advanced graduate courses and seminars on the topic.

This text will also be of interest to those working in differential equations.

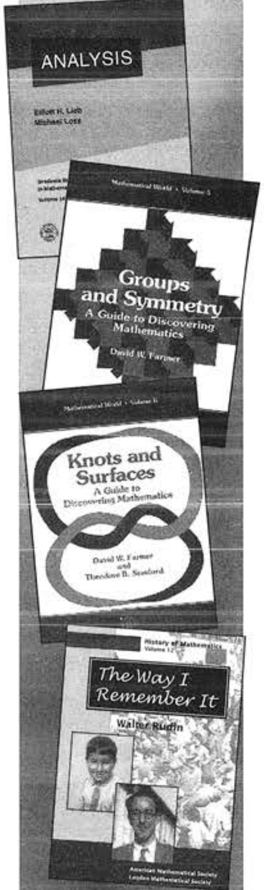
Contents: R. D. Benguria and **M. C. Depassier**, A variational method for nonlinear eigenvalue problems; **J. Fleckinger-Pellé** and **P. Takáč**, Maximum and anti-maximum principles for some elliptic problems; **M. Hoffmann-Ostenhof**, **T. Hoffmann-Ostenhof**, and **N. Nadirashvili**, On the nodal line conjecture; **K. Yajima**, On fundamental solution of time dependent Schrödinger equations; **P. Exner**, Laterally coupled quantum waveguides; **A. Kupiainen**, Some mathematical problems in passive advection; **E. H. Lieb**, Stability and instability of relativistic electrons in classical electromagnetic fields; **R. Brummelhuis** and **M. B. Ruskai**, A simple one-dimensional model for atoms in strong magnetic fields; **G. Zhislin** and **S. Vugal'ter**, Geometric methods for many-particle Hamiltonians with magnetic fields; **L. Erdős** and **H.-T. Yau**, Linear Boltzmann equation as scaling limit of quantum Lorentz gas; **S. Molchanov**, Multiscattering on sparse bumps; **A. Ya. Gordon**, Purely continuous spectrum for generic almost-periodic potential; **J. M. Combes**, **P. D. Hislop**, and **E. Mourre**, Correlated Wegner inequalities for random Schrödinger operators; **D. Petz** and **F. Hiai**, Logarithmic energy as an entropy functional.

Contemporary Mathematics, Volume 217

April 1998, 221 pages, Softcover, ISBN 0-8218-0861-3, LC 97-48877, 1991 *Mathematics Subject Classification*: 35B40, 35J10, 35P05, 35P15, 35P30, 35Q30, 60Fxx, 81Q10, 81V10, 81V80, 82B44, 82C22, **Individual member $26**, List $44, Institutional member $35, Order code CONM/217N

American Mathematical Society

PUBLICATIONS of CONTINUING INTEREST



Bestsellers from the AMS

These works have proven to be among the most popular selections from the AMS publishing program. They make substantial contributions to any mathematical books collection. Choose from these bestselling titles available at special member discounts.

Recommended Text

Analysis

Elliott H. Lieb, *Princeton University, NJ*, and
Michael Loss, *Georgia Institute of Technology, Atlanta*

The authors introduce the subject with a thorough presentation ... [an] informative exposition.

—***CHOICE***

I find the selection of the material covered in the book very attractive and I recommend the book to anybody who wants to learn about classical as well as modern mathematical analysis.

—***European Mathematical Society Newsletter***

Graduate Studies in Mathematics, Volume 14; 1996; ISBN 0-8218-0632-7; 278 pages; Hardcover; **All AMS members $28,** List $35, Order Code GSM/14CI84

Recommended Text

Basic Partial Differential Equations

David Bleecker and **George Csordas**, *University of Hawaii, Honolulu*

International Press publications are distributed worldwide, except in Japan, by the American Mathematical Society.

International Press; 1996; ISBN 1-57146-036-5; 735 pages; Hardcover; **All AMS members $47,** List $59, Order Code INPR/23CI84

Euler Products and Eisenstein Series

Goro Shimura, *Princeton University, NJ*

CBMS Regional Conference Series in Mathematics, Number 93; 1997; ISBN 0-8218-0574-6; 259 pages; Softcover; **All Individuals $31**, List $39, Order Code CBMS/93CI84

Groups and Symmetry: A Guide to Discovering Mathematics

David W. Farmer, *Bucknell University, Lewisburg, PA*

On the basis of this book it is possible to tailor a good course for high school students to really discover mathematics.

—***Zentralblatt für Mathematik***

Written in a lively conversational style ... entertaining, and sometimes provoking, and will doubtlessly prove useful to its intended audience.

—***Mathematical Reviews***

Mathematical World, Volume 5; 1995; ISBN 0-8218-0450-2; 102 pages; Softcover; **All AMS members $15,** List $19, Order Code MAWRLD/5CI84

Knots and Surfaces: A Guide to Discovering Mathematics

David W. Farmer, *Bucknell University, Lewisburg, PA*, and **Theodore B. Stanford**, *University of Nevada, Reno*

The book is perfectly suited to a course for non-science majors in need of fulfilling a math requirement. All the sections have worked well at sparking student interest and convincing them that math is much more interesting than mere number-crunching and graphing.

—***Professor William Bloch, Wheaton College***

Would serve well as the basis of an independent study course in which the student would work through the tasks in a journal subject to periodic review by the instructor ... the writing is clear and engaging, and the tasks should be effective at setting a reasonable pace.

—***American Mathematical Monthly***

Mathematical World, Volume 6; 1995; ISBN 0-8218-0451-0; 101 pages; Softcover; **All AMS members $15**, List $19, Order Code MAWRLD/6CI84

Lectures on the Mathematics of Finance

Ioannis Karatzas, *Columbia University, New York, NY*

CRM Monograph Series, Volume 8; 1996; ISBN 0-8218-0909-1; 148 pages; Softcover; **All AMS members $31**, List $39, Order Code CRMM/8.SCI84

Supplementary Reading

Stable Marriage and Its Relation to Other Combinatorial Problems

Donald E. Knuth, *Stanford University, CA*

CRM Proceedings & Lecture Notes, Volume 10; 1996; ISBN 0-8218-0603-3; 74 pages; Softcover; **All AMS members $15,** List $19, Order Code CRMP/10CI84

The Way I Remember It

Walter Rudin, *University of Wisconsin, Madison*

It is a real pleasure to read this book and to admire the charming personal style we have come to know from Rudin's textbooks, monographs and articles. The book is strongly recommended not only to analysts, but also to all mathematicians as well as historians.

—***European Mathematical Society Newsletter***

Of noteworthy significance.

—***Zentralblatt für Mathematik***

With this memoir, Rudin gives the entire mathematical community a chance to make his acquaintance both mathematically and personally, and a very worthwhile acquaintance it is. The biographical section ... is fascinating ... It's what the literary critics call "a good read" ... this book is a delight to read and will also help to inspire and guide young analysts in the path of wisdom. You will not want to miss a single page of it. I recommend it to everyone.

—***Mathematical Reviews***

Co-published with the London Mathematical Society. Members of the LMS may order directly from the AMS at the AMS member price. The LMS is registered with the Charity Commissioners.

History of Mathematics, Volume 12; 1996; ISBN 0-8218-0633-5; 191 pages; Softcover; **All AMS members $23**, List $29, Order Code HMATH/12CI84

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Send résumé and 3 letters of recommendation by April 30, 1998, to: Mathematics Dept. Hiring Committee, Community College of Philadelphia, 1700 Spring Garden St., Philadelphia, PA 19130. We are committed to a work force reflective of our community. AA/EOE.

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MSRI features three programs in 1999-2000. You may apply for Postdoctoral Fellowships, Research Professorships, and General Memberships in these programs, or in Area III (the rest of mathematics).

Noncommutative Algebra (Fall 1999-Spring 2000)

A recent change in noncommutative algebra has been the shift in emphasis from theory to the study of concrete examples, leading to significant and unexpected interactions both within algebra and between algebra and other areas. The program will be based on these developments and interactions, concentrating on: noncommutative algebraic geometry, Hopf, Lie and Jordan algebras, combinatorial methods and computation in algebra, and classical ring theory. *The program committee consists of Michael Artin, Susan Montgomery, Claudio Procesi, Lance Small (Chair), Toby Stafford, Efim Zelmanov.*

Galois Groups and Fundamental Groups (Fall 1999)

This topic brings together aspects of several established fields of mathematics, including algebraic geometry, field theory, number theory, representation theory, and topology. The program is designed to increase communication among researchers in those fields. Key topics will include: Galois actions and arithmetic fundamental groups, fundamental groups of moduli spaces, constructive Galois theory, Grothendieck's anabelian conjectures, Galois cohomology, and connections to field arithmetic, Galois representations. *The program committee consists of Eva Bayer, Michael Fried, David Harbater (Chair), Yasutuka Ihara, B. Heinrich Matzat, Michel Raynaud, John Thompson.*

Numerical and Applied Mathematics (March 6 - April 28, 2000)

The program will consist of four intensive two week workshops, stressing discussion and collaboration on research areas of current interest. Although there will be some lectures presenting the state of the art, the main emphasis will be on informal seminars and discussions. These are the workshops: (1) *Homogenization and Effective Media Theories*, chair: M. Vogelius, (2) *Superconvergence in Finite Element Methods*, chair: L. Wahlbin, (3) *A posteriori Error Estimation and Adaptive Approaches in the Finite Element Method*, chair: R. Bank, (4) *Elastic Shells: Modeling, Anaslysis and Numerics*, chair: D. Arnold, April 17-April 28, 2000. *The program committee consists of Ivo Babuska (Chair) and the chairs of the four workshops.*

Further details may be downloaded from the MSRI website **http://www.msri.org/activities/programs/9900.**

RESEARCH PROFESSORSHIPS — **Deadline: September 25, 1998**

These awards are intended for midcareer mathematicians with a Ph.D. awarded 1993 or earlier. There is a preference for U. S. applicants.

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Applications are invited for part or all of 1999-2000. It is expected that members at this level will come with partial or full support from other sources.

Application forms are available from the Mathematical Sciences Research Institute, 1000 Centennial Drive, Berkeley CA 94720-5070, or by email (send email to: **send-application@msri.org**), and can be downloaded from our website **http://www.msri.org/activities/applications/**. Women and minority candidates are especially encouraged to apply. Candidates should assure that their application materials and letters of reference arrive before the deadline; late applications cannot be assured complete consideration. Awards will be announced by mid-December, 1998 for Research Professorships and February, 1999 for all others.

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93	Systems theory; control
94	Information and communication, circuits

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*For **ordinary members** whose annual professional income is below $45,000, the dues are $96; for those whose annual professional income is $45,000 or more, the dues are $128.*

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Besides mailing addresses for members, the Society's records contain information about members' positions and their employers (for publication in the Combined Membership List). In addition, the AMS maintains records of members' honors, awards, and information on Society service.

When changing their addresses, members are urged to cooperate by supplying the requested information. The Society's records are of value only to the extent that they are current and accurate.

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Meetings & Conferences of the AMS

PROGRAM ALERT: In order that AMS meeting programs include the most timely information for each speaker, abstract deadlines have been moved to dates much closer to the meeting. What this means is that most meeting programs will appear in the *Notices* *after* the meeting takes place. However, complete meeting programs will be available on e-MATH about two to three weeks after the abstract deadline. ***Remember***, e-MATH is your most comprehensive source for up-to-date meeting information. See `http://www.ams.org/meetings/`.

Louisville, Kentucky

University of Louisville

March 20–21, 1998

Meeting #931

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: January 1998
Program issue of *Notices*: May 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Program

The complete program for this meeting is available at `http://www.ams.org/meetings/`. Follow the links to Sectional Meetings to get the most up-to-date information on all of the speakers and the titles of the talks. The May issue of the *Notices* will carry the full program of record for this meeting.

Registration and Meeting Information

Note change: The registration desk will be located in the lobby of the Founder's Union Building, not Burhans Hall. The hours of operation will be 7:30 a.m. to 5:00 p.m. on Friday and 7:30 a.m. to noon on Saturday. Lectures will take place in Burhans Hall and the Founder's Union Building.

Registration fees: (payable on-site only) $30/AMS members; $45/nonmembers; $10/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Manhattan, Kansas

Kansas State University

March 27–28, 1998

Meeting #932

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: January 1998
Program issue of *Notices*: June 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Program

The complete program for this meeting is available at `http://www.ams.org/meetings/`. Follow the links to Sectional Meetings to get the most up-to-date information on all of the speakers and the titles of the talks. The June issue of the *Notices* will carry the full program of record for this meeting.

Registration and Meeting Information

The registration desk will be located inside the main entrance to Cardwell Hall and will be open from 8:00 a.m. to 5:00 p.m. on Friday and from 8:00 a.m. to noon on Saturday. Invited Addresses will take place in Cardwell Hall, Room 101, and all Special Sessions will take place in Cardwell Hall or Ackert Hall.

Registration fees: (payable on-site only) $30/AMS members; $45/nonmembers; $10/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Philadelphia, Pennsylvania

Temple University

April 4–6, 1998

Meeting #933

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: January 1998
Program issue of *Notices*: June 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses

Tobias H. Colding, New York University-Courant Institute, *Title to be announced.*

Martin Davis, University of California, Berkeley, *Why foundations are important.*

Ezra Getzler, Max-Planck Institute and Northwestern University, *Gromov-Witten invariants in higher genus: A survey.*

Yanyan Li, Rutgers University, *The Yamabe problem on manifolds with boundaries: Existence and compactness results.*

Elias M. Stein, Princeton University, *Singular Radon transforms: Continuous and discrete.*

Special Sessions

Differential Geometric Methods in Hydrodynamics, **Gerard K. Misiolek**, University of Notre Dame and California Institute of Technology.

Harmonic Analysis and Its Applications to PDEs, **Cristian E. Gutierrez**, Temple University, and **Guozhen Lu**, Wright State University.

Heat Kernel Analysis on Lie Groups, **Leonard Gross**, Cornell University, and **Omar Hijab**, Temple University.

Mathematical Pedagogy, **Orin N. Chein**, Temple University.

Modular Identities and Q-Series in Number Theory, **Marvin I. Knopp** and **Boris Datskovsky**, Temple University.

Nonlinear Partial Differential Equations, **Yanyan Li**, Rutgers University.

PDEs in Several Complex Variables, **Shiferaw Berhanu** and **Gerardo Mendoza**, Temple University.

Radon Transforms and Tomography, **Eric L. Grinberg**, Temple University, and **Eric Todd Quinto**, Tufts University.

Rings and Representations, **Maria E. Lorenz**, Ursinus College, and **Martin Lorenz**, Temple University.

Sparse Elimination Methods in Polynomial System Solving, **Ioannis Z. Emiris**, INRIA, Sophia-Antipolis, France, and **J. Maurice Rojas**, Massachusetts Institute of Technology.

Sparse Matrix Computations, **Jesse Barlow**, Pennsylvania State University, and **Daniel B. Szyld**, Temple University.

The History of American Mathematics, **David E. Zitarelli**, Temple University, and **Karen H. Parshall**, University of Virginia.

Topology of Manifolds and Varieties, **Georgia Triantafillou**, Temple University, and **Sylvain E. Cappell**, New York University-Courant Institute.

There also will be sessions for contributed papers.

Davis, California

University of California

April 25–26, 1998

Meeting #934

Western Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: February 1998
Program issue of *Notices*: June 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses

Edward Frenkel, University of California, Berkeley, *Recent progress in geometric Langlands correspondence.*

Ian Fraser Putnam, University of Victoria, *Interactions between C*-algebras and dynamics.*

Boris Rozovsky, University of Southern California, *Wiener chaos and stochastic PDEs.*

William Thurston, University of California, Davis, *Three-manifolds, foliations and circles.*

Special Sessions

C-Algebras and Dynamics*, **Jerry Kaminker**, Indiana University-Purdue University at Indianapolis, **Ian Fraser Putnam**, University of Victoria, and **Jack Spielberg**, Arizona State University.

Differential Equations with Applications, **Sally Sailai Shao**, Cleveland State University, and **Tatsuhiko J. Tabara**, Golden Gate University.

Dualities in Mathematics and Physics, **Edward Frenkel** and **Nicolai Reshetikhin**, University of California, Berkeley.

Dynamical Systems and Mathematical Physics, **Motohico Mulase** and **Bruno L Nachtergaele**, University of California, Davis.

Finite Groups and Representations, **Kenechukwu Kenneth Nwabueze**, University of Brunei Darussalam.

Geometric Analysis, **Chikako Mese**, University of Southern California, and **Richard M. Schoen**, Stanford University.

Graph Theory, **David Barnette**, University of California, Davis.

Mathematical Biology, **Alexander Isaak Mogilner**, University of California, Davis.

Nonlinear Analysis, **John K. Hunter** and **Blake Temple**, University of California, Davis.

Random Fields and Stochastic Partial Differential Equations, **Arthur J. Krener**, University of California, Davis, and **Boris Rozovsky**, University of Southern California.

The Geometry and Topology of 3-Manifolds, **Dmitry Fuchs**, **Joel Hass**, **Ramin Naimi**, and **William Thurston**, University of California, Davis.

There also will be sessions for contributed papers .

Chicago, Illinois

DePaul University-Chicago

September 12–13, 1998

Meeting #935

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: June 1998
Program issue of *Notices*: November 1998
Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: May 26, 1998
For abstracts: July 21, 1998

Invited Addresses

Vitaly Bergelson, Ohio State University, *Title to be announced.*

Sheldon Katz, Oklahoma State University, *Title to be announced.*

Ralf Spatzier, University of Michigan, *Title to be announced.*

Vladimir Voevodsky, Northwestern University, *Title to be announced.*

Special Sessions

Algebraic Coding (Code: AMS SS C1), **William C. Huffman**, Loyola University of Chicago, and **Vera S. Pless**, University of Illinois at Chicago.

Algebraic Combinatorics: Association Schemes and Related Topics (Code: AMS SS L1), **Sung Yell Song**, Iowa State University.

Algebraic Geometry and Mirror Symmetry (Code: AMS SS N1), **Ezra Getzler** and **Mikhail Kapranov**, Northwestern University, and **Sheldon Katz**, Oklahoma State University.

Commutative Algebra (Code: AMS SS J1), **Irena V. Peeva**, Massachusetts Institute of Technology, and **Michael Stillman**, Cornell University.

Complex Dynamics (Code: AMS SS H1), **Shmuel Friedland**, University of Illinois at Chicago.

Complexity of Geometric Structures on Manifolds (Code: AMS SS F1), **Melvin G. Rothenberg** and **Shmuel A. Weinberger**, University of Chicago.

Ergodic Theory and Topological Dynamics (Code: AMS SS G1), **Roger L. Jones**, DePaul University, and **Randall McCutcheon**, Wesleyan College.

Fourier Analysis (Code: AMS SS E1), **Marshall Ash**, DePaul University, and **Mark A. Pinsky**, Northwestern University.

K-Theory and Motivic Cohomology (Code: AMS SS D1), **Kevin Knudson**, Northwestern University, and **Mark Walker**, University of Nebraska-Lincoln.

Nonlinear Partial Differential Equations (Code: AMS SS O1), **Gui-Qiang Chen** and **Konstantina Trivisa**, Northwestern University.

Number Theory (Code: AMS SS I1), **Jeremy T. Teitelbaum** and **Yuri Tschinkel**, University of Illinois at Chicago.

Orthogonal Polynomial Series, Summability and Conjugates (Code: AMS SS M1), **Calixto P. Calderon**, University of Illinois at Chicago, and **Luis A. Caffarelli**, University of Texas at Austin.

Rigidity in Geometry and Dynamics (Code: AMS SS K1), **Steven E. Hurder**, University of Illinois at Chicago, and **Ralf J. Spatzier**, University of Michigan.

Stochastic Analysis (Code: AMS SS A1), **Richard B. Sowers**, University of Illinois-Urbana, and **Elton P. Hsu**, Northwestern University.

Topics in Mathematics and Curriculum Reform (Code: AMS SS B1), **Richard J. Maher**, Loyola University Chicago.

There also will be sessions for contributed papers (Code: AMS CP 1).

Winston-Salem, North Carolina

Wake Forest University

October 9–10, 1998

Meeting #936

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: December 1998

Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 23, 1998
For abstracts: August 18, 1998

Invited Addresses

David F. Anderson, University of Tennessee, *Title to be announced.*

Idris Assani, University of Carolina, Chapel Hill, *Title to be announced.*

Marcy Barge, Montana State University, *Title to be announced.*

Roger Temam, University of Paris XI and Indiana University, *Title to be announced.*

Special Sessions

Abelian Groups and Modules (Code: AMS SS B1), **Ulrich Albrecht**, Auburn University.

Boundary Value Problems (Code: AMS SS K1), **John V. Baxley** and **Stephen B. Robinson**, Wake Forest University.

Combinatorics and Graph Theory (Code: AMS SS A1), **Bruce Landman**, University of North Carolina.

Commutative Ring Theory (Code: AMS SS E1), **David F. Anderson**, University of Tennessee, Knoxville, and **Evan Houston**, University of North Carolina, Charlotte.

Ergodic Theory (Code: AMS SS F1), **Idris Assani**, University of North Carolina, Chapel Hill.

Modern Methods in Set Theory and General Topology (Code: AMS SS H1), **Winfried Just** and **Paul Szeptycki**, Ohio University.

Noncommutatuve Algebra (Code: AMS SS C1), **Ellen Kirkman** and **James Kuzmanovich**, Wake Forest University.

Operator Theory and Holomorphic Spaces (Code: AMS SS L1), **Tavan T. Trent** and **Zhijian Wu**, University of Alabama.

Recent Results on the Topology of Three-Manifolds (Code: AMS SS D1), **Hugh Nelson Howards**, Wake Forest University.

Spectral Theory of Differential Equations and Applications (Code: AMS SS G1), **Dominic Clemence** and **Alexandra Kurepa**, North Carolina A&T University.

Topology in Dynamics (Code: AMS SS J1), **Marcy Barge**, Montana State University-Bozeman, and **Krystyna M. Kuperberg**, Auburn University.

There also will be sessions for contributed papers (Code: AMS CP 1).

State College, Pennsylvania

Pennsylvania State University

October 24–25, 1998

Meeting #937

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: January 1999
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: July 7, 1998
For abstracts: September 1, 1998

Invited Addresses

Jeffrey Adams, University of Maryland, College Park, *Title to be announced.*

Nigel D. Higson, Pennsylvania State University, *Title to be announced.*

Tasso J. Kaper, Boston University, *Title to be announced.*

Kate Okikiolu, University of California, San Diego, and MIT, *Title to be announced.*

Special Sessions

C-Algebraic Methods in Geometry and Topology* (Code: AMS SS B1), **Nigel D. Higson**, Pennsylvania State University, and **Erik Guentner** and **John D. Trout Jr.**, Dartmouth College.

Least Squares and Total Least Squares (Code: AMS SS G1), **Jesse L. Barlow**, Pennsylvania State University.

Mathematical Modeling of Inhomogeneous Materials: Homogenizaton and Related Topics (Code: AMS SS D1), **Leonid Berlyand**, Pennsylvania State University, and **Karl Voss**, Yale University.

Metric Topology (Code: AMS SS F1), **Steve Armentrout**, **Joseph Borzelino**, **Hossein Movahedi-Lankarani**, and **Robert Wells**, Pennsylvania State University.

Modeling of Phase Transitions of Partially Ordered Physical Systems (Code: AMS SS C1), **Maria-Carme T. Calderer**.

Partitions and q-Series (Code: AMS SS A1), **George E. Andrews** and **Ken Ono**, Pennsylvania State University.

Symplectic Geometry and Quantization (Code: AMS SS E1), **Jean-Luc Brylinski**, **Ranee Brylinski**, **Boris Tsygan**, and **Ping Xu**, Pennsylvania State University.

There also will be sessions for contributed papers (Code: AMS CP 1).

Tucson, Arizona

University of Arizona-Tucson

November 14–15, 1998

Meeting #938

Western Section
Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: September 1998
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: July 29, 1998
For abstracts: September 23, 1998

San Antonio, Texas

Henry B. Gonzales Convention Center

January 13–16, 1999

Meeting #939

Joint Mathematics Meetings, including the 105th Annual Meeting of the AMS, 82nd Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).

Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 1998
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 14, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Gainesville, Florida

University of Florida

March 12–13, 1999

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

Deadlines

For organizers: June 11, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Continuum Theory and Dynamical Systems (Code: AMS SS A1), **Philip Boyland** and **Beverly Brechner**, University of Florida, and **John Mayer**, University of Alabama at Birmingham.

Finite Groups and Their Representations (Code: AMS SS D1), **Alexandre Turull**, University of Florida.

Markov Processes and Potential Theory (Code: AMS SS C1), **Joe Glover** and **Murali Rao**, University of Florida.

The Erdös Legacy and Connections to Florida (Code: AMS SS B1), **Krishnaswami Alladi** and **Jean Larson**, University of Florida.

Urbana, Illinois

University of Illinois, Urbana-Champaign

March 18–21, 1999

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 18, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Galois Representations (Code: AMS SS C1), **Nigel Boston**, University of Illinois-Urbana, and **Michael Larsen**, University of Missouri.

Martingales and Analysis (Code: AMS SS D1), **Joseph Max Rosenblatt**, **Renming Song**, and **Richard B. Sowers**, University of Illinois-Urbana.

Nonstandard Analysis (Code: AMS SS B1), **C. Ward Henson** and **Peter Loeb**, University of Illinois-Urbana.

Recent Progress in Elementary Geometry (Code: AMS SS A1), **John E. Wetzel**, University of Illinois-Urbana, and **Clark Kimberling**, University of Evansville.

Las Vegas, Nevada

University of Nevada-Las Vegas

April 10–11, 1999

Western Section
Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 10, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Buffalo, New York

State University of New York at Buffalo

April 24–25, 1999

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

Deadlines

For organizers: July 24, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Michele M. Audin, University Louis Pasteur, Strasbourg, *Title to be announced.*

Jeff Smith, Purdue University, *Title to be announced.*

Alexander A. Voronov, Massachusetts Institute of Technology, *Title to be announced.*

Gregg J. Zuckerman, Yale University, *Title to be announced.*

Providence, Rhode Island

Providence College

October 2–3, 1999

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

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Austin, Texas

University of Texas-Austin

October 8–10, 1999

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Washington, District of Columbia

Sheraton Washington Hotel and Omni Shoreham Hotel

January 19–22, 2000

Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), and the annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).

Associate secretary: Robert M. Fossum, pro tem
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 20, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Lowell, Massachusetts

University of Massachusetts, Lowell

April 1–2, 2000

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

Deadlines

For organizers: July 1, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Notre Dame, Indiana

University of Notre Dame

April 7–9, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 7, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New Orleans, Louisiana

New Orleans Marriott and ITT Sheraton New Orleans Hotel

January 10–13, 2001

Joint Mathematics Meetings, including the 107th Annual Meeting of the AMS, 84th Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).

Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 11, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Columbia, South Carolina

University of South Carolina

March 16–18, 2001

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

Deadlines

For organizers: June 15, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Williamstown, Massachusetts

Williams College

October 13–14, 2001

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

Deadlines

For organizers: January 11, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California

San Diego Convention Center

January 6–9, 2002

Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 4, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: Robert M. Fossum (pro tem), Department of Mathematics, University of Illinois, 1409 W. Green St., Urbana, IL 61801-2975; e-mail: rmf@ams.org; telephone: 217-244-1741.

Central Section: Susan J. Friedlander, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

Eastern Section: Lesley M. Sibner, Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: lsibner@magnus.poly.edu; telephone: 718-260-3505.

Southeastern Section: Robert J. Daverman, Department of Mathematics, University of Tennessee, Knoxville, TN 37996-1300; e-mail: daverman@novell.math.utk.edu; telephone: 423-974-6577.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.

Meetings:

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 150 in the January 1998 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of TeX is necessary to submit an electronic form, although those who use plain TeX, AMS-TeX, LaTeX, or AMS-LaTeX may submit abstracts with TeX coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

1998:

June 21–July 23: Joint Summer Research Conferences in the Mathematical Sciences, South Hadley, MA. See pp. 1412–1416 (November 1997) and pp. 148–149 (January 1998) for details.

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